New concept allows additional routes to be established, without constraints of VOR site locations, by use of airborne 'course-line computers.' Increased traffic and greater safety are envisioned for high density areas

The Promise Of Area Navigation

by BARRY SCHIFF / AOPA 110803

■■ During the early 1950's, the obsolescent four-legged, low-frequency range was in its death throes; a more reliable method of radio navigation had appeared to displace it—the omnirange. At first, general aviation bellowed and roared because of the expense required to install the more elaborate VOR receivers. But few could ignore the march of progress. Aircraft owners broke out their hard-earned cash and began the retrofit process.

The obvious advantages of VOR navigation soon overcame the costly resentment it had created. VHF reception was far superior to that of low-frequency radio and was considerably less susceptible to atmospheric disturbances. Navigation became a pleasure; it could be performed in peaceful bliss, relieving the pilot of having to listen to the torturous din of dit-dahs and dah-dits for hours on end.

One of the most significant advantages of VOR navigation is the 360 courses provided by each station. A single L/MF radio range produced only four. Air traffic experts believed this alone justified implementation of the VOR system. More airways could be created to keep separated the growing number of aircraft flying the amber, blue, green, and red low-frequency airways.

In the jet-propelled years that followed, air traffic increased beyond all expectations. It appears now that VOR navigation, as used today, has its limitations also. Once thought to be "ideal," the Victor airways are beginning to bog down and already have reached saturation in some high-density traffic areas during peak traffic hours.

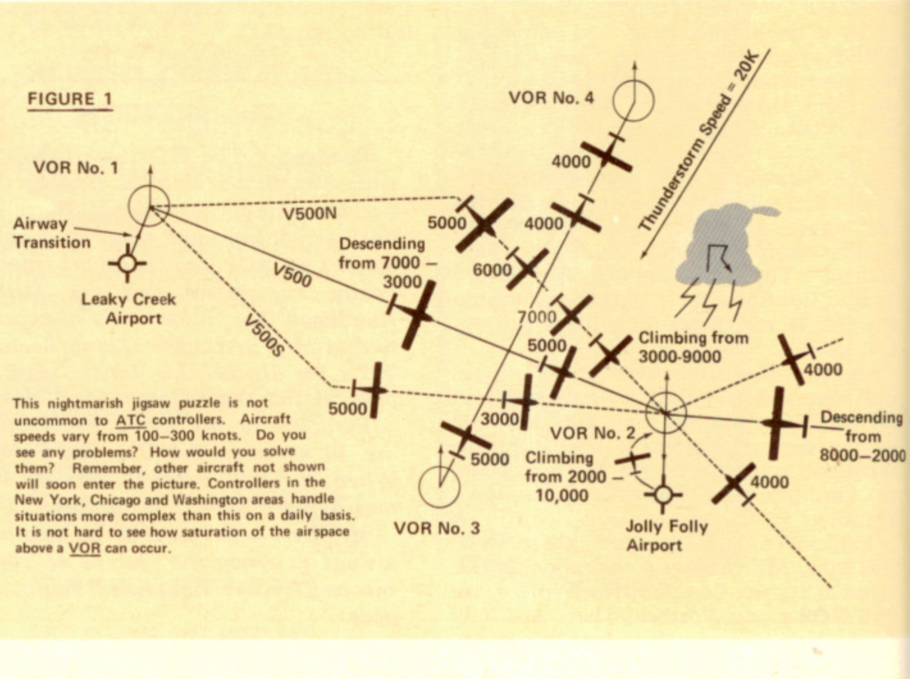
The weakness of the VOR structure is obvious. Victor airways lead aircraft directly toward or away from VOR stations. This results in a convergence or funneling of air traffic and creates severe limitations on the number of routes available between any two given stations.

The funneling effect is complicated further by arrival and departure procedures. These depend frequently on use of the same VOR stations that define the en route airways. Air traffic controllers have the nightmarish burden of separating climbing, descending and cruising traffic, all converging upon the same point.

A temporary solution to the funneling problem is provided by radar vectoring aircraft out of each other's way, but this places a grueling load on the controller, leaving him little, if any, tolerance for error. Many controllers feel that the added burden of "navigating" several aircraft at one time forces them to divide attention to the point of jeopardizing safety. The controller's primary and most vital function is aircraft separation, not navigation. This objective seems to be best met when navigational responsibility is placed in the cockpit, leaving the controller free from distractions to observe and concentrate on monitoring the proximity of one aircraft to another. Pilots generally agree. They feel they should be accurately aware of their positions at all times; while accepting radar vectors, they frequently are not.

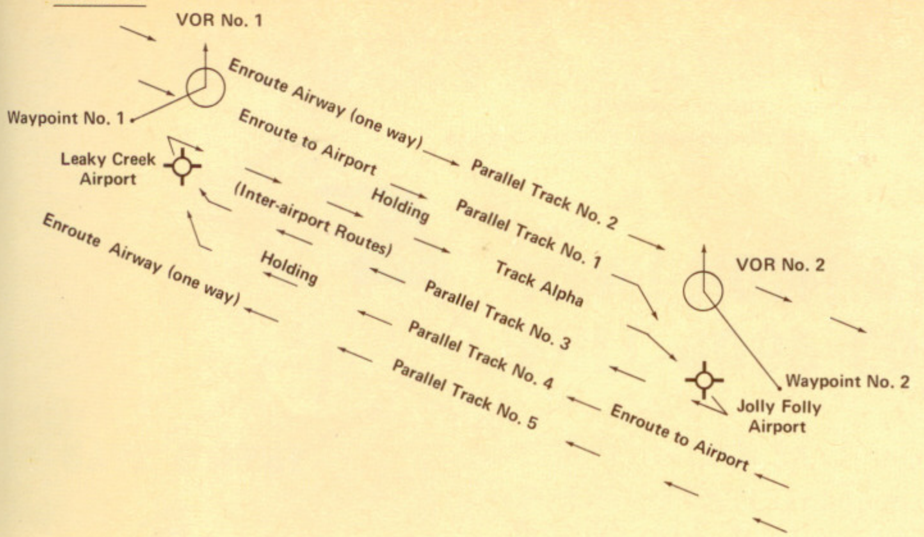
According to FAA, "the next logical step towards providing more airspace and reducing [the hazards of] air traffic congestion is the development of a new system of navigation that allows routes to be established without the constraints of VOR site location or course alignment. This capability is commonly termed 'area navigation,' which could be described as navigation not confined to flying a radial toward or away from a station providing guidance."

Figure 1 is an example of the problems created by the present airway



This nightmarish jigsaw puzzle is not uncommon to ATC controllers. Aircraft speeds vary from 100–300 knots. Do you see any problems? How would you solve them? Remember, other aircraft not shown will soon enter the picture. Controllers in the New York, Chicago and Washington areas handle situations more complex than this on a daily basis. It is not hard to see how saturation of the airspace above a VOR can occur.

FIGURE 2



structure. A flight from Leaky Creek to Jolly Folly Airport would be conducted along Victor 500, or perhaps along an alternate airway such as Victor 500N or 500S. There simply is no other way to go, except for dead reckoning or pilotage, neither of which adapts very well to IFR flying. It's easy to see how this system can be overloaded with heavy traffic.

Suppose that another airway system (Figure 2) could be superimposed upon this "area"—one that provides half a dozen or more parallel routes. By restricting each airway to "one-way" operation, it is clear how more traffic could be accommodated in complete safety. All aircraft departing one airport with the intention of overflying the other might be assigned an airway not to be used by local, inter-airport traffic, and vice versa. Aircraft overflying both airports might have their own airways. Since this new system has the apparent flexibility of being independent of VOR site locations, more direct routes could be established, actually reducing the time required to fly from A to B along a Victor airway. The system is a logical improvement over the present airway structure, seemingly without limitation. It takes advantage of almost all airspace, not just a part of it. More traffic can be handled, with a significant decrease in controller workload and a corresponding increase in safety.

The technology required to employ this concept is here; it has been for many years. It attracted little attention in the past, primarily because there was no apparent need for it. But the aviation fleet has grown to such proportions that area navigation system manufacturers are now optimistic about future business prospects.

Four methods of area navigation are available: (1) course-line computers (CLC), (2) pictorial displays, (3) Doppler radar (AOPA Pilot, June 1967), and (4) inertial guidance. Each system is capable of providing accurate area navigation, but the latter two are intended primarily for transoceanic navigation.

The course-line computer (CLC) is the bright star on the general aviation horizon. It is the simplest, in terms of required electronics, and is therefore the least expensive of all area navigation hardware.

The principles of the CLC depend upon being within reception range of one Vortac station or two VOR stations, the former being the most popular with CLC manufacturers. This implies that a DME receiver will be a required part of the system.

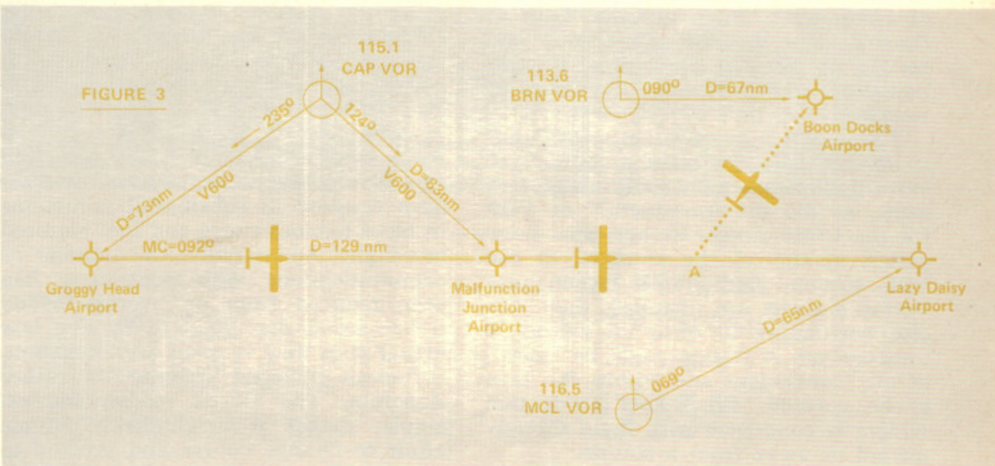


Figure 3 illustrates the principles of area navigation using CLC. A pilot wants to fly from Groggy Head to Malfunction Junction, under IFR conditions. The only method of navigation normally available is to follow the needle along V600, a 156 n.m. dogleg course. But with CLC, he can fly the direct course of only 129 n.m., reducing en route flight time by 17.3%, a figure that is not abnormally high according to some area navigation proponents.

Prior to departure, the pilot informs his course-line computer of the position of Malfunction Junction with respect to its nearest VOR (CAP). This is done by selecting the bearing and range of the airport on two small dials on the CLC control panel. In this case, the first dial is set to 124°, the second to 83 n.m. By doing this, the pilot has, in effect, told the CLC he would like to move the CAP VOR from its position northwest of the airport to a new and more convenient site (if you please) directly on the destination airport.

After takeoff, the pilot tunes in CAP. The computer determines the present position of the aircraft (using bearing and DME information from the CAP VOR), refers to the "new" VOR location "established" by the pilot and then feeds course information to the left-right needle. From then on, the needle will remain centered only when the aircraft is on the direct course of 092° from Groggy Head to Malfunction Junction. The left-right needle behaves exactly as if the CAP VOR had been physically moved to the destination airport.

The "new" VOR site (CAP 124°, 83 n.m.), in CLC jargon, is called the "waypoint," "phantom station," or "ghost station," depending on which manufacturer you talk to.

The CLC presentation varies considerably from one model to the next. Butler National's VAC (Vector Analog Computer) has its own guidance instrument, a pair of cross-pointers that are similar in appearance to an ILS indicator. The vertical needle moves rectilinearly left and right of center. The amount of needle displacement indicates how far (in miles) the aircraft is being flown left or right of course, and thus allows a dandy method of paralleling any given course.

The horizontal needle indicates distance to or from the waypoint on a vertical scale. As the waypoint is approached, the needle moves downward toward the center of the instrument. Waypoint passage is indicated by a centered needle, and so forth.

A simpler setup will be offered shortly by Narco. The familiar VOR needle is used as a CLC indicator, and the conventional DME indicator may be used to determine distance to the waypoint.

When the CLC is not in use, the left-right needle and DME readout revert to their conventional roles.

Assume that a pilot intends to fly to Lazy Daisy. When he arrives over his first waypoint, he tunes in the MCL VOR. Then he "moves" this VOR to a more suitable location. The magical dials on the CLC console are set to 069° and 65 n.m., the destination location with respect to the MCL VOR. The pilot continues along the direct course from Groggy Head to Lazy Daisy by keeping the CLC needle centered.

In such a manner, a pilot could fly a beeline all the way from LAX to JFK simply by navigating from one waypoint to the next.

Diversions to alternates or fixes represent no problem either. Suppose a pilot at Point A decides to change course for Boon Docks. All he has to do is tune in the BRN VOR, "move it" 67 n.m. to the east, and follow the needle. When the DME (or horizontal bar) reads "zero," he's there.

The least expensive course-line computer probably will cost between $1,000 and $3,000 (here we go again), but some units already run as high as $30,000. Since the lower-priced models probably won't meet IFR accuracy standards, one can only wonder how much demand will be created for these VFR-only units. While a CLC can eliminate costly doglegs, hundreds—if not thousands—of cross-country hours will have to be flown before enough flight time can be saved to justify this great an expenditure.

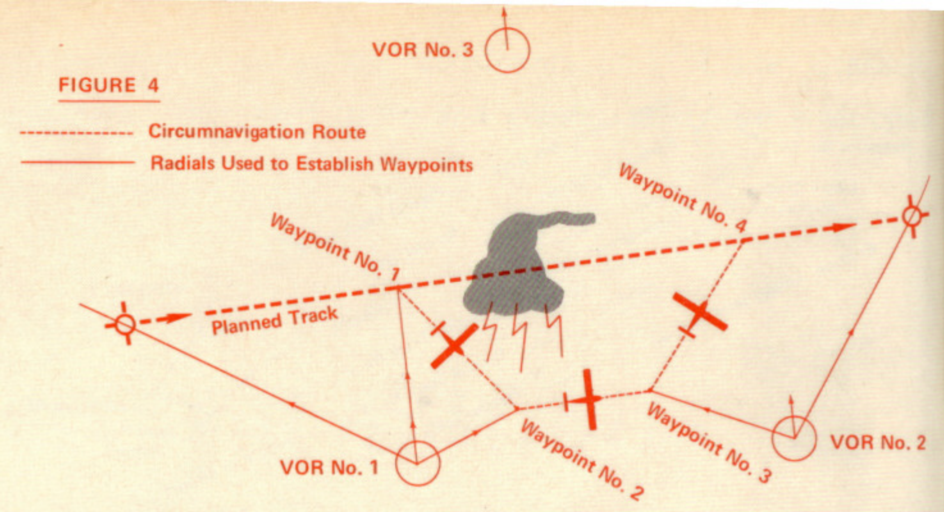
But CLC might be thought of in the same light as an autopilot or any one of a number of other luxuries. "George" doesn't save the aircraft owner any money either, but "he" does provide added convenience and reduce cockpit workload.

The beauty of area navigation is that it doesn't sound a death knell for the existing Vortac and VOR/DME network, as did the introduction of VOR for the L/MF range. Rather, area navigation maximizes the potential of the VOR system. Additionally, when new Vortac stations are installed, their precise positioning to form an airway is unnecessary. A station could be erected at any convenient site within the area to be covered, since area navigation seldom is concerned with flight directly toward or away from a station.

Another advantage offered by area navigation will be that an aircraft properly equipped could make an IFR approach to any airport without normal approach facilities, as long as it's within reception range of any Vortac station. These IFR approaches wouldn't offer the precision of an ILS or PAR approach, but letdowns to a runway threshold might eventually be feasible with a 400-foot ceiling and one-mile visibility.

Some amount of chart and plotter work is necessary to establish waypoints, but this load has been eased by Jeppesen's new VFR Avigation Charts. Many courses are preplotted, and those that are not are determined more easily on this format than on any other genus of chart.

FIGURE 4



Expanding the CLC concept further leads to the natural evolution of pictorial display. Information from a nearby Vortac station (range and bearing) is fed to an electronic computer that continuously traces and superimposes aircraft position on either a chart scroll or a 35-mm. projected filmstrip. Pilots who have used these systems react favorably because they literally can see their positions on the "pictorial logs." It isn't necessary to translate needle indications into a pair of coordinates that must be transposed to a hand-held chart. With pictorial navigation, aircraft position and its relationship to nearby fixes can be seen at a glance. It's about as nifty as looking out the window.

Eastern Airlines (along with other carriers around the world) has evaluated two different pictorial systems on two of its DC-9's during more than 700 Washington-to-New York shuttle flights. According to A. Scott Crossfield, Eastern's vice-president of flight research and development, the pictorial systems have resulted in substantial reductions in block-to-block times and fuel required per flight. Additionally, the number of communications with controllers has been reduced from an average of 98 transmissions per flight to 75, and less actual pilot time is spent on navigation.

Present pictorial systems are rather elaborate. The Decca model, for example, makes it a childishly simple affair to change course and proceed to a given fix. All a pilot has to do is move a "bug" on the pictorial log to a point over the desired fix. Whammo! Before the pilot can say "Shazam," the computer spits out the course and distance from his present position to that fix. The pilot turns the aircraft to the proper heading and watches his flight path traced on the pictorial log.

Some pictorial systems accept other than VOR/DME information. They work equally well with inputs from Loran, inertial sensors, Doppler radar, Decca (discussed later), Dectra, Omega, or just about any other navigation system.

Additionally, guidance information from on-board computers can be fed to flight directors and autopilot couplers. It's not hard to see why the future of area navigation lights the horizon so brightly.

Some airline officials feel the state of the art might advance to the point where weather radar echoes could be superimposed on a pictorial display. Avoidance of weather cells would be a snap, as would reinterception of the original course line. ATC could issue a simple area navigation clearance that would allow all aircraft to circumnavigate the storm area (Figure 4), something far simpler than having to issue a multitude of radar vectors.

One of the most flexible of the pictorial displays is the Hughes Navigation Director, which has the tremendous capacity to flash almost 4,000 different images on its seven-inch display screen by taking advantage of microfilm techniques. While most of these images obviously would be IFR chart displays, some of the films could be used to illuminate the screen with check lists, approach plates, airport diagrams—or they might even be used by a cunning pilot to store girlfriends' phone numbers where they certainly wouldn't be found by a suspecting wife.

Area navigation using VOR/DME information has one pitfall. VHF reception distance is dependent upon the altitude of the receiver above the ground and the geography of the terrain surrounding the transmitter. Flying at relatively low altitudes (especially in the vicinity of hills and mountains) often results in the loss of a navigable VOR signal.

The problem of providing accurate, low-level guidance can be solved with Decca navigation. This system was developed by the British and has been in use over scattered areas of the world since 1946. Decca is a hyperbolic navigation system similar to Loran (AOPA PILOT, November 1967). It is quite satisfactory for use at very low altitudes because the system uses (get ready for this!) low-frequency signals (70-130 kHz) that are unaffected by aircraft altitude. Navigation accuracy is superb. According to the American Practical Navigator, a U.S. Navy publication, Decca navigational position errors can be as small as 30 yards, at a distance of 100 n.m. from the station, during

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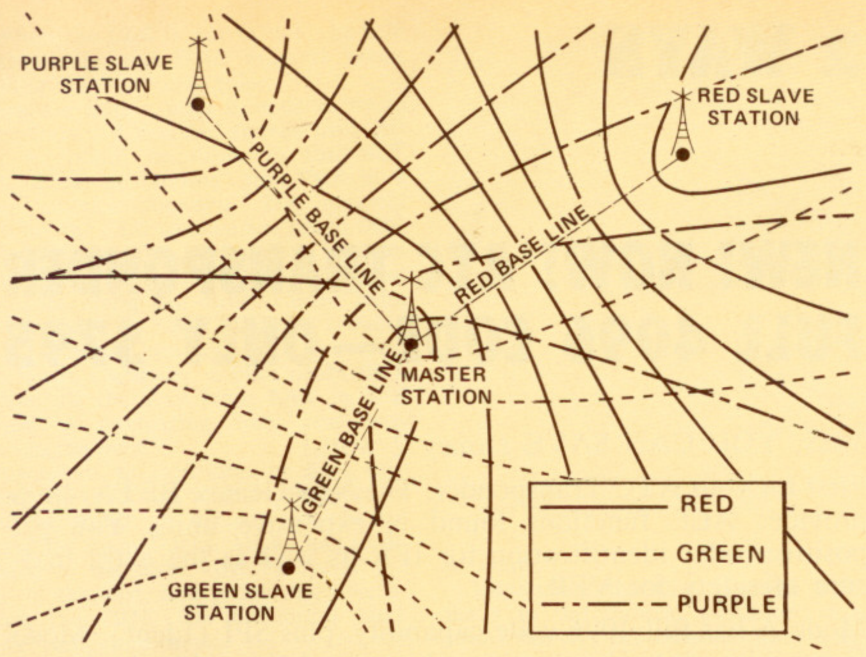
FIGURE 5



A typical Decca Lattice. Slave stations are, on the average, 75 miles distant from the master station.

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daytime transmissions (100 yards at night).

Decca signals of reasonable strength have been received at distances as great as 1,000 miles from the transmitter, but the reliable day-and-night range is considered to be 240 n.m.

Since Decca is a low-frequency navaid, it is subject to atmospheric disturbances and is almost useless when used within 25 miles of heavy electrical storms.

When applied to area navigation principles and pictorial systems, Decca's low-altitude accuracy is hard to resist. Perhaps that is why California has already opted to install a chain of Decca transmitters in its northern half. Wait! Hold it, Californians! Don't go swapping Mark 12's for Decca receivers. The new system is intended ultimately to supplement VOR/DME-fed area navigation, not replace it. [California is having a Decca chain installed for evaluation purposes, but Decca will continue to own the stations.—Ed.]

Figure 5 is a typical Decca installation. The center transmitter is called the master station and the other three are its slave stations, designated green, purple, and red, respectively. The master and each slave produce a series of independent, hyperbolically-curved lines of position that appear identical to those produced by Loran. Since Decca employs three slave stations, three hyperbolic patterns are formed.

The major difference between Decca and Loran is that Decca-formed hyperbolas represent lines of zero-phase difference for each master-slave combination. Loran principles rely on the time difference of received signals from a master/slave pair.

The area between any two hyperbolas (the curved lines) formed by a given master/slave pair is called a zone. Each "red" zone is divided further into 24 narrow lanes, while the green and purple zones each contain 18 and 20 lanes, respectively.

Special Decca equipment allows a navigator to determine not only the lane in which he is flying (or steaming), but his precise position along the width of that lane. Maximum accuracy (measurable in yards) is obtained near the base line of each master/slave pair where the distance between each hyperbola is at a minimum, resulting in the narrowest lane widths.

The application of Decca to area navigation eliminates the need for a pilot to plot zone and lane positions. The black boxes do all this for him. All the pilot has to do is glance occasionally at the moving chart scroll of his Decca Flight Log to "see" his position and flight path. [One great drawback of the Decca Flight Log is that it does not provide steering information, i.e., a left-right needle.—Ed.]

Area navigation is an expensive luxury, but its benefits to aviation cannot, and no doubt will not, be overlooked. It reduces cockpit and controller workloads, increases the volume of navigable airspace, and provides for better separation of IFR traffic. Area navigation may well be one of the solutions that will enable us to survive in the crowded skies of tomorrow. □

THE AUTHOR

In presenting this article by Barry Schiff, the editors of The Pilot *believe that readers of the magazine will find it a valuable contribution. Mr. Schiff, whose previous* Pilot *contributions have included "Why Not Really Learn To Navigate" (June 1963), "Dial-In Doppler Navigation" (June 1967), "Loran" (November 1967), and "Pressure-Pattern Navigation" (May 1968), is an airline pilot, flying Boeing 727's for Trans World Airlines. His book, "All About Flying," was published in 1965 by Aero Products Research.*

General Aviation And Area Navigation

by VICTOR J. KAYNE
Vice President, AOPA Policy and Technical Planning Division

The accompanying article by Barry Schiff is very timely, since every indication points to area navigation playing a large part in the future of general aviation.

The planning efforts of almost every group having anything to do with the future of civil aviation in the United States include area navigation as an integral part of our future system of navigation and air traffic control. The area navigation being worked into these plans is based on our VOR/DME system and permits implementation according to the needs of the user. This is not to be confused with area navigation systems that would require an entirely new system of ground stations and airborne equipment.

Currently, there are thousands of airports and landing strips in our country which are not served by navigation aids or which do not have instrument approach capability. In the next 15 years, the number of landing areas is expected to double. The number of navigation aids cannot greatly increase because of economics and the squeeze on available frequencies. Thus, we must provide service to these new airports and our existing ones with the basic VOR/DME system, much as we know it today. The area navigation equipment now in use, and being developed by companies like Narco, promises to give general aviation the capability to navigate to almost any one of thousands of landing areas widely scattered throughout the country. It will enable pilots to make instrument approaches down to reasonable weather minimums, even though the VOR/DME station may be located many miles away. It will provide utility for owners of general aviation airplanes and enhance the value of both the airplane and the smaller airports that now can be used only in VFR weather conditions. As in the case of VOR receivers and VHF communications, we are certain that continued development will bring the price of area navigation within reasonable reach of those who have a need for this type of service. □