BYTE Game Contest

JETSET

Eugene Szymanski
693 Rosedale Rd.
Princeton, NJ 08540

JETSET, for those of you whose fantasies include manning a perilous flight, offers the adventure of flying—minus the jet lag and the risk. With the Jet Simulator Electronic Trainer (hence JETSET), you'll maneuver an aircraft through the three stages of flight—takeoff, cruising, and landing—in less than ideal conditions. The program, which runs on the TRS-80 Model II, uses the keyboard and screen to make a personal computer version of a commercial flight simulator. You and the controls, of course, remain firmly planted on the ground.

I designed JETSET with three criteria in mind. I wanted it to be technically sound and complex enough to require a certain amount of skill and judgment at the keyboard. Above all, I wanted the game to hold the player's interest by presenting a challenge. To make JETSET a realistic simulation, everything the pilot does in this program must be coordinated with an instrument panel displayed on the computer screen. In addition, the pilot must follow the actual procedures required when flying in near-zero visibility. A plane flown in such inclement weather must proceed according to Instrument Flight Rules (IFR) established by the government, and the pilot must be specially trained and certified to fly *on instruments*. This information is incorporated into the JETSET program.

Instrument landing is the most complex part of the simulation.

JETSET, which is written in TRS-80 Model II BASIC, requires about 27K bytes of memory after the language is loaded. (See listing 1.) I'll begin by describing how JETSET works and follow with a descriptive series of flight lessons.

Computer-Simulated Flight

The JETSET program lets the pilot activate the control surfaces of the jet aircraft, adjust engine thrust, and tune navigational radio equipment by pressing a set of keys. (See table 1.) The program responds to the keypress commands by adjusting aircraft attitude to match the control surfaces and updating the instrument panel display every four seconds as the trajectory of the jetliner is tracked through space by the computer.

The jet instrument panel gives the pilot all the flight information he needs to take off, navigate, and land an aircraft using standard flight procedures and the radio facilities established for modern-day flying. The panel functions reveal what the aircraft is doing and where it is located, so that after a short period of training the pilot knows instinctively how to scan and interpret the panel data.

Position tracking, a vital ingredient in the simulation, is performed in real time to keep the flight situation up to date. Although the pilot completely controls the motion of the jet, wind forces that vary with altitude can influence the flight. The program uses an analytical combination of jet and wind motion to solve the "wind triangle" that is formed whenever an aircraft is aloft and moving through layers of air. The wind-triangle solution yields the "true" motion of the jet relative to the earth's surface.

When the simulation begins, the jetliner is poised for takeoff on the runway at Philadelphia International Airport. The geographic coordinates of Philadelphia mark the starting point of flight. The computer fixes this initial position in memory and cranks out a new longitude and latitude 15 times a minute. The pilot controls the path of the jet during the takeoff roll down the runway. If everything is done correctly in the cockpit, this path will lead to a takeoff with room to spare.

Once airborne, the jet is tracked against a grid of meridians and parallels, an involved computation that requires the program to use spherical trigonometry because of the earth's curved surface. Because the geographic coordinates of airports and radio beacons are stored in the computer's memory, a comparison of positions yields the information it needs to update the instrument panel the pilot uses to navigate.

An instrument landing, the trickiest part of any actual flight, is also the most complex operation for the computer to simulate. This type of landing requires a programmed geometry to simulate the Instrument Landing System (ILS) pattern formed by special radio beams. These beams, which converge at the landing end of a runway, deflect an indicator on the instrument panel of the landing jet and give the pilot an exact path to follow during the final approach to the airport.

Because JETSET knows precisely where the pilot is telling the plane to go, the program will continue to run until the jet lands safely and rolls to a halt or until the flight ends in disaster. When the simulation has ended, for whatever reason, JETSET provides a complete report of the pilot's performance. The report includes the landing location of the plane—whether on or off the runway—to the nearest foot, and, in case of pilot error, a description of the error and the likely damage to the aircraft.

Listing 1: *The program listing for JETSET.*

```
1 REM:PROGRAM NAME= JETSET
2 REM:IFR FLIGHT SIMULATOR (BOEING 747)
3 REM:CREATED 06-28-81 BY GENE SZYMANSKI
4 REM:REVISED 02-25-82
9 SYSTEM "CLOCK OFF"
10 GOTO10000
23 REM:BEGIN CRUISE MODULE HERE
24 CLS:CLEAR2000:RANDOM
25 DIM M$(20)
26 KR=57.2958:XU=64
27 RS=1:IFRND(0)<0.5THENRS=-1
28 RW=(15-5)*RND(0)+5
29 RW=RS*RW
30 REM:SET UP WIND TABLE
32 DIM WA(10,1)
34 FOR I=0TO7:WA(I,0)=RND(359):NEXT
36 FOR I=8TO10:WA(I,0)=90*RND(0)+225:NEXT
38 A=0
40 FORI=1TO10:WA(I,1)=25*RND(0)+A:A=A+25:NEXT
41 RS$(0)=STRING$(31,"_")
42 RS$(1)=SPACE$(13)+".    ."+SPACE$(13)
43 RS$(2)=SPACE$(11)+".          ."
44 RS$(3)=SPACE$(9)+STRING$(13,"_")
45 REM:VOR STATION FREQS TABLE
46 DIM VF(15)
47 VF(0)=115.9:VF(1)=113.8:VF(2)=112.7
48 VF(3)=117.7:VF(4)=117.8:VF(5)=112.2
49 VF(6)=117.4:VF(7)=115.5:VF(8)=116.4
50 VF(9)=113.6:VF(10)=116.9:VF(11)=117.0
51 VF(12)=112.3:VF(13)=117.9:VF(14)=115.7
52 VF(15)=112.8
62 REM:ILS CONSTANTS FOR AIRPORTS
63 DIMVG(15,1)
64 VG(0,0)=238:VG(0,1)=28
66 VG(2,0)=240:VG(2,1)=30
69 VG(5,0)=90:VG(5,1)=217
71 VG(7,0)=299:VG(7,1)=164
72 VG(8,0)=166:VG(8,1)=42
79 VG(15,0)=341:VG(15,1)=75
100 REM:VOR STATION COORDINATES TABLE
101 DIM VP(15,1)
102 VP(0,0)=40.633:VP(0,1)=73.773
103 VP(1,0)=40.202:VP(1,1)=74.495
104 VP(2,0)=42.358:VP(2,1)=70.993
105 VP(3,0)=41.282:VP(3,1)=70.027
106 VP(4,0)=42.743:VP(4,1)=73.802
107 VP(5,0)=46.412:VP(5,1)=84.315
108 VP(6,0)=38.350:VP(6,1)=81.770
109 VP(7,0)=40.917:VP(7,1)=77.993
110 VP(8,0)=42.928:VP(8,1)=78.647
111 VP(9,0)=41.358:VP(9,1)=82.162
112 VP(10,0)=42.967:VP(10,1)=83.742
113 VP(11,0)=44.555:VP(11,1)=88.195
114 VP(12,0)=41.547:VP(12,1)=88.318
115 VP(13,0)=39.495:VP(13,1)=76.978
116 VP(14,0)=42.048:VP(14,1)=83.458
117 VP(15,0)=39.637:VP(15,1)=75.303
155 DATA FUEL,LBS,%,VHF,MHZ,THRUST,MAX,IDLE,REV
160 DATA PITCH," +"," -",DEG,FLAPS,UP,DWN,WHEELS,UP,MID,DOWN
165 DATA COMPASS,AIRSPEED,KTS," VERT",SPEED,FPM
170 DATA ALTITUDE,FEET,CLOCK
175 DIM P$(28)
180 FOR I=0 TO 28:READ P$(1):NEXT
185 DIM S$(25)
190 FOR I=1 TO 25:S$(I)=SPACE$(1):NEXT
192 FOR I=0 TO 9:F(1)=0:NEXT
195 REM:INIT FLITE VARIABLES TO STATE AT LIFTOFF
196 FU=195480:FP=63:CC=75:AS=380:RU=6704:AL=1900
198 MZ=77:TR=4:FL=1:FA=10:BR=10:WH=10
200 RA=0:AS(1)=380:FA(1)=10:CC(1)=75:AL(1)=1900:RP=40
201 DP(4)=39:DP(5)=52:DP(6)=75:DP(7)=15
202 L1=39.8667:G1=75.25:LL(1)=L1:GL(1)=G1:LS(1)=L1:GS(1)=G1
203 VO(1)=0.0:VO$(1)="OUT ":VO(3)=0:VO(4)=999.9
204 GX(0)=0:GY(0)=0
205 XO=36481:YO=0
220 TV$=TIME$:GOSUB 7050:TL=TD
221 TW(1)=TD
222 GOSUB335
224 PRINTCHR$(2):GOSUB600
300 K$=INKEY$:IFLEN(K$)=0GOTO304
302 GOSUB800
304 GOSUB1000
335 REM:DISPLAY PANEL (HEADERS ONLY)
340 PRINT@(0,3),P$(0);S$(4);P$(5);S$(3);P$(9);S$(3);S$(6);S$(3);P$(20)
341 PRINT@(9,54),P$(13);S$(3);P$(16)
342 PRINT@(10,56),P$(14);S$(6);P$(14)
343 PRINT@(12,56),P$(15);S$(5);P$(15)
345 PRINT@(1,13),P$(6);S$(6);P$(10);S$(6)
350 PRINT@(1,68),P$(28)
355 PRINT@(2,1),P$(1);S$(4);P$(2);S$(21);S$(3);S$(13);P$(23)
360 PRINT@(3,22),P$(11);S$(13);P$(21);S$(2);P$(24);S$(2);P$(26)
365 PRINT@(4,0),P$(3)
370 PRINT@(5,39),P$(22);S$(6);P$(25);S$(5);P$(27)
375 PRINT@(6,0),P$(4);S$(10);P$(7);S$(3);P$(12);S$(7)
380 PRINT@(7,13),P$(8)
381 PRINT@(3,68),"VLF OMEGA":PRINT@(4,65),"LAT"
382 PRINT@(5,64),"LONG"
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Listing 1 continued on page 304

Key	Function	Definition
F	Thrust increase*	increases power applied to jet engines
S	Thrust decrease*	decreases power
Q	Thrust reverse	reverses engine thrust direction during landing
↑	Pitch down*	lowers nose of aircraft by an angle of 5 degrees
↓	Pitch up*	lifts nose by an angle of 5 degrees
→	Pitch cancel	sets nose to level flight (horizontal)
<	Rudder left*	increases rudder angle to left by one increment
>	Rudder right*	increases rudder angle to right
/	Rudder cancel	returns rudder to center position
L	Flaps	raises and lowers wing flaps
W	Wheels	raises and lowers landing gear
B	Brakes	releases wheel brakes for takeoff
M	Missed approach	signals an aborted landing attempt
V	VOR frequency tune	inputs a frequency to VOR receiver
R	VOR radial select	selects a radial value for navigating
A	VOR auto select	automatically rotates the radial selector dial

Notes: 1. The TRS-80 keyboard CAPS key must be engaged throughout the simulation.
2. An asterisk (*) identifies keys that may be typed additional times to increase their control functions.

Table 1: *Keys used for pilot control.*

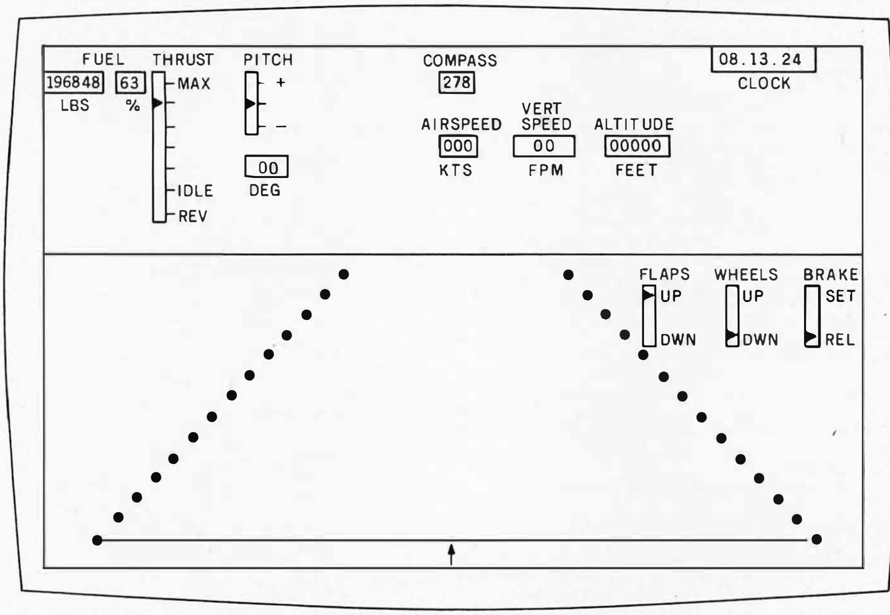


Figure 1: *The instrument panel display during takeoff.*

Flying Lesson #1
Taking Off

When you load JETSET into memory and type RUN, the screen will flash a message authorizing a takeoff from Philadelphia International on runway 9R. The screen will then display the upper section of the jet instrument panel and a perspective view of the runway as it would appear from the cockpit (see figure 1). At this point the jet is parked in the takeoff position with its engines idling, ready to go when its brakes are released. (Note: The "CAPS" key of the TRS-80 keyboard must be engaged and remain on for all key commands used during the simulation.)

To prepare for takeoff, press the L key to lower the flaps and check the panel FLAP indicator. A down position shows that the wing flaps are now extended. The flaps provide the vital extra lift needed during landing and takeoff, when the jet airspeed is marginal. Next, release the wheel brakes (W key). The jet will begin to move slowly because the engines are idling at only a fraction of their rated power or thrust. To apply full takeoff power, press the F key and watch the THRUST lever indicator move to its maximum forward position. The program will now apply acceleration to gradually bring the jet up to its rated takeoff speed, 150 knots (173 mph).

As momentum builds, the AIRSPEED indicator begins to register. The jet begins its takeoff roll down the 10,500-foot runway. Soon afterward, the COMPASS indicator begins to deflect from its 075 degree reading as the jet is hammered by gusts of wind sweeping across the runway. This is a busy time in the cockpit because you must carefully steer the jet along the 200-foot-wide runway strip as you come up to takeoff speed. A sliding arrow at the base of the runway graphic shows how far the jet is wandering from the runway centerline. Use the rudder keys (< and >) to steer the jet via its nosewheel whenever this arrow veers away from the center position. The arrow will shift left or right whenever the compass reading deviates from the 075 degree direction of the runway. Careful steering, then, is an exercise in coordinating both keys with the compass reading and the runway graphic (each press of a rudder key alters the direction of travel by one degree).

Assuming that the jet doesn't veer off the runway (which would end the flight), you must be ready to execute the lift-off maneuver when the airspeed reaches 150 knots, at which point you press the ↓ key once, and once only, to tilt the nose up 10 degrees. The jet will lift off just before the end of the runway moves to the bottom of the screen, and the horizon line will vanish.

Immediately following the lift-off, you must execute a three-step sequence to gain altitude promptly:

1. raise the landing gear (W key) to reduce "drag" (air friction)
2. retract the wing flaps (L key)
3. reduce the thrust (S key) to attenuate engine noise—in accor-

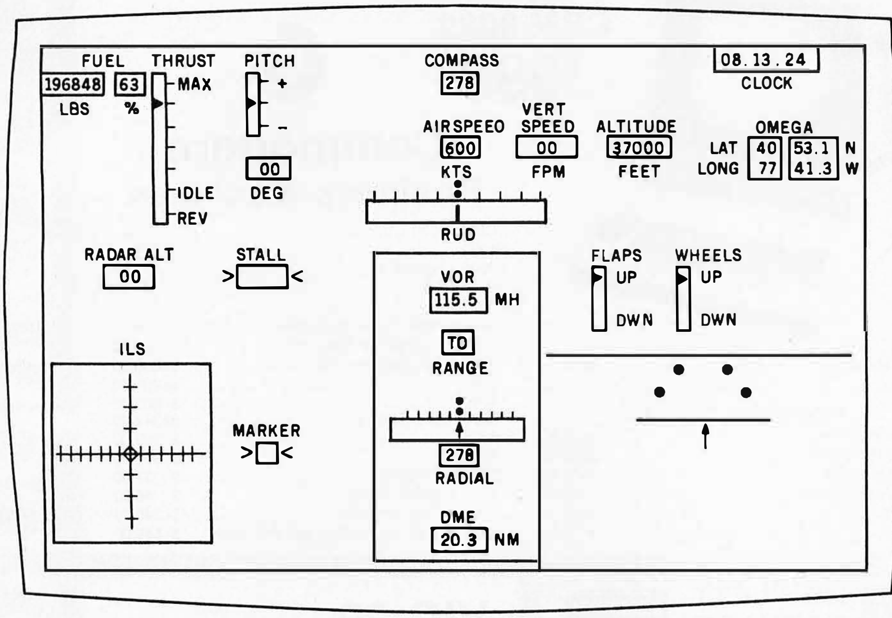


Figure 2: *The full instrument panel display.*

Instrument	Units	Function
FUEL	pounds, %	fuel aboard (in pounds and percentage full)
VHF	MHz	communications channel
THRUST	——	position of engine thrust levers
PITCH	——	attitude of aircraft pitch
DEG	degrees	angle of pitch, measured from horizontal
COMPASS	degrees	compass heading of aircraft (direction of nose)
AIRSPEED	knots	aircraft velocity through the air
VERT SPEED	feet/minute	rate of climb or descent
ALTITUDE	feet	aircraft altitude
CLOCK	hr.min.sec	time of day (local time)
VLF OMEGA	degrees and minutes	aircraft position (latitude and longitude) in degrees and minutes of arc
RUD	——	rudder angle
FLAPS	——	flap position
WHEELS	——	landing gear position
BRAKE	——	position of wheel brakes
VOR	MHz	frequency to which VOR receiver is tuned
RANGE	——	displays status of VOR receiver
RADIAL	degrees	value of selected radial (needle moves along window directly above RADIAL)
DME	nautical miles	distance to VOR ground station
RADAR ALT	feet	aircraft elevation during final approach
MARKER	——	turns on when flying directly over the ILS outer and middle marker beacons
ILS	——	pair of needles that deflect according to aircraft position in ILS radio cone
STALL	——	flashes when aircraft is stalled during final approach

Table 2: *Instrument panel legend.*

dance with federal antinoise regulations—as the jet passes over metropolitan Philadelphia

You must perform this sequence in the above order because the three keys are software-interlocked. In addition, you must complete the three steps before the ALTITUDE indicator reads 1200 feet. If you do everything correctly, the screen will erase to indicate a successful takeoff and a display of the complete instrument panel will appear. (See figure 2.)

Takeoff Mishaps

JETSET doesn't introduce random flight emergencies, but the simulation will abort with a grim message if you mishandle the jet. Using the built-in program specifications of a Boeing 747, the equations of motion dictate that it takes 63 seconds to reach takeoff velocity (150 knots) after full engine thrust is applied. During this interval, the accelerating jet uses up 80 percent of the two-mile runway.

This equation of motion establishes the safe takeoff envelope for the simulation. You must use the ↓ key promptly when the airspeed reaches 150 knots. If you hesitate for another 10 seconds, it will be too late—the jet will simply charge down the runway at 172 knots, plunge into the marshlands beyond, and . . . you get the picture.

The anxious pilot who pulls the nose up too sharply at lift-off time (by pressing the ↓ key more than once) also comes to grief. The abort message will point out that the tail-end of the fuselage has struck the runway; the aft end of a 747 will clear the ground by only a few feet during a normal takeoff. Most important, as pilot you must always remember to lower the wing flaps before you attempt to take off in a 400-ton jet, even in a simulation.

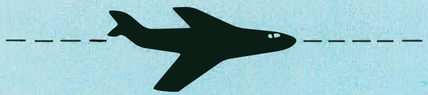
Flying Lesson #2
Maneuvering

Following the takeoff, the jet slowly gains altitude as it passes over central New Jersey and heads toward the Atlantic coast. None of this geography is visible, of course, because of the blanket of clouds below. At this point, you must navigate the jetliner entirely on instruments until it's just a few hundred feet from the point of landing at the destination airport, wherever that may be.

This lesson will give you a "feel" for the controls and show you how they relate to the instrument panel functions. (See table 2 for a list of controls.) The PITCH indicator shows that the nose is tilted upward (positive pitch) at an angle of 10 degrees. With the current position of the THRUST lever, the jet is gaining altitude at the rate of 6704 feet per minute (VERTICAL SPEED). Press the ↑ key twice to level the nose to a zero-degree pitch. The AIRSPEED will now increase, VERTICAL SPEED will become zero, and the ALTITUDE will remain constant. The ↓ and ↑ keys, which correspond

Takeoff Procedure

A. *Lower flaps (L key).*
B. *Release brakes (B key).*
C. *Apply full throttle (F key).*
D. *Steer along the 075-degree runway using left/right rudder keys (< and >). Coordinate steering with the COMPASS reading and the position of the arrow located at the base of the runway graphic.*
E. *As soon as the AIRSPEED indicates 150 knots, press the ↓ key once to gently lift the jet off the runway.*
F. *After the horizon line drops below the screen, press the W key to raise the landing gear.*
G. *Retract the flaps (L key).*
H. *Throttle back the engines (S key).*
I. *Sit back and relax for a minute or so as the jet gains altitude.*



Practice Flight

A. *Execute the takeoff from Philadelphia.*
B. *Level off at 10,000 feet.*
C. *Steer approximately north.*
D. *Adjust airspeed to 600 knots.*
E. *Tune to the frequency of the Buffalo VOR station.*
F. *Input the reciprocal value of the 115-degree radial into the receiver.*
G. *When the VOR needle moves to center, alter course to 295 degrees (COMPASS).*
H. *Now steer to keep the VOR needle centered. This indicator, not the compass, will provide exact guidance for the remainder of the flight.*
I. *Use the DME indicator to keep track of distance remaining, in nautical miles, to Buffalo. To estimate the remaining flying time (in minutes), simply divide the DME reading by 10.*
J. *When the DME readout reaches zero, the jet has arrived.*

Instrument Landing

A. *Execute the takeoff procedures.*
B. *Follow the directives given in the Flight Plan (figure 7) for the intended destination (Buffalo, NY or JFK International). This will lead the flight right up to the ILS Outer Marker along the initial approach radial.*
C. *Begin the initial approach, trimming as soon as the DME readout agrees with the value given on the Flight Plan (20 nautical miles for JFK International Airport). Trim as follows:*
- *Reduce airspeed to 300 knots (S key).*
- *Drop the landing gear (W key).*
- *Lower the flaps (L key).*
- *Adjust altitude to between 1700 and 1900 feet (elevator keys).*
- *Keep the VOR needle centered (rudder keys) to stay on the initial approach radial.*

D. *Be alert for the flash of the MARKER lamp (which occurs when the DME=12). At this signal the jet must be maneuvered for the final approach:*
- *Quickly swing the nose until the compass agrees with the localizer direction shown on the Flight Plan.*
- *Use rudder and elevator keys to keep the ILS indicator needles centered as the jet descends along the glidepath.*
- *As soon as the runway graphic appears on the screen, use the graphic arrow as a guide to apply rudder corrections.*

E. *When the MARKER lamp flashes again to announce arrival at the decision-height point, check the runway alignment using the graphic displayed on the screen. If necessary, press the M (Missed Approach) key to abort the landing attempt. Otherwise, if the plane is lined up safely, take all cues from the RADAR ALT from here on in:*
- *At 100 feet, idle the engines (S key).*
- *At 50 feet, flare up the nose (→ key).*
- *At 0 feet, the jet is on the runway. Slow it down by applying reverse thrust to the engines (Q key).*

to motion of the pilot's control stick, are used to climb or descend to a new altitude. Each press of the ↑ key pushes the nose down another 5 degrees, causing a rapid loss of altitude as both airspeed and vertical speed build up. Regardless of the maneuver—climbing or diving—you should always use the → key to quickly level off the jet when the ALTITUDE readout reaches the desired value.

You can steer the jet to a new COMPASS course by pressing the keys that control rudder angle. Press the < key once to begin a slow turn to the left and watch both the COMPASS and the rudder-angle indicator (RUD). Each additional push of the rudder key will make the angle more acute, causing the COMPASS to swing faster as the rate of turn increases. Always use the rudder-cancel key (/) to stop further turning as soon as the COMPASS indicates the desired course.

You can adjust AIRSPEED by moving the thrust lever forward or backward (F and S keys) one step at a time. Each tap of the key shifts the position of the arrow displayed on the THRUST indicator and alters the AIRSPEED reading. The 747 normally cruises at 600 knots, and for a given thrust setting the AIRSPEED indication will drop back during a climb and increase during descent.

Because the instrument response time is 4 seconds, you must delay consecutive applications of the stick or rudder keys until the panel instrument readings catch up. The jet will automatically level off when it reaches an altitude of 45,000 feet; a dive to ground level while cruising, however, will abort the flight with a simulated crash.

In a plane, the VLF OMEGA indicator is part of an electronic subsystem that receives and correlates specially phased, very-low-frequency radio waves. These waves, which propagate over great distances, are processed in the airborne receiver to give the pilot a continuous display of the changing position of the aircraft. The JETSET simulator tracks aircraft motion as the sum of two vectors: aircraft movement relative to the wind

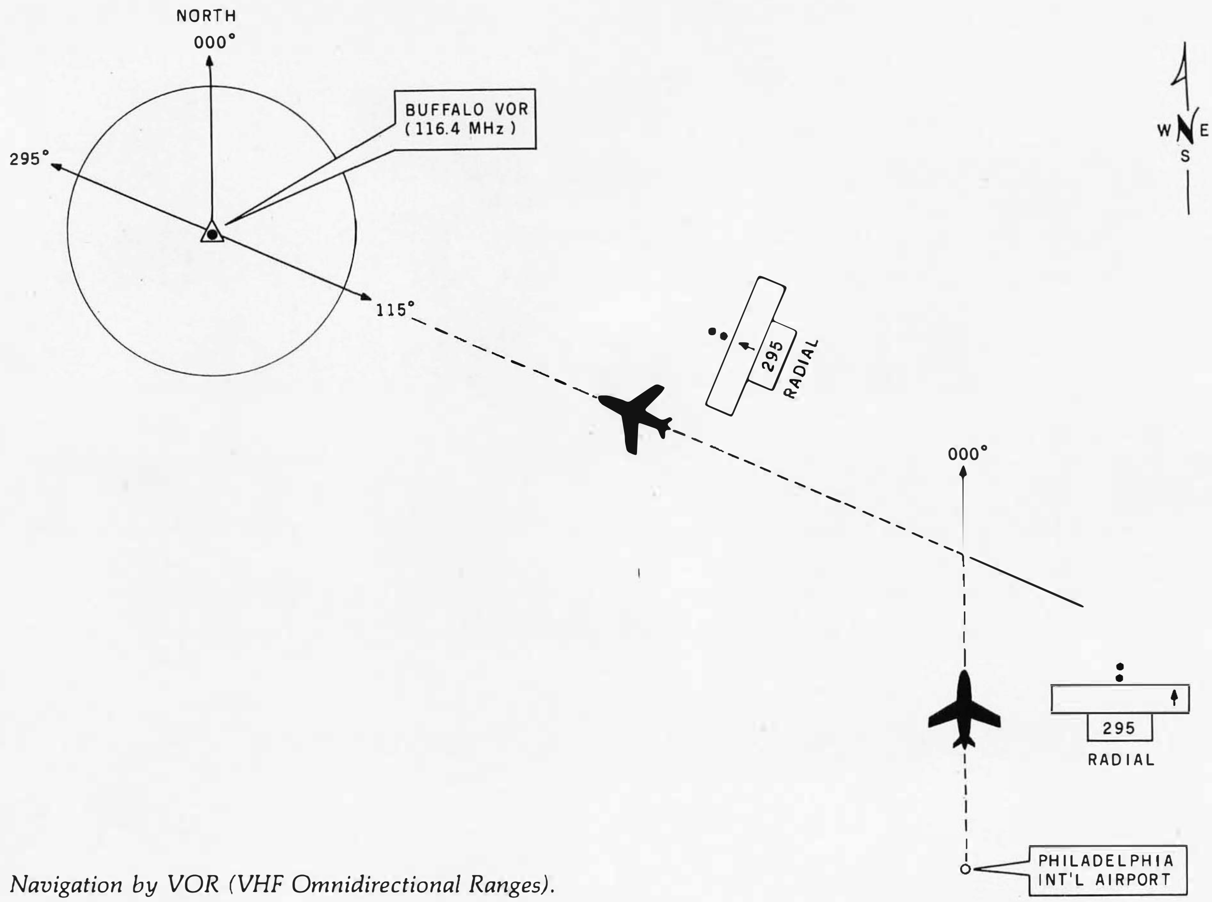


Figure 3: *Navigation by VOR (VHF Omnidirectional Ranges).*

(compass heading and airspeed) and wind movement relative to the earth's surface. As a result of this tracking, the longitude and latitude displayed by the OMEGA readout can fix the exact geographic position of the jet as it is maneuvered through computer-simulated winds. This process results in an effective real-time simulation of the actual OMEGA system.

Although the longitude and latitude displayed on the OMEGA indicator may be used along with any chart or road map to check the progress of the simulated flight, the actual OMEGA system is normally used for flying between continents. For short-range and cross-country flights, most aircraft—and the JETSET simulator—rely on a more convenient system popularly known as VOR (VHF Omnidirectional Ranges).

Flying Lesson #3
Navigating

Most aircraft navigate from point to point using VOR radio facilities. A ground station transmits radio beams that radiate horizontally outward in all directions like the spokes of a wheel. Each spoke or radial (there are 360) is fixed in direction and can be used to provide an accurate and unvarying path to its source, the VOR station transmitter.

In practice, the pilot first tunes the VOR receiver to a ground station located at or near the destination. Each station is assigned a unique frequency. Next the pilot adjusts the receiver's radial selector dial to match the particular radial intended for use as a path (this dial is calibrated in one-degree steps, from 000 to 359 degrees). The pilot then flies while watching the needle of a sensitive meter connected to the VOR receiver. When the needle moves to its center position, the aircraft has intercepted the selected radial. By altering the course to keep the VOR needle centered, the pilot will be able to guide the plane directly along the radial in a straight line toward the VOR transmitter.

Figure 3 shows you how to navigate to Buffalo, New York from Philadelphia International Airport. First tune the VOR receiver to 116.4 MHz (the frequency assigned to the Buffalo VOR station) and select the desired radial, 115 degrees in this example. Rotate the radial dial until it points to 295 degrees, the reciprocal value of 115 (115+180=295). (The reciprocal value is always used when setting the selector dial to match the chosen radial. This process gives the VOR receiver proper internal orientation.)

Once tuning is completed, you fly in an approximate northerly direction and watch the movement of your VOR panel indicator. Initially the needle will be "pegged" to the right side of its travel, but it will slowly begin to move toward the center as the plane nears the 115-degree radial. Once the needle is at center, alter your course to 295 degrees by compass and swing the nose of your jet toward Buffalo. Now you must make minor steering corrections, using the rudder to keep the VOR needle centered.

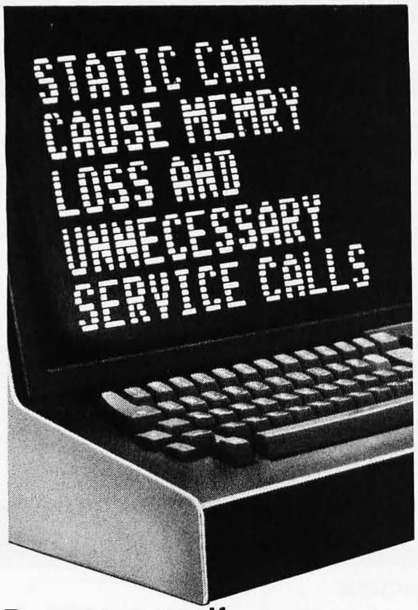
This needle, rather than the compass reading, provides the guidance for the remainder of the trip. Upper-air winds will generally deflect the heading (compass course) of the jet from its actual track over the earth's surface, but if the plane is flown with the needle centered, the path of travel will remain exactly on the 115-degree radial. The compass reading may differ by a dozen or more degrees when you are flying at upper altitudes in the presence of high-velocity jet streams.

The process of adjusting the steering to keep the VOR needle on center is called "chasing the needle." If the needle (which represents the radial) begins moving to the left, you must apply some left rudder until the needle returns to center. For needle deflection to the right, steer to the right. After a minute or two you should be able to establish a compass heading that keeps the VOR needle centered until the jet arrives in Buffalo.

The VOR system carried aboard a jetliner includes a very useful and important device known as the DME (Distance-Measuring Equipment). Once the VOR receiver is tuned to a station, the DME indicator continuously displays the distance in nautical miles (NM) to that station. In a flight to Buffalo, for example, the DME would read about 180 NM when the northward-flying jet first intercepted the 115-degree radial. From then on, as the pilot steered toward Buffalo the DME value would progressively decrease in step with the aircraft's position until the reading reached zero. A zero reading would indicate that the jet had flown over the VOR station. The DME readout would then slowly begin to increase as the pilot passed by Buffalo.

The simulator VOR receiver is tuned and adjusted from the keyboard. To tune to a station, first press the V key, then type in the station frequency. The typed characters will echo on the screen; to correct them, use the Backspace key. Finally, press Enter to terminate the input. To tune in the Buffalo station, type the 6-key sequence V116.4 followed by the Enter key.

A similar procedure sets the VOR receiver to any selected radial except



that you type R first rather than V. To adjust the receiver for the flight to Buffalo, type R295 followed by the Enter key.

The RANGE window of the VOR receiver displays OUT whenever the receiver is not tuned to any station or whenever it is tuned to an incorrect frequency. An OUT also appears if the receiver is tuned to a VOR station whose distance exceeds 300 NM, the maximum range of the VOR signals.

Flying Lesson #4 Practicing VOR

Several practice flights to Buffalo on the JETSET simulator will acquaint you with the simple principle of VOR navigation. Although it isn't necessary, a chart or group of road maps that encompass the Buffalo-Philadelphia area would help you visualize the progress of the jet.

Begin by taking off from Philadelphia, climbing to about 10,000 feet, and leveling off. Then apply the left rudder until the compass reads 000, give or take a few degrees. While you're on this northerly course, adjust the thrust (F and S keys) for an airspeed of 600 knots.

Tune to the Buffalo VOR station by typing V116.4 and the Enter key. Set the receiver for the reciprocal of the 115-degree radial by typing R295 followed by Enter. This completes the tuning procedure. The VOR needle, which is located directly above the RADIAL window on the display, will now remain pegged to the rightmost position for about seven minutes as the jet flies north.

Once the VOR needle begins moving toward the center of the graphic slot, prepare to alter course. When the needle reaches center, apply the left rudder (< key) and bring the jet on a compass course of 295 degrees. Remain on this course for about a minute and watch the motion of the VOR needle. Now you can begin chasing the needle by applying the rudder corrections needed to center the needle and keep it there. You may need to make an occasional steering adjustment if the needle begins to wander, but as long as it remains within one dot of center (each dot represents one degree), your course will be reasonably accurate.

When the Buffalo radial is first intercepted, the DME indicator should read approximately 180 NM, and it should take about 18 minutes for the 600-knot jet to reach its destination. The exact flying time, of course, will depend on the strength and direction of the prevailing winds, but the DME readout will always show the exact remaining distance. If you use a map to keep tabs on the practice flight, remember that DME distances are nautical (not statute) miles. A DME reading of 100 NM corresponds to 115.2 statute miles.

As the jet moves along the radial, the RANGE window of the VOR panel will display TO, indicating orientation toward the VOR station. As soon as the DME reads zero, note the reading of the OMEGA display. Because the jet is passing directly over the ground station, the display should read 42° 55′ North, 78° 38′ West, equal to the geographic coordinates of the VOR station. This reading confirms that the navigation was accurately performed by the VOR system. If you have maintained the course, a FROM will appear in the RANGE window as the jet proceeds in a westerly direction away from Buffalo, New York.

Flying along Airways

Although I used the 115-degree radial for the practice flight to Buffalo, I could just as well have chosen other radials for guidance. For example, a map shows that the 140-degree radial passes directly through Philadelphia and would therefore reduce the flying time if it had been used as a path. I selected 115 degrees instead because it is designated as a jet route by the FAA (Federal Aviation Administration). The FAA has established a network of special radials that high-altitude jets must use when flying on instruments. An aviation chart reveals that radial 115 from Buffalo corresponds to jet route J-95 when the radial direction is adjusted for the earth's magnetism (the JETSET program works with true, not magnetic, directions).

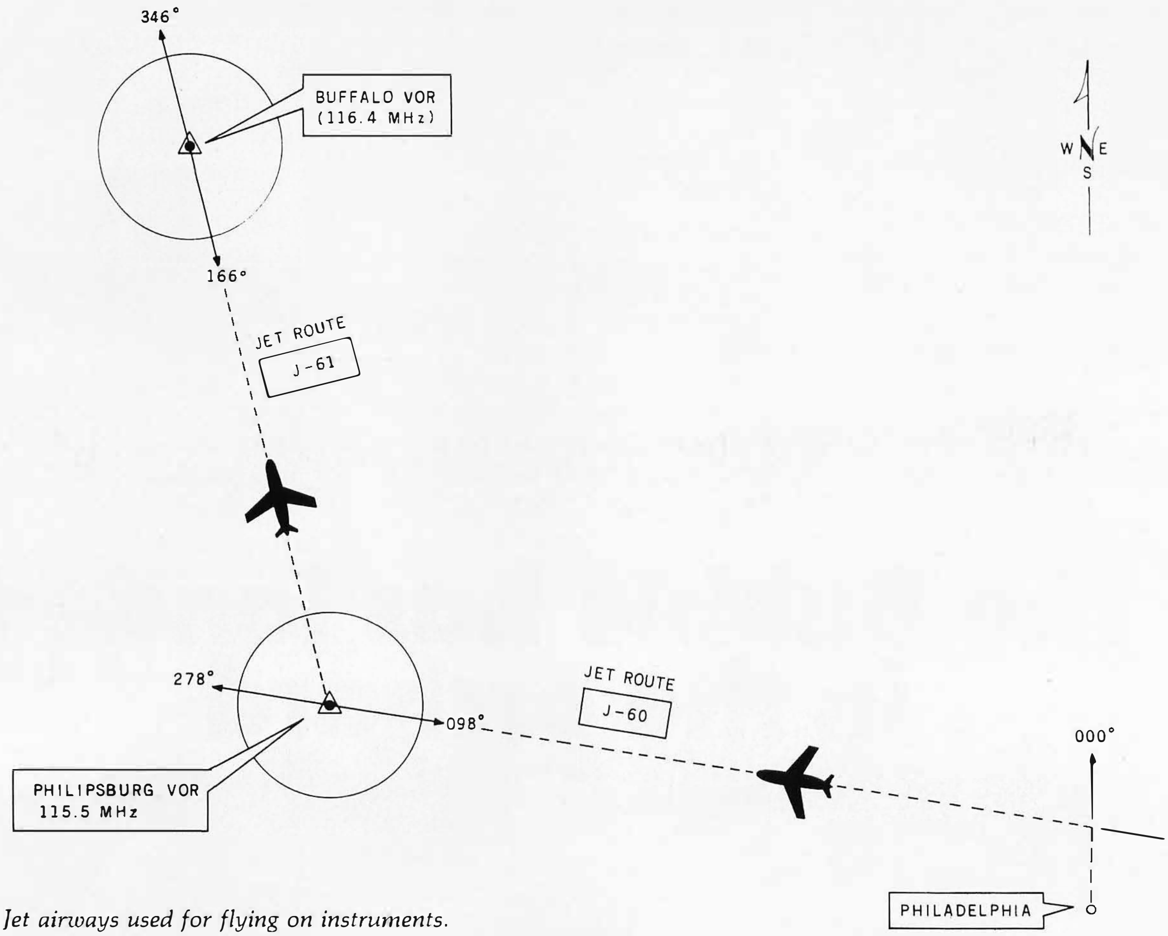


Figure 4: *Jet airways used for flying on instruments.*

In order to comply with regulations, an actual high-altitude flight from Philadelphia to Buffalo might require the pilot to proceed as follows:

- fly toward Philipsburg, Pennsylvania along jet route J-60 (as shown in figure 4)
- alter course at Philipsburg to pick up jet route J-61, which leads directly to Buffalo

During the first leg of the trip, the pilot would tune the VOR receiver to 115.5 MHz, the frequency of the Philipsburg ground station, and fly along the J-60 radial (278 degrees). Just before the pilot reached Philipsburg (as shown by the DME indicator), he would retune the receiver for Buffalo (116.4 MHz) and adjust it to the radial that corresponded to jet route J-61 (346 degrees). The pilot would then alter his course, chasing the needle to follow radial 346 until he arrived at Buffalo.

Numerous VOR stations scattered throughout the country enable a pilot to fly extended distances simply by hopping from one station to the next, retuning the receiver to locate the designated jet routes. JETSET, however, needs only a handful of VOR stations to establish a network for instrument flight simulation. Figure 5 shows the frequencies and locations of the VOR stations built into the program. You may use any of these VOR stations for practice flights to the given cities or as steppingstones for navigating from city to city. (Remember that a tuned-in VOR station must be within 300 miles to activate the airborne VOR receiver.)

The VOR receiver in the JETSET simulator is as versatile as its real-life counterpart. When a pilot is lost or disoriented the receiver can be tuned to a VOR station and the radial-selector dial rotated until the needle of the VOR meter centers. The reading shown on the radial dial then represents the direction from the VOR station. Combining this with the distance read on the DME indicator results in an exact position "fix."

In the JETSET simulator a press of the A key results in an exact position fix. The program automatically rotates the invisible radial-selector dial for the pilot and quickly displays the direction from the tuned-in station in the RADIAL window.

Instrument Landing

Using the VOR receiver as a guide, a pilot can navigate accurately from one city to another without any view of the earth below. VOR radials are suitable for point-to-point navigation, but when a pilot arrives at his destination he needs another system of guidance to get to the airport run-

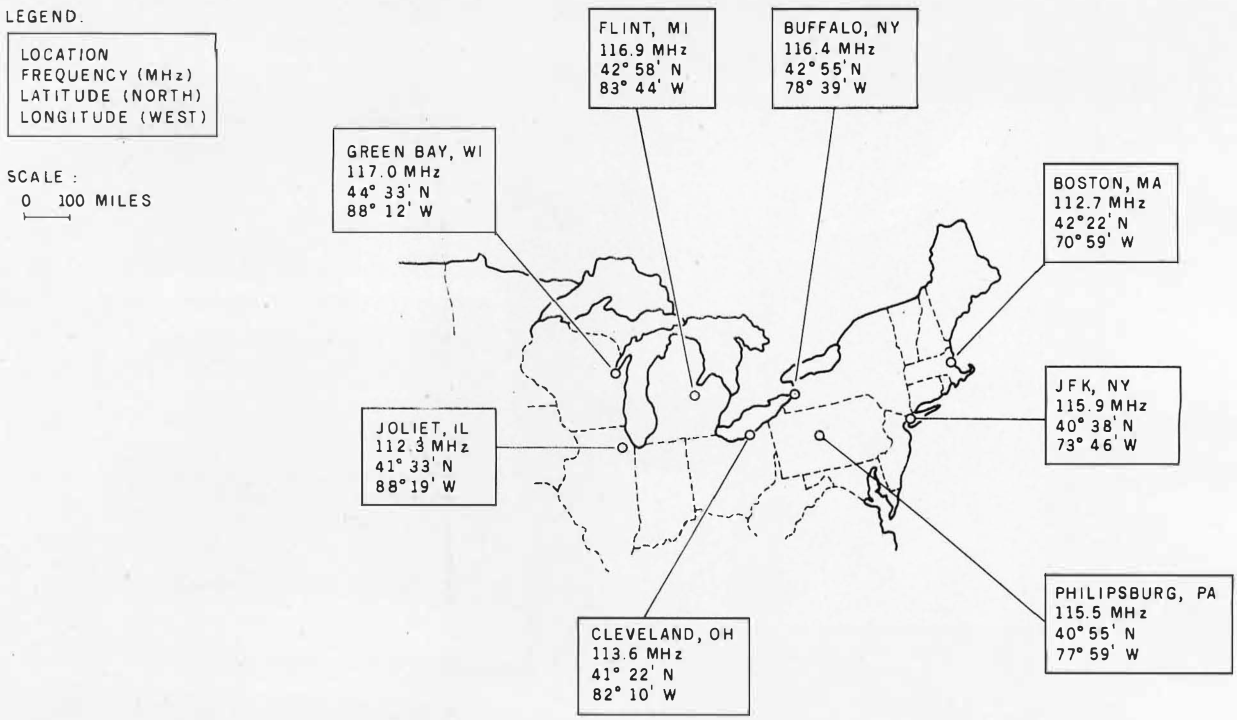


Figure 5: *Locations and frequencies of simulated VOR ground stations.*

way itself. In this case, the pilot must revert to a radio aid, the Instrument Landing System (ILS), a facility designed to make blind landings possible. A trained pilot flying an aircraft equipped with an ILS receiver can locate an airport and safely land on a runway that may not be visible until a minute or so before the actual touchdown.

An ILS installation consists of a group of radio transmitters arranged in the vicinity of the airport where ILS landings are to take place. These transmitters radiate highly directional radio beams that converge at the foot of the runway, forming a cone-shaped pattern like the rays of a searchlight (see figure 6). The pilot first maneuvers the plane into this invisible cone, then uses the ILS receiver to follow the radio waves down until the aircraft is just a few hundred feet above the ground. At this low altitude the runway should be visible, so the actual landing can be completed in the usual way.

The airborne instruments used to locate and follow the cone of radio waves are a marker lamp, an ILS indicator, and a radar altimeter. On the JETSET simulator panel these three components are identified as the MARKER, ILS, and RADAR ALT respectively. The panel MARKER lamp flashes on when the aircraft flies over a point called the "outer marker" (OM in figure 6), telling the pilot that the plane has just entered the ILS cone. The crosshairs (horizontal and vertical needles) of the panel ILS meter will now begin to deflect, and the pilot must maneuver the plane to keep the needles centered in order to follow the path of the ILS radio cone. As the aircraft descends along this narrow path, the radio altimeter (RADAR ALT) gives a continuous display of the exact elevation from the ground (in feet). The radar altimeter is much more sensitive than the conventional altimeter, so it is always used for precision landings.

During the time the aircraft has entered the ILS cone and is heading toward the runway, when the pilot is making the final approach, the plane flies in a direction known as the "localizer" direction of the ILS radio beams. The angle that the radio cone makes with the ground is called the "glideslope" angle, and the descending plane is said to be flying within the ILS "glidepath." The two moving needles of the ILS indicator correspond to the localizer and glideslope axes during the final approach. The pilot chases the vertical needle (which moves left and right) to remain aligned with the localizer direction. The horizontal needle (which deflects up and down) must be chased using the elevator controls to keep the plane within the glidepath.

Once the descending aircraft reaches the ILS "middle marker" (labeled as MM on figure 6), the panel MARKER lamp will flash again, alerting the pilot that the plane is just a fraction of a mile from the runway. This critical location is called the "decision height" of the final approach because the pilot must now decide whether he can safely complete the landing. If the runway appears in view directly ahead, the pilot can make a visual landing. If, however, the plane is not properly lined up with the runway (because the ILS needles were not kept centered), the pilot must abort the landing attempt at once by climbing out of the glidepath. This situation is known as a "missed approach." When a pilot misses the approach, he flies a safe distance away from airport traffic and then returns to the OM point for another try.

Every ILS-equipped airport uses

(6a)

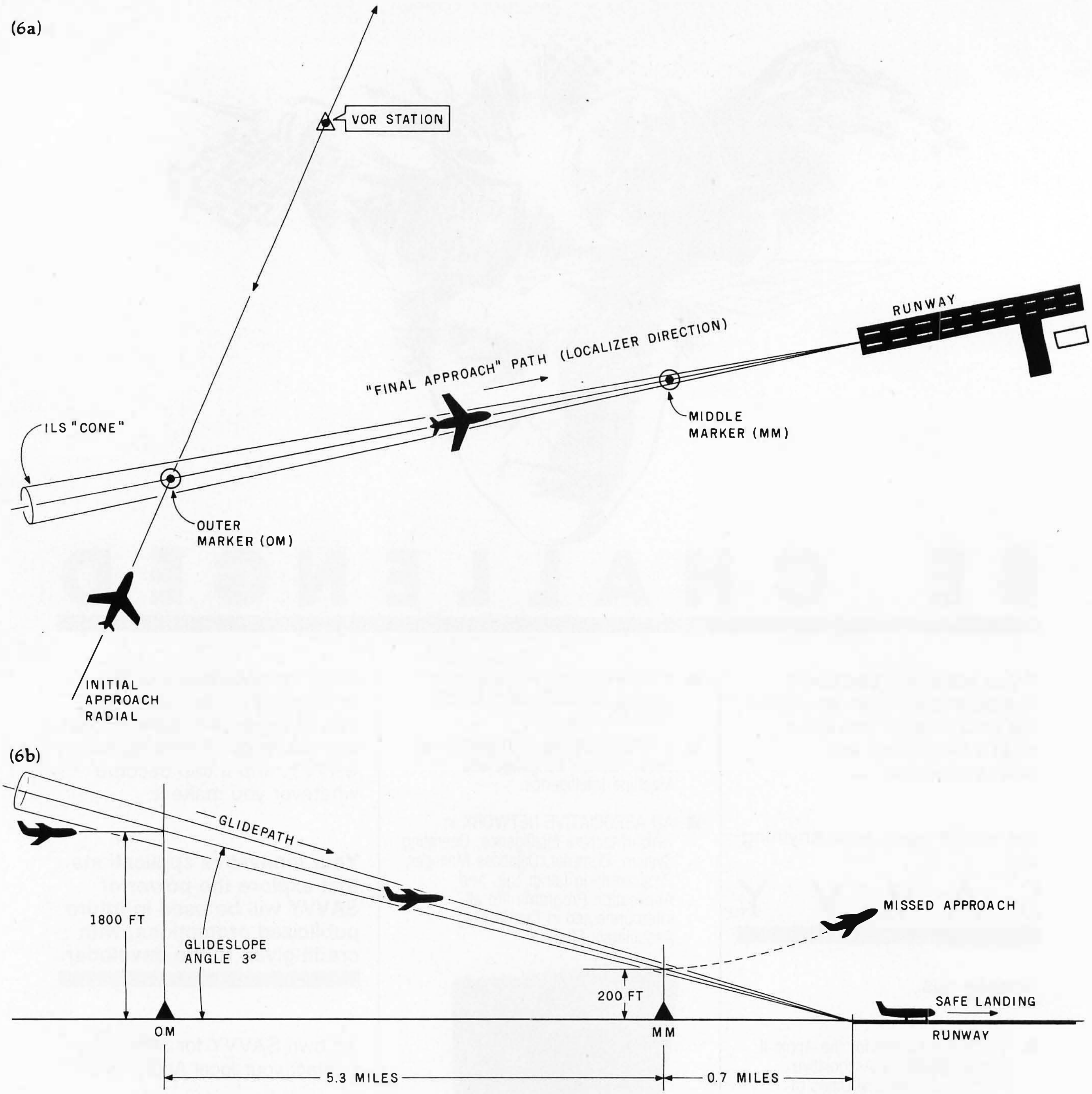


Figure 6: *ILS (Instrument Landing System) geometry showing the localizer direction (a); ILS geometry showing the vertical glideslope angle (b).*

the geometric layouts shown in figure 6 for its instrument landing pattern, with minor variations to suit the terrain. The exact ILS arrangement (localizer direction and glideslope angle) for any given airport is published in a manual of approach diagrams (one for each airport), which the pilot studies well in advance of his instrument landing.

Obviously, an instrument landing is a tricky procedure that airline pilots must practice in large-scale simulators to perfect. The routines that simulate landing are an important part of the JETSET program; they closely follow the sequences that develop when a plane flies into the ILS pattern. You may have to make several attempts at a simulated landing before you can consider yourself qualified to handle a jetliner under bad weather conditions.

Flying Lesson #5 Practicing ILS

Preparing for an instrument landing, even aboard the JETSET simulator, begins when the plane is still many miles away from the airport. Because all ILS landing procedures follow a standard pattern, the John F. Kennedy (JFK) International Airport, conveniently located with respect to Philadelphia, can serve as a practice landing site. A simulated flight from Philadelphia to JFK lasts about 20 minutes from takeoff until the jet rolls to a stop on the runway.

Every airline flight must be conducted in accordance with a flight plan, a document that specifies the routes the pilot will fly until he arrives at the destination. An actual flight takes place at standard altitude levels and under close supervision of air traffic controllers, but the flight plan prepared for the practice run to JFK International tells the JETSET pilot exactly how to proceed. (See figure 7.)

Using the Philadelphia-JFK flight plan as a guide, execute the takeoff procedure and climb to 5000 feet while maintaining a compass course of 075 degrees. During the climb, tune your VOR to the JFK ground station (115.9 MHz) and input the radial value of 058 degrees.

Level off at an altitude of approximately 6000 feet. Use the < key for the left rudder to alter the compass course to approximately 000 degrees. Hold this course until the VOR needle nears its center position. Now steer to 058 degrees and begin chasing the VOR needle.

The jet will head directly for JFK as long as you keep the VOR needle centered—the 058-degree radial is used because it's the "initial approach" radial defined for the JFK airport. It will lead to an intercept with the runway outer marker (OM), a prerequisite for the instrument landing.

As soon as the DME indicator reads 38, you must prepare for landing. To begin a descent, adjust the elevators for a pitch of −10 degrees (press the ↑ key twice) and level off at an altitude of about 1900 feet.

Start the "initial approach trim" procedure for the jetliner when the DME distance is 20 NM. First reduce your airspeed to 300 knots (S key), lower the landing gear (W key), and lower the wing flaps (L key). The airspeed will automatically drop back to 120 knots as soon as the flaps are lowered, as required for a proper landing. Complete the trim procedure by adjusting altitude until the ALTITUDE indicator reads between 1700 and 1900 feet.

You must execute this procedure quickly so that the aircraft is in its proper "profile" or flight configuration as it approaches the OM along the initial approach radial. You will

Philadelphia, PA To Buffalo, NY

1. After takeoff, continue climbing to 3000 feet on course 075 degrees.
2. At 3000 feet alter course to 000 degrees and continue climbing. Adjust thrust for airspeed 580 knots, tune VOR to Philipsburg station (115.5 MHz), and set radial to 278 degrees.
3. Steer along 278-degree radial when intercepted. Level off at 40,000 feet and proceed to Philipsburg at 600 knots.
4. At DME = 20 NM, retune VOR to Buffalo (116.4 MHz) and set radial to 346 degrees.
5. Upon intercepting 346-degree radial, alter course to follow radial to Buffalo.
6. At DME = 73 NM, begin descent to 1900 feet (descend at approximately 11,000 FPM).
7. Level off at 1900 feet. Remain aligned with radial.
8. Begin initial approach trim when DME = 20 NM.
9. Execute ILS final approach procedures when MARKER lamp flashes. Localizer direction is 042 degrees.

Philadelphia, PA To JFK International, NY

1. After takeoff, continue climbing to 6000 feet on course 075 degrees. While climbing, tune VOR to JFK station (115.9 MHz) and set radial to 058 degrees.
2. Level off at 6000 feet. Steer left to intercept radial, align with it, and proceed toward Long Island, NY at 400 knots.
3. At DME = 38 NM, begin descent to 1900 feet (descend at approximately 7410 FPM).
4. Level off at 1900 feet. Remain aligned with radial.
5. Begin initial approach trim when DME = 20 NM.
6. Execute ILS final approach procedures when MARKER lamp flashes. Localizer direction is 028 degrees.

Figure 7: *Flight plans for a simulated instrument flight.*

reach the OM when the DME reads exactly 12 NM, so the jet should be in its trim profile and steered to keep the VOR needle centered (to within two graphic dots) as the OM point nears.

If you've done these steps carefully, the panel MARKER lamp will flash when the DME indicator reads 12 NM. This is a signal that the aircraft has just intercepted the ILS radio cone and must be promptly steered to align with the localizer direction (028 degrees) at JFK airport.

Press the left rudder key (<) quickly when the MARKER lamp flashes. It's imperative that you swing the jet to a compass course of 028 degrees before it flies out of the narrow area of the radio cone (this would occur about 15 seconds after the MARKER lamp turns on). A compass reading of 028 degrees (give or take one degree) before the MARKER lamp goes off will ensure that you completed the turn in time for the jetliner to enter the ILS radio cone. Both the ILS indicator and the RADAR ALT meter should be activated. If not, the turn took too long to complete and you need more practice in making a fast turn. For another attempt, you can stop the simulation program and begin again or raise the flaps and wheels and circle back to pick up the initial approach radial for another attempt.

The rapid updating of the ILS indicator means the jet is now beginning its crucial final approach. You have very little margin for error. The program will automatically change the sensitivity of the elevator and rudder keys; each press of the elevator key varies the pitch by one degree and the course changes by one degree each time a rudder key is typed. Quickly press the ↑ key three times to pitch the nose down 3 degrees and turn your full attention to the ILS display.

You must use the rudder keys to chase the vertical needle of the ILS indicator as the jet loses altitude (as shown by the RADAR ALT reading). If the ILS horizontal needle moves from center, chase it by using the elevator keys. Crosswinds blowing across the airport will tend to deflect the jet (and the vertical ILS needle), so you must make every effort to keep the two ILS needles where they belong—exactly on center.

The RADAR ALT indicator, a meter that activates when the final approach begins, shows the elevation of the descending jet (feet above ground level). At an elevation of about 600 feet, JETSET will display the approaching runway on the lower-right portion of the screen to simulate that the ground is now visible. The arrow appearing at the foot of the graphic shows the exact alignment of the jet in relation to the approach end of the airport runway. You must now use this visual reference instead of the ILS indicator to quickly correct any course errors. For example, if the arrow extends too far to the left, beyond the runway base, apply some right rudder to realign the jet's path.

After a few more seconds the MARKER lamp should flash again to announce that the plane has just reached the middle marker point along the approach path, the decision-height location. Now a quick decision is vital. If the arrow of the runway graphic extends too far left or right, beyond the runway base, the jet is not properly lined up for a safe landing and you must press the M key immediately to signal a missed approach to the computer. JETSET will comply by announcing that the pilot's decision was a correct one for the landing situation.

If however, the runway arrow shows that the jetliner is safely aligned for a landing, you must bring it down as follows:

1. At an elevation of 100 feet (RADAR ALT reading), press the S key once. This command will "chop the throttle" (abruptly reduce the engine thrust to idle).
2. At 50 feet, press the → key once to "flare up" the nose of the jet. This maneuver automatically tilts the aircraft upward slightly to a positive pitch, causing a controlled stall. The jet will now sink gently down to ground level as it loses aerodynamic lift.
3. At 0 feet the jet has landed and is rolling along the runway. Quickly press the Q key to apply reverse thrust to the engines. Reverse thrust decelerates the aircraft gradually until the AIRSPEED readout reaches zero.

Your JETSET flight concludes with a display of the landing information that tells you how well you handled the jet. This information specifies where ground contact occurred and where the jet finally rolled to a halt. If you made a mistake at the middle marker, the landing report will point out the consequences. ■

The author has offered to make copies of his program available to BYTE readers for $8. Send a blank disk, a check, and a self-addressed, stamped envelope to

Eugene Szymanski
693 Rosedale Rd.
Princeton, NJ 08540

← Circle 336 on inquiry card.

Listing 1 continued from page 273

```
383 PRINT@(6,32),". . . . : . . . .":PRINT@(8,39),"RUD"
384 PRINT@(9,32),CHR$(128);STRING$(15,150);CHR$(129)
386 FORX=32TO48STEP16
387 FORY=10TO22
388 PRINT@(Y,X),CHR$(148);
389 NEXTY
390 NEXTX
391 PRINT@(23,32),CHR$(131);STRING$(15,150);CHR$(130);
392 PRINT@(10,39),"VOR":PRINT@(11,44),"MHZ"
393 PRINT@(14,38),"RANGE"
394 PRINT@(16,35),".....:....."
395 PRINT@(19,38),"RADIAL"
396 PRINT@(21,39),"DME":PRINT@(22,44),"NM";
397 FORY=1TO7:PRINT@(Y,12),CHR$(150):NEXT
398 FORY=1TO3:PRINT@(Y,21),CHR$(150):NEXT
400 PRINT@(14,0),CHR$(128);STRING$(15,150);CHR$(129)
402 FORX=0TO16STEP16
404 FORY=15TO21
406 PRINT@(Y,X),CHR$(148);
408 NEXTY
410 NEXTX
412 PRINT@(22,0),CHR$(131);STRING$(15,150);CHR$(130);
414 PRINT@(13,7),"ILS"
416 PRINT@(17,19),"MARKER":PRINT@(18,20),">  <"
418 GX(1)=0:GY(1)=0
420 GOSUB2100
422 PRINTCHR$(26):PRINT@(10,6),"      "
424 PRINTCHR$(25):PRINT@(9,4),"RADAR ALT";SPC(6);"STALL"
425 PRINT@(10,18),">      <"
599 RETURN
600 REM:DISPLAY INSTRUMT READINGS
601 GOTO720
605 YP=1:XP=0:F$="######":V1=FU:GOSUB 9000
610 YP=1:XP=7:F$="###":V1=FP:GOSUB 9000
615 YP=1:XP=39:V1=CC:GOSUB 9000
620 YP=4:XP=39:V1=AS:GOSUB 9000
625 YP=4:XP=46:F$="######":V1=RC:GOSUB 9000
630 YP=4:XP=55:F$="##,###":V1=AL:GOSUB 9000
635 YP=5:XP=0:F$="###":V1=MZ:GOSUB 9000
636 IFF(2)=1THENYP=10:XP=6:F$="#####":V1=AL:GOSUB9000
640 REM:DISPLAY THRUST
650 FOR I=1 TO 7
651 PRINT@(I,11),CHR$(26);" "
652 NEXT
655 PRINT@(TR,11),">";
660 REM:DISPLAY FLAPS
665 FOR I=1 TO 3:PRINT@(I,20),CHR$(26);" ":NEXT
670 PRINT@(FL,20),">"
674 F$="+###"
675 YP=5:XP=20:V1=FA:GOSUB 9000
676 IFF(6)=0THENSX=25:GOTO679
677 IFSX=25THENSX=26:GOTO679
678 SX=25
679 IFF(7)=0THENPRINTCHR$(SX):PRINT@(10,19),"      "
680 REM:DISPLAY BRAKES
690 FOR I=10 TO 12:PRINT@(I,54),CHR$(26);" ":NEXT
695 PRINT@(BR,54),">"
700 REM:WHEELS
705 FOR I=10 TO 12:PRINT@(I,62),CHR$(26);" ":NEXT
710 PRINT@(WH,62),">"
711 IFF(2)=1GOTO723
712 REM:DISPLAY LAT/LONGIT
713 YP=4:XP=69:F$="###":V1=DP(4):GOSUB9000
714 YP=4:XP=73:F$="##.#":V1=DP(5):GOSUB9000
715 YP=5:XP=69:F$="###":V1=DP(6):GOSUB9000
716 YP=5:XP=73:F$="##.#":V1=DP(7):GOSUB9000
717 PRINT@(4,78),"N"
718 PRINT@(5,78),"W"
719 GOTO723
720 REM:DISPLAY RUDDER POSIT
721 PRINT@(7,32),CHR$(26);S$(17)
722 PRINT@(7,RP),CHR$(147);CHR$(25):GOTO605
723 IFF(2)=1THENRETURN
724 REM:DISPLAY VOR VALUES
725 YP=11:XP=38:F$="###.#":V1=VO(1):GOSUB9000
726 PRINT@(13,39),CHR$(26);VO$(1);CHR$(25)
727 YP=18:XP=39:F$="###":V1=VO(3):GOSUB9000
728 YP=22:XP=38:F$="###.#":V1=VO(4):GOSUB9000
729 PRINT@(17,34),CHR$(26);S$(13)
730 IFVO$(1)="OUT "GOTO732
731 PRINT@(17,VO(2)),CHR$(159)
732 RETURN
800 REM:KEY POLL SUBROUT
805 IF K$="F" OR K$="S" THEN KK=1:GOTO 850
810 IF K$="," OR K$="." THEN KK=2:GOTO 850
811 IFK$="/"THENRA=0:GOTO855
825 IF ASC(K$)=30 OR ASC(K$)=31 THEN KK=3:GOTO 850
830 IF K$="W" THEN KK=4:GOTO 850
835 IF K$="V" THEN KK=5:GOTO 850
836 IFK$="R"THENKK=6:GOTO850
837 IFK$="L"THENKK=7:GOTO850
838 IFK$="A"THENKK=8:GOTO850
839 IFK$="O"THENKK=9:GOTO850
840 IFK$="M"THENKK=10:GOTO850
841 IFASC(K$)=29THENKK=11:GOTO850
850 ONKKGOSUB900,908,914,928,931,935,940,944,946,950,953
855 RETURN
900 REM:THRUST KEY
902 IFK$="F"THENTR=TR-1ELSETR=TR+1
904 IFTR<1THENTR=1:RETURN
906 IFTR>6THENTR=6:RETURN
907 RETURN
908 REM:RUDDER KEYS
909 IFK$=","GOTO912ELSERA=RA+1
910 IFRA>4THENRA=4
911 RETURN
912 RA=RA-1:IFRA<-4THENRA=-4
913 RETURN
914 REM:ELEVATOR KEYS
915 J=5:IFBR=12THENJ=1
916 IFK$=CHR$(31)THENFA=FA+JELSEFA=FA-J
918 IFFA>40THENFA=40
920 IFFA<-40THENFA=-40
922 IFFA>0THENFL=1:RETURN
924 IFFA=0THENFL=2:RETURN
926 FL=3:RETURN
928 REM:WHEELS KEY
929 IFWH=10THENWH=12:RETURN
930 IFWH=12THENWH=10:RETURN
931 REM:SET VOR FREQ
932 PRINT@(14,55),CHR$(1);
933 LINE INPUT"VOR FREQ ";VX$:VO(1)=VAL(VX$)
934 PRINT@(14,55),SPC(16);CHR$(2):RETURN
935 REM:SET VOR RADIAL
936 PRINT@(14,55),CHR$(1);
937 LINE INPUT"VOR RADIAL ";VX$:VO(3)=VAL(VX$)
938 PRINT@(14,55),SPC(14);CHR$(2):RETURN
940 REM:FLAPS KEY
941 IFBR=10THENBR=12:RETURN
942 IFBR=12THENBR=10:RETURN
944 REM:AUTO-OBS KEY
945 F(3)=1:RETURN
946 REM:REV THRUST KEY
947 IFF(7)=1THENTR=7
948 RETURN
950 REM:MISSED APPROACHED KEY
951 IFF(2)=1THENF(5)=1
952 RETURN
953 REM:FLARE KEY
954 IFF(2)=0THENFA=0:FL=2:RETURN
955 FA=1:FL=1:RETURN
1000 REM:SITUATION UPDATE ROUTINE
1002 TV$=TIME$:GOSUB 7050:TJ=TD-TL:TL=TD
1010 GOSUB1100
1012 GOSUB1130
1013 GOSUB1145
1014 IFTR=7THENGOSUB1800ELSEGOSUB1124
1016 GOSUB1106
1018 GOSUB1114
1019 IFF(2)=1GOTO1600
1020 GOSUB1400
1021 GOSUB1500
1030 IFAL<=0THENAF=1:GOTO3000
1031 IFF(2)=0GOTO1099
1032 IFAL>0GOTO1068
1033 IFF(7)=1GOTO1090
1034 F(7)=1
1036 TY=YN
1038 TX=XN-750
1042 IFFA>1THENAF=2:GOTO3000
1044 IFFA<0THENAF=3:GOTO3000
1046 IFF(6)=0GOTO1062
1048 IFAX>100THENAF=4:GOTO3000
1050 IFAX>80THENAF=5:GOTO3000
1052 IFWH=10THENAF=6:GOTO3000
1054 IFTX>0THENAF=7:GOTO3000
1056 IFTX<-10500THENAF=7:GOTO3000
1058 IFABS(TY)>100THENAF=7:GOTO3000
1060 GOTO1099
1062 AF=8:GOTO3000
1068 IFF(5)=1GOTO1082
1070 IFFA>0GOTO1076
1072 IFFA<0THENF(6)=0
1074 GOTO1099
1076 IFF(6)=0THENAX=AL:F(6)=1
1077 IFTR=6GOTO1080
1078 IFFA<2THENRC=-1800:GOTO1099
1079 FA=2:FL=1:RC=-1800:GOTO1099
1080 FA=1:FL=1:RC=-300:GOTO1099
1082 IFAL<20THENAF=9:GOTO3000
1084 TR=3:FA=0:FL=2
1086 AF=10:GOTO3000
1090 IFXN<-9750 OR ABS(YN)>100GOTO1094
1091 IFAS>0GOTO1099
1092 AF=0:GOTO3000
1094 AF=9:GOTO3000
1099 GOTO1700
1100 REM:UPDATE FUEL
1102 FU=FU-(14-TR)*TJ:IFFU<0THENFU=0
1104 FP=FU/3120:RETURN
1106 IFF(7)=1THENRC=0:RETURN
1107 IFF(6)=1THENRETURN
1108 RC=AS*SIN(ABS(FA/KR))*101.6
1110 IFFA<0THENRC=-1*RC
1112 RETURN
1114 REM:UPDATE ALTITUDE
1115 IFF(7)=1THENRETURN
1116 AL=AL+TJ*RC/60
```

Listing 1 continued on page 306

Listing 1 continued:

```
1118 IFAL<0THENAL=0:RETURN
1120 IFAL>45000THENAL=45000
1122 RETURN
1124 REM:UPDATE AIRSPEED
1125 AS=800-100*TR
1126 AS=AS-2*FA
1127 IFBR=10THENRETURN
1128 AS=AS/3+20:RETURN
1130 IFF(5)=1GOTO1132
1131 IFF(2)=1GOTO1142
1132 IFRA=0THENRT=0:RETURN
1133 IFRA<0THENJ=-1ELSEJ=1
1134 RA=ABS(RA):IFRA=1THENRT=1:GOTO1137
1135 IFRA=2THENRT=10:GOTO1137
1136 IFRA=3THENRT=20ELSERT=30
1137 RT=J*RT:RA=J*RA
1138 CC=CC+RT
1139 IFCC=>360THENCC=CC-360:RETURN
1140 IFCC<0THENCC=360+CC
1141 RETURN
1142 IFRA=0THENRETURN
1143 IFRA<0THENCC=CC-1ELSECC=CC+1
1144 RA=0:GOTO1139
1145 REM:UPDATE RUDDER POSIT VARIABLE
1146 RP=40+RA+RA:RETURN
1200 REM:COMPUTES DIST&BEARING TO A KNOWN POINT LOCATION
1202 VL=ABS(LB-LC):BL(5)=-1:IFLB=>LCTHENBL(5)=1
1204 VG=ABS(GB-GC):BL(4)=1:IFGB=>GCTHENBL(4)=-1
1206 LA=LC:GOSUB2400
1208 M1=MP
1210 LA=LB:GOSUB2400
1212 M2=MP:DM=ABS(M2-M1)
1214 IFDM=0GOTO1220
1216 QO=VG/(DM/60):IFQO>114.59GOTO1220
1218 CA=KR*ATN(QO):DR=VL*(1/COS(CA/KR)):GOTO1222
1220 CA=90:DR=VG*COS(LC/KR)
1222 DR=DR*60:IFBL(5)=-1GOTO1226
1224 IFBL(4)=1THENCR=CAELSECR=360-CA
1225 RETURN
1226 IFBL(4)=1THENCR=180-CAELSECR=180+CA
1228 RETURN
1250 REM:GET WIND VECTOR FOR CURR ALTITUDE
1252 I=FIX(AL/4000):IFI=>10THENI=10
1254 WD=WA(I,0):WV=WA(I,1)
1256 RETURN
1260 REM:SOLVES WIND TRIANGLE
1262 A=CC:L=AJ:GOSUB1300
1264 MX=LX:MY=LY
1266 GOSUB1250
1268 A=WD+180:IFA=>360THENA=A-360
1270 L=WV:GOSUB1300
1272 MX=MX+LX:MY=MY+LY:GOSUB1350
1274 TK=MA:GS=VZ
1276 RETURN
1300 REM:RESOLVES A VECTOR INTO RECTANGULAR COORDINATES
1302 IFA<=90THENQ=1:B=90-A:GOTO1310
1304 IFA<=180THENQ=2:B=A-90:GOTO1310
1306 IFA<=270THENQ=3:B=270-A:GOTO1310
1308 Q=4:B=A-270
1310 LX=L*COS(B/KR):LY=L*SIN(B/KR)
1312 IFQ=1THENRETURN
1314 IFQ=2THENLY=-1*LY:RETURN
1316 IFQ=3THENLX=-1*LX:LY=-1*LY:RETURN
1318 LX=-1*LX
1320 RETURN
1350 REM:COMPOSES X,Y COMPONENTS INTO A POLAR VECTOR
1352 VZ=SQR(MX^2+MY^2)
1354 IFMX<=0GOTO1358
1356 IFMY<=0THENQ=2ELSEQ=1
1357 GOTO1360
1358 IFMY<=0THENQ=3ELSEQ=4
1360 IFMX=0THENMA=90:GOTO1366
1362 MQ=ABS(MY/MX)
1364 MA=ATN(MQ)*KR
1366 IFQ=1THENMA=90-MA:RETURN
1368 IFQ=2THENMA=90+MA:RETURN
1370 IFQ=3THENMA=270-MA:RETURN
1372 MA=270+MA
1374 RETURN
1400 REM:GET POSITION FOR OMEGA DISPLAY
1402 AS(2)=AS:FA(2)=FA:CC(2)=CC:AL(2)=AL
1404 AS=AS(1):FA=FA(1):CC=CC(1):AL=AL(1)
1406 IFAS(2)<>ASORFA(2)<>FAGOTO1440
1408 IFCC(2)<>CCORAL(2)<>ALGOTO1440
1410 F(0)=1:IFTD<TW(1)+60GOTO1442
1412 AJ=AS*COS(ABS(FA)/KR)
1414 GOSUB1260
1416 DN=GS*(TD-TW(1))/3600
1418 CN=TK:L1=LL(1):G1=GL(1)
1420 GOSUB2000
1422 F(0)=0:TW(1)=TD:LL(1)=L2:GL(1)=G2
1424 LS(1)=L2:GS(1)=G2
1426 FORJ=4TO7:DP(J)=CP(J):NEXT
1428 AS(1)=AS(2):FA(1)=FA(2):CC(1)=CC(2):AL(1)=AL(2)
1430 AS=AS(2):FA=FA(2):CC=CC(2):AL=AL(2)
1432 RETURN
1440 TW(1)=TD:F(0)=0
1442 AJ=AS*COS(ABS(FA)/KR)
```

Listing 1 continued on page 308

Listing 1 continued:

```
1444 GOSUB1260
1446 DN=GS*TJ/3600
1448 CN=TK:L1=LS(1):G1=GS(1)
1450 GOSUB2000
1452 LS(1)=L2:GS(1)=G2
1454 IFF(0)=1GOTO1458
1456 LL(1)=L2:GL(1)=G2
1458 GOTO1426
1500 REM:VOR ROUTINE
1502 IFVO(1)=0GOTO1540
1504 FORJ=0TO15:IFVO(1)=VF(J)GOTO1506
1505 NEXT:GOTO1540
1506 LC=VP(J,0):GC=VP(J,1)
1508 LB=L2:GB=G2
1509 AR=VG(J,0):LL=VG(J,1)
1510 LO=360-LL
1512 GOSUB1200
1514 IFDR>300GOTO1540
1516 IFCR=>360THENCR=CR-360
1517 GOTO1578
1518 VO$(1)="FROM"
1519 VO(5)=CR-VO(3):IFVO(5)<=180GOTO1522
1520 VO(5)=VO(5)-360:GOTO1524
1522 IFVO(5)<-180THENVO(5)=VO(5)+360
1524 IFABS(VO(5)) >90THENI1=VO(3):GOTO1536
1526 IFVO$(1)="FROM"THENI=-1ELSEI=1
1527 IFI=1THENVO(3)=I1
1528 VO(2)=40+I*INT(VO(5)):VO(4)=DR
1530 IFVO(2)<35THENVO(2)=34
1532 IFVO(2)>45THENVO(2)=46
1534 GOTO1560
1536 VO$(1)=" TO ":VO(3)=VO(3)+180:IFVO(3)=>360THENVO(3)=VO(3)-360
1538 GOTO1519
1540 VO$(1)="OUT ":VO(4)=999.9:F(3)=0:RETURN
1546 IFDR>12ORDR<1OTHENMK=0:GOTO1518
1548 IFAL>4000THENMK=0:GOTO1518
1550 IFF(1)=1THENJ=9ELSEJ=2.5
1552 IFCR>AR+JORCR<AR-JTHENMK=0:GOTO1518
1554 F(1)=1:MK=1:GOTO1518
1560 PRINTCHR$(25+MK)
1562 PRINT@(18,21),"  "
1564 PRINTCHR$(25)
1566 IF MK=0THENF(1)=0:RETURN
1570 IFCC>LL+1ORCC<LL-1THENRETURN
1572 IFRA<>0THENRETURN
1574 F(1)=0:F(2)=1
1576 GOTO1540
1578 IFF(3)=1THENVO(3)=CR:F(3)=0
1580 GOTO1546
1600 REM:ILS ROUTINE
1602 ZN=AL:TH=2.82471:MK=1
1603 DW=1.69*RW*TJ:IFF(7)=1THENDW=0
1604 IFF(7)=1THENCC=LL:RA=0
1606 CJ=CC
1608 IFCJ>180THENCJ=360-CJ:CJ=-1*CJ
1610 HA=LO+CJ
1612 DC=360-HA:TS=1:IFHA<180THENDC=HA:TS=-1
1614 IFDC<0THENDC=-1*DC:TS=-1*TS
1616 TL$="W":IFTS=1THENTL$="E"
1618 DD=1.69*AS*TJ
1620 DY=DD*SIN(DC/KR):DX=DD*COS(DC/KR)
1622 XN=XO-DX:IFTL$="E"THENDY=-1*DY
1624 YN=YO+DY+DW
1626 LM=KR*ATN(AL/XN)
1628 BE=KR*ATN(ABS(YN)/ABS(XN)):IFBE>2.5THENMK=0
1630 J=(LM-TH)/0.25:J=FIX(J)
1632 IFJ>3THENJ=3
1633 IFJ<-3THENJ=-3
1636 BE=BE/0.25:BE=FIX(BE)
1637 IFBE<-7THENBE=-7
1638 IFBE>7THENBE=7
1639 IFYN=>0THENBE=-1*BE
1640 IFMK=0GOTO1648
1642 IFXN>34960ANDXN<38000GOTO1648
1644 IFXN>2534ANDXN<5574GOTO1648
1646 MK=0
1648 GX(1)=BE:GY(1)=J
1650 GOSUB2100
1654 PRINTCHR$(25+MK)
1656 PRINT@(18,21),"  "
1658 PRINTCHR$(25)
1662 XO=XN:YO=YN
1664 IFF8=1GOTO1676
1666 IFXN>12000GOTO1676
1668 F8=1
1670 FORI=0TO3
1672 PRINT@(13+I,49),RS$(1)
1674 NEXT I
1676 IFF8=0GOTO1699
1678 PRINT@(17,XO)," "
1680 YU=FIX(YN/16.7):XC=64+YU
1682 IFXC<49THENXC=49
1684 IFXC>79THENXC=79
1686 PRINT@(17,XC),CHR$(159)
1688 XO=XC
1699 GOTO1031
1700 GOTO1799
1799 GOTO224
```

Listing 1 continued on page 310

Listing 1 continued:

```
1800 REM:REVERSE THRUST APPLIED
1802 IFF(4)=1GOTO1806
1804 VO=AS*1.152*1.47:F(4)=1
1806 V=VO-(3.23636)*TJ
1808 IFV<=0THENV=0
1810 VO=V
1812 AS=V/(1.152*1.47)
1814 RETURN
2000 REM:COMPUTES NEW POSITION
2004 IF CN=0THENCA=0:LB(5)=1:LB(6)=1:GOTO2014
2006 IFCN>0ANDCN<=90THENCA=CN:LB(5)=1:LB(6)=1:GOTO2014
2008 IFCN>90ANDCN<=180THENCA=180-CN:LB(5)=-1:LB(6)=1:GOTO2014
2010 IFCN>180ANDCN<=270THENCA=CN-180:LB(5)=-1:LB(6)=-1:GOTO2014
2012 CA=360-CN:LB(5)=1:LB(6)=-1
2014 IFCA>89.5GOTO2034
2016 DL=DN*COS(CA/KR):DL=DL/60:LB(3)=LB(5)
2018 IFLB(3)=1THENL2=L1+DL:GOTO2024
2020 L2=ABS(L1-DL)
2024 LA=L1:GOSUB2400
2026 M1=MP
2028 LA=L2:GOSUB2400
2030 M2=MP
2032 DM=ABS(M1-M2):DG=DM*TAN(CA/KR):GOTO2036
2034 L2=L1:DG=DN/COS(L1/KR)
2036 DG=DG/60:LB(4)=LB(6)
2038 IFLB(4)=-1GOTO2046
2040 G2=ABS(G1-DG)
2044 GOTO2050
2046 G2=G1+DG
2050 CP(4)=FIX(L2):CP(5)=(L2-CP(4))*60
2052 CP(6)=FIX(G2):CP(7)=(G2-CP(6))*60
2054 RETURN
2100 REM:PLOT GLIDESLOPE CROSSHAIRS
2101 IFX0<=750THENRETURN
2102 X0=8+GX(0):X1=8+GX(1):Y0=18+GY(0):Y1=18+GY(1)
2103 PRINTCHR$(25)
2104 FORY=15TO21:PRINT@(Y,X0)," ":NEXT
2106 PRINT@(Y0,1),STRING$(15,32)
2108 FORY=15TO21:PRINT@(Y,X1),CHR$(149):NEXT
2110 PRINT@(Y1,1),STRING$(15,151)
2112 PRINT@(Y1,X1),CHR$(143)
2114 PRINT@(18,8),"0"
2116 GX(0)=GX(1):GY(0)=GY(1)
2118 RETURN
2400 REM:COMPUTES MERIDIONAL PARTS,MP
2404 KM(0)=7915.704468
2406 KM(1)=23.268932
2408 KM(2)=0.0525
2410 KM(3)=0.000213
2414 IFLA=0THENLA=0+1/60
2416 IFLA>(89+59/60)THENLA=89+59/60
2418 S1=SIN(LA/KR)
2420 S2=S1*S1:S3=S1*S2
2422 TM(0)=TAN((45+LA/2)/KR)
2424 TM(0)=KM(0)*LOG(TM(0))/LOG(10)
2426 TM(1)=KM(1)*S1
2428 TM(2)=KM(2)*S3
2430 TM(3)=KM(3)*S2*S3
2432 MP=TM(0)-TM(1)-TM(2)-TM(3)
2436 RETURN
3000 REM:ABORT ROUTINES
3002 M$(1)="----------- A CRASH HAS OCCURRED -----------"
3004 M$(2)="YOU ACCIDENTLY STALLED THE AIRCRAFT DURING FINAL APPROACH."
3006 M$(3)="THE STALL OCCURRED AT AN ALTITUDE OF"
3008 M$(4)="THE AIRCRAFT STRUCK THE GROUND IN A NOSE-HIGH ATTITUDE."
3010 M$(5)="THE IMPACT RUPTURED THE TAIL SECTION OF THE FUSELAGE."
3012 M$(6)="---- LOCATION OF CRASH ----"
3013 M$(7)="---- LANDING POSITION ----"
3016 M$(8)="     PITCH ANGLE="
3018 M$(9)="     AIRSPEED="
3020 M$(10)="YOU FLARED AT TOO HIGH AN ALTITUDE DURING FINAL APPROACH."
3022 M$(11)="THE RESULTING STALL OCCURRED AT AN ALTITUDE OF"
3024 M$(12)="THE IMPACT RUPTURED THE "
3026 M$(13)="YOU FORGOT TO LOWER THE LANDING GEAR."
3028 M$(14)="YOU FAILED TO TOUCH DOWN INSIDE THE RUNWAY."
3030 M$(15)="---------- AN IMPROPER LANDING WAS MADE ----------"
3032 M$(16)="NO DAMAGE OR INJURIES OCCURRED."
3033 RL=0:IFTX>0THENRL=1
3034 RW=0:IFABS(TY)>100THENRW=1
3040 N$(2)="FEET INSIDE OF RUNWAY"
3041 IFTX=>0THENN$(2)="FEET SHORT OF RUNWAY"
3042 N$(3)="FEET TO LEFT OF RUNWAY CENTERLINE"
3043 IFTY=>0THENN$(3)="FEET TO RIGHT OF RUNWAY CENTERLINE"
3044 RX=FIX(TX):RX=ABS(RX)
3045 RY=FIX(TY):RY=ABS(RY)
3050 IF AF=0 GOTO 3600
3055 AX=INT(AX):FA=INT(FA):AS=INT(AS)
3060 ONAFGOTO3100,3150,3200,3250,3300,3350,3400,3450,3500,3550
3100 GOSUB3700
3101 YP=4:XP=55:F$="##,###":V1=AL:GOSUB9000
3102 PRINT@(15,0),M$(1)
3104 PRINT"YOU FLEW INTO THE GROUND."
3106 PRINT"THE INSTRUMENT READINGS AT TIME OF CRASH ARE AS SHOWN ABOVE."
3108 END
3150 CLS
3152 PRINT M$(1)
3154 PRINT M$(2)
```

Listing 1 continued on page 314

Listing 1 continued:

```
3156 PRINT M$(3);AX;"FEET."
3158 PRINT M$(4)
3160 PRINT M$(5)
3162 N$(1)=M$(6)
3164 GOSUB 3800
3166 END
3200 CLS
3202 PRINT M$(1)
3204 PRINT"YOU FLEW INTO THE GROUND DURING FINAL APPROACH."
3206 PRINT"AT TIME OF CRASH, THE AIRCRAFT PROFILE WAS AS FOLLOWS :"
3208 PRINT M$(8);FA;"DEGREES"
3210 PRINT M$(9);AS
3212 N$(1)=M$(6)
3214 GOSUB3800
3216 END
3250 CLS
3252 PRINT M$(1)
3254 PRINT M$(10)
3256 PRINT M$(11);AX;"FEET."
3258 PRINT M$(12)+"FUSELAGE."
3260 N$(1)=M$(6)
3262 GOSUB 3800
3264 END
3300 CLS
3302 IF WH=10THEN PRINT M$(1)
3304 IF WH=12THEN PRINT"----------- A MINOR CRASH HAS OCCURRED ----------"
3306 PRINT M$(10)
3308 PRINT M$(11);AX;"FEET."
3310 IF WH=10THEN PRINT M$(13)
3312 IF WH=10THEN PRINT M$(12)+"FUSELAGE."
3314 IF WH=12THEN PRINT"THE IMPACT DAMAGED THE LANDING GEAR."
3316 IF WH=12THEN PRINT"ALL PASSENGERS HAVE BEEN SAFELY EVACUATED."
3318 N$(1)=M$(6)
3320 GOSUB 3800
3322 END
3350 CLS
3352 PRINT M$(1)
3354 PRINT M$(13)
3356 PRINT"THE AIRCRAFT LANDED ON ITS BELLY, CAUSING MODERATE DAMAGE."
3358 PRINT"ALL PASSENGERS HAVE BEEN SAFELY EVACUATED."
3360 N$(1)=M$(6)
3362 GOSUB 3800
3364 END
3400 CLS
3402 PRINT M$(15)
3404 PRINT M$(14)
3406 N$(1)=M$(7)
3408 GOSUB 3800
3410 END
3450 CLS
3452 PRINT M$(15)
3454 PRINT"YOU FAILED TO EXECUTE A FLARE PRIOR TO TOUCHING DOWN."
3456 PRINT"THIS IS A VIOLATION OF COMPANY PROCEDURES."
3458 PRINT M$(16)
3460 N$(1)=M$(7)
3462 GOSUB 3800
3464 END
3500 CLS
3502 PRINT M$(15)
3504 PRINT"YOU ROLLED OFF THE RUNWAY AFTER TOUCHING DOWN."
3506 PRINT M$(16)
3508 N$(1)=M$(7)
3512 GOSUB 3800
3513 PRINT
3514 IFXN<-9750THENPRINT"YOU ROLLED PAST FAR END OF RUNWAY"
3516 IFABS(YN)>100THENPRINT"YOU ROLLED THRU RUNWAY SIDE BORDERS"
3518 END
3550 CLS
3552 PRINT"----- YOUR MISSED APPROACH SIGNAL IS ACKNOWLEDGED -----"
3554 PRINT"YOU HAVE FOLLOWED PROPER PROCEDURES."
3556 END
3600 CLS
3602 PRINT"----- YOU HAVE SUCCESSFULLY COMPLETED THE FLIGHT -----"
3604 PRINT"ALL PROCEDURES WERE PROPERLY EXECUTED."
3606 N$(1)=M$(7)
3610 PRINT"CONGRATULATIONS ON A SUCCESSFUL FLIGHT."
3612 GOSUB 3800
3613 PRINT
3614 XN=ABS(XN):JN=FIX(XN+750)
3615 YN=ABS(YN):YN=FIX(YN)
3616 PRINT"YOUR AIRCRAFT CAME TO REST AT THE FOLLOWING POSITION:"
3617 PRINT"      ";JN;"FEET INSIDE THE RUNWAY"
3618 PRINT"      ";YN;"FEET FROM RUNWAY CENTERLINE"
3620 END
3700 REM:SUBROUTINE TO CLEAR LOWER PART OF DISPLAY
3702 FOR I=9TO23
3704 PRINT@(I,0),SPC(79);
3706 NEXT I
3708 RETURN
3800 REM:LANDING STATISTICS
3802 PRINT
3804 PRINT SPACE$(26);N$(1)
3806 PRINT
3808 IFRL=0THENPRINT RX;N$(2)
3809 IFRL=1THENPRINTCHR$(26);RX;N$(2);CHR$(25)
3810 PRINT
3812 IFRW=0THENPRINT RY;N$(3)
3813 IFRW=1THENPRINTCHR$(26);RY;N$(3);CHR$(25)
```

Listing 1 continued on page 316

Listing 1 continued:

```
3814 PRINT
3816 PRINT"--- SIZE OF RUNWAY IS 10,500 FEET  X  200 FEET ---"
3818 RETURN
5085 REM:TIME DELAY PAD
5090 FOR I=1 TO TQ
5095 NEXT I
5099 RETURN
7050 REM:CONVERT RTC TO TIME OF DAY IN SECONDS ABSOLUTE.
7055 J=7
7060 FOR I=0 TO 2
7065 TC$(I)=MID$(TV$,J,2)
7070 J=J-3
7075 TC(I)=VAL(TC$(I))
7080 TD=(3600*TC(2))+(60*TC(1))+TC(0)
7085 NEXT I
7090 RETURN
9000 REM:PLOTS VARIABLE ON REVERSE BACKGROUND
9005 PRINT@(YP,XP),CHR$(26);
9010 PRINT USING F$;V1;
9015 PRINT CHR$(25)
9020 RETURN
9999 END
10000 REM:BEGIN TAKEOFF MODULE HERE
10020 CLS:CLEAR 1000:RANDOM
10025 KR=57.2958
10030 DIM XM(13),WM(13)
10031 DIM P$(31)
10035 DATA 37,35,32,30,27,25,22,20,17,15,12,10,7,5
10040 DATA 6,11,16,21,26,31,36,41,46,51,56,61,66,71
10041 FOR I=0 TO 28:READ P$(I):NEXT
10045 FOR I=0 TO 13:READ XM(I):NEXT
10050 FOR I=0 TO 13:READ WM(I):NEXT
10055 M$(1)="_":M$(2)="_":M$(3)="_"
10060 DIM XE(13),WE(13)
10065 K1=29:K2=23
10070 FOR I=0 TO 13
10075 XE(I)=K1:WE(I)=K2
10080 K1=K1-2:K2=K2+4
10085 NEXT
10090 IO=40
10095 RN=RND(0)
10100 RS=1:IF RN<0.5 THEN RS=-1
10105 W1=75:IF RS=-1 THEN W1=255
10110 W2=RND(20):WS=RS*W2
10115 DIM XL(14),XR(14)
10120 J=31:K=49
10125 FOR I=0 TO 14
10130 XL(I)=J:XR(I)=K
10135 J=J-2:K=K+2
10140 NEXT
10145 DATA FUEL,LBS,%,VHF,MHZ,THRUST,MAX,IDLE,REV
10150 DATA PITCH," +"," -",DEG,FLAPS,UP,DWN,WHEELS,UP,MID,DOWN
10155 DATA COMPASS,AIRSPEED,KTS," VERT",SPEED,FPM
10160 DATA ALTITUDE,FEET,CLOCK,BRAKE,SET,REL
10170 FOR I=0 TO 31:READ P$(I):NEXT
10175 DIM S$(25)
10180 FOR I=1 TO 25:S$(I)=SPACE$(I):NEXT
10185 FOR I=0 TO 9:F(I)=0:NEXT
10190 REM:INIT VARIABLES FOR TAKEOFF MODE
10195 FU=200000:FP=0:CC=75:AS=0:RC=0:AL=0
10200 MZ=77:TR=6:FL=2:FA=0:WH=13:IX=40:HY=9:BR=11:BK=11
10205 AB=0
10215 PRINT@(8,17),"UNITED 312     CLEARED AS FILED"
10217 PRINT:PRINT
10218 PRINT"         SURFACE WINDS VARIABLE, GUSTING TO 15."
10219 PRINT"         MINIMUM CEILING CONDITIONS ARE IN EFFECT."
10230 PRINT"         SKY CONDITIONS AT 20,000 SCATTERED."
10235 PRINT"                       AT 30,000 BROKEN."
10240 PRINT:PRINT
10245 PRINT"UPON TAKEOFF, MAINTAIN HEADING 075 TO 3000, THEN PROCEED AS FILED."
10248 PRINT:PRINT:PRINT"           STANDBY FOR TAKEOFF CLEARANCE"
10255 TQ=7000:GOSUB 11535
10260 CLS
10265 PRINT@(10,17),"UNITED 312":PRINT:PRINT
10270 PRINT"YOU ARE CLEARED FOR TAKEOFF AT 0800 HOURS"
10275 TQ=3000:GOSUB 11535
10280 CLS
10285 SYSTEM "TIME 07.59.00":SYSTEM "CLOCK":CLS
10290 TV$=TIME$:GOSUB 11555:TL=TD
10295 GOSUB 10330
10300 GOSUB 10410
10305 GOSUB 10480
10310 PRINT CHR$(2);:GOSUB 10615
10315 K$=INKEY$:IF LEN(K$)=0 GOTO 10325
10320 GOSUB 10790
10325 GOTO 10945
10330 REM:DISPLAY PANEL (HEADERS ONLY)
10335 PRINT@(0,3),P$(0);S$(4);P$(5);S$(3);P$(9);S$(3);S$(6);S$(3);P$(20)
10340 PRINT@(10,59),P$(13);S$(3);P$(16);S$(2);P$(29)
10345 PRINT@(11,61),P$(14);S$(6);P$(14);S$(6);P$(30)
10350 PRINT@(13,61),P$(15);S$(5);P$(15);S$(5);P$(31)
10352 IFF(9)=1THENRETURN
10355 PRINT@(1,13),P$(6);S$(6);P$(10);S$(6)
10360 PRINT@(1,68),P$(28)
10365 PRINT@(2,1),P$(1);S$(4);P$(2);S$(21);S$(3);S$(13);P$(23)
10370 PRINT@(3,22),P$(11);S$(13);P$(21);S$(2);P$(24);S$(2);P$(26)
10375 PRINT@(4,0),P$(3)
```

Listing 1 continued on page 318

Listing 1 continued:

```
10380 PRINT@(5,39),P$(22);S$(6);P$(25);S$(5);P$(27)
10385 PRINT@(6,0),P$(4);S$(10);P$(7);S$(3);P$(12);S$(7)
10390 PRINT@(7,13),P$(8)
10395 FORY=1TO7:PRINT@(Y,12),CHR$(150):NEXT
10400 FORY=1TO3:PRINT@(Y,21),CHR$(150):NEXT
10405 RETURN
10410 REM:DISPLAY HORIZON LINE
10415 IF F(9)=0 GOTO 10430
10420 PRINT@(9,0),SPACE$(80);
10425 IF HY=20 GOTO 10440
10430 PRINT@(HY,0),STRING$(80,"_")
10435 RETURN
10440 OH=9:HY=10
10445 FOR I=HY TO 22
10450 PRINT@(OH,0),SPACE$(80);
10455 PRINT@(I,0),STRING$(80,"_");
10460 OH=I
10465 NEXT I
10470 PRINT@(23,IO)," ";
10475 RETURN
10480 REM:DISPLAY RUNWAY
10485 IF F(4)=1 GOTO 10525
10490 S=10:X=29
10495 FOR Y=10 TO 22
10500 PRINT@(Y,X),".";SPACE$(S);" ";SPACE$(S);".";
10505 X=X-2:S=S+2
10510 NEXT
10515 S$=S$(13)
10520 RETURN
10525 REM:PRINTS RUNWAY GRAPHICS
10530 IF N>3 GOTO 10600
10535 PRINT@(OY,OX),SPACE$(WM);
10540 PRINT@(NY,NX),MK$;
10545 OY=NY:OX=NX
10550 WM=FW
10555 RETURN
10560 REM:ENTRY WHEN SHIP IN FINAL ZONE
10565 PRINT@(OY,OX),SPACE$(WM):IF F(9)=1 THEN RETURN
10570 FOR I=10 TO NY-1
10575 PRINT@(I,XE(J)),SPACE$(WE(J))
10580 NEXT I
10585 IF N>4 THEN RETURN
10590 PRINT@(NY,NX),MK$;
10595 RETURN
10600 IFF(2)=1GOTO10560ELSEF(2)=1
10605 FORI=10TO13:PRINT@(I,59),SPACE$(21):NEXT
10610 GOTO10560
10615 REM:DISPLAY INSTRUMT READINGS
10620 YP=1:XP=0:F$="######":V1=FU:GOSUB 11600
10625 YP=1:XP=7:F$="###":V1=FP:GOSUB 11600
10630 YP=1:XP=39:V1=CC:GOSUB 11600
10635 YP=4:XP=39:V1=AS:GOSUB 11600
10640 YP=4:XP=46:F$="######":V1=RC:GOSUB 11600
10645 YP=4:XP=55:F$="##,###":V1=AL:GOSUB 11600
10650 YP=5:XP=0:F$="###":V1=MZ:GOSUB 11600
10655 REM:DISPLAY THRUST
10660 FOR I=1 TO 7
10665 PRINT@(I,11),CHR$(26);" "
10670 NEXT
10675 PRINT@(TR,11),">";
10680 REM:DISPLAY PITCH
10685 FOR I=1 TO 3:PRINT@(I,20),CHR$(26);" ":NEXT
10690 PRINT@(FL,20),">"
10695 F$="+###"
10700 YP=5:XP=20:V1=FA:GOSUB 11600
10705 REM:DISPLAY FLAPS
10710 IFF(2)=1GOTO10760
10715 FOR I=11 TO 13:PRINT@(I,59),CHR$(26);" ":NEXT
10720 PRINT@(BR,59),">"
10725 REM:WHEELS
10730 FOR I=11 TO 13:PRINT@(I,67),CHR$(26);" ":NEXT
10735 PRINT@(WH,67),">"
10740 REM:BRAKES
10745 FORI=11TO13:PRINT@(I,75),CHR$(26);" ":NEXT
10750 PRINT@(BK,75),">"
10755 PRINTCHR$(25)
10760 REM:DISPLAY RUNWAY ALIGNMT INDEX
10765 IF F(9)=1 THEN RETURN
10770 PRINT@(23,IO)," ";
10775 PRINT@(23,IX),CHR$(159);
10780 IO=IX
10785 RETURN
10790 REM:KEY POLL SUBROUT
10795 IF K$="F" THEN KK=1:GOTO 10820
10800 IF K$="," OR K$="." THEN KK=2:GOTO 10820
10805 IF K$="B" THEN KK=3:GOTO 10820
10810 IF ASC(K$)=30 OR ASC(K$)=31 THEN KK=4:GOTO 10820
10815 IF K$="L" THEN KK=5:GOTO 10820
10817 IFK$="W"THENKK=6:GOTO10820
10818 IFK$="S"THENKK=7:GOTO10820
10820 ON KK GOSUB 10830,10845,10865,10880,10925,10941,10826
10825 RETURN
10826 REM:THRUST KEY (DECREASE)
10827 IFF(7)=1ANDBR=11THENTR=4
10829 RETURN
10830 REM:THRUST KEY (INCREASE)
10831 IFF(7)=1THENRETURN
10835 IF F(0)=0 THEN RETURN
```

Listing 1 continued on page 320

Listing 1 continued:

```
10840 F(1)=1:TR=1:RETURN
10845 REM:RUDDER KEYS
10846 IFF(7)=1THENRETURN
10850 IF AS<=50 THEN RETURN
10855 IF K$="," THEN CC=CC-1 ELSE CC=CC+1
10860 RETURN
10865 REM:BRAKES
10870 IF F(0)=1 THEN RETURN
10875 F(0)=1:BK=13:RETURN
10880 REM:PITCH
10881 IFF(7)=1THENRETURN
10885 IF AS<=50 THEN RETURN
10890 FD=-10:IF K$=CHR$(31) THEN FD=10
10895 FA=FA+FD
10900 IF FA>60 THEN FA=60
10905 IF FA<-60 THEN FA=-60
10910 IF FA>0 THEN FL=1:RETURN
10915 IF FA=0 THEN FL=2:RETURN
10920 FL=3:RETURN
10925 REM:FLAPS
10926 IFF(7)=1ANDWH=11THENBR=11:RETURN
10930 IF F(3)=1 THEN RETURN
10935 IF F(3)=0 THEN F(3)=1: BR=13:RETURN
10940 RETURN
10941 REM:WHEELS
10942 IFF(7)=1THENWH=11
10944 RETURN
10945 REM:SITUATION UPDATE ROUTINE
10950 TV$=TIME$:GOSUB 11555:TJ=TD-TL:TL=TD
10955 IF F(9)=1 GOTO12000
10960 IF F(0)=1 GOTO 10970
10965 GOSUB 11130:GOTO 10310
10970 IF F(4)=1 GOTO 10990
10975 F(4)=1
10980 XX=0:YY=0
10985 TX=TD:VO=0:N=1:OY=23:OX=5:WM=71
10990 REM
10995 A=(118-18*TR)*0.04028
11000 GOSUB 11190
11005 IF AL>0 GOTO 11060
11010 IF YY>10500 OR ABS(XX)>100 GOTO 11390
11015 IF FA<=0 GOTO 11100
11020 IF AS<150 GOTO 11385
11025 IF FA>10 GOTO 11385
11030 IFF(3)=0GOTO11100
11035 AL=25
11040 GOSUB 11130
11045 GOSUB 11150
11050 GOSUB 11300
11055 GOTO 10305
11060 F(9)=1
11065 GOSUB 11130
11070 GOSUB 11150
11075 GOSUB 11170
11080 FOR I=10 TO 22:PRINT@(I,0),SPACE$(80);:NEXT
11085 HY=20
11090 GOSUB10410
11095 GOTO11115
11100 GOSUB 11130
11105 GOSUB11300
11110 GOTO10305
11115 REM:NOW DO DEPARTURE PROCEDURES
11120 GOTO10310
11130 REM:UPDATE FUEL
11135 FU=FU-40*TJ
11140 FP=FU/3120
11145 RETURN
11150 REM:UPDATE RATE OF CLIMB
11155 RC=AS*SIN(ABS(FA/57.3))*1.693*60
11160 IF FA<0 THEN RC=-1*RC
11165 RETURN
11170 REM:UPDATE ALT
11175 AL=AL+TJ*RC/60
11180 IF AL<=0 THEN AL=0
11185 RETURN
11190 REM:EQUATIONS OF MOTION
11195 T=TJ
11200 V=VO+A*T
11205 VB=(V+VO)/2:VO=V
11210 S=VB*T
11215 IF TD<(TX+18)GOTO 11235
11220 TX=TD
11225 WB=RS*RND(2)
11230 CC=CC+WB
11235 DA=(CC-75)/57.3
11240 DY=S*COS(ABS(DA))
11245 DX=S*SIN(ABS(DA))
11250 IF DA<0 THEN DX=-1*DX
11255 YY=YY+DY
11260 XX=XX+DX
11265 AS=V/1.69278
11270 IF AS>20 THEN AS=AS+WS
11275 IX=40+FIX(XX*7/20):IFIX>79THENIX=79
11280 IFIX<0THENIX=0
11285 ZP=FIX(YY-2500*(N-1))
11290 IF ZP>2500 THEN N=N+1:GOTO 11285
11295 RETURN
11300 REM:VARIABLES FOR RUNWAY GRAPHICS
```

Listing 1 continued on page 322

Listing 1 continued:

```
11305 MP=FIX(10+(13*ZP)/2500)
11310 IF N>3 GOTO 11350
11315 NY=MP
11320 J=NY-10
11325 NX=XM(J)
11330 FW=WM(J)
11335 S$=SPACE$(J)
11340 MK$=M$(N)+S$(J)+"_"+S$(J)+"_"+S$(J)+"_"+S$(J)+"_"+S$(J)+"_"
11345 RETURN
11350 REM:IN ZONE 4-MARKER IS RUNWAY EDGE
11355 NY=MP
11360 J=NY-10
11365 NX=XE(J)
11370 IF N>4 THEN RETURN
11375 MK$=STRING$(WE(J),"_")
11380 RETURN
11385 AB=1:GOTO11415
11390 AB=2:IF YY<10500 GOTO 11415
11395 FOR I=10 TO 22
11400 PRINT@(I,0),SPACE$(80);
11405 NEXT I
11410 GOTO 11415
11415 REM:ABORT
11420 FOR I=10 TO 22
11425 PRINT@(I,0),CHR$(26);SPACE$(80);
11430 NEXT I
11435 PRINT@(10,29),"*** TAKEOFF FAILED ***":PRINT:PRINT
11440 ON AB GOSUB 11455,11480
11445 PRINT@(19,34),CHR$(25);"END OF PROGRAM";
11450 END
11455 PRINT" YOU PULLED BACK ON THE STICK AT TOO SLOW A SPEED, OR YOU"
11460 PRINT" PULLED BACK THE STICK TOO FAR WHEN AT PROPER SPEED."
11465 PRINT" AS A RESULT THE TAIL END OF THE FUSELAGE SCRAPED THE RUNWAY"
11470 PRINT" AND THE AIRCRAFT SPUN OUT OF CONTROL."
11475 RETURN
11480 IF YY>10500 GOTO 11505
11485 PRINT" YOU FAILED TO STAY WITHIN THE RUNWAY BOUNDRIES."
11490 PRINT" AS A RESULT YOU VEERED OFF THE RUNWAY AND COLLIDED WITH"
11495 PRINT" THE RUNWAY LIGHTS."
11500 RETURN
11505 PRINT" YOU RAN OUT OF RUNWAY. AS A RESULT YOU ROLLED INTO THE
11510 PRINT" MARSHLANDS LOCATED";FIX(YY)-10500;"FEET PAST THE END OF THE RUNWAY.
"
11515 IFF(3)=1THENRETURN
11520 PRINT:PRINT:PRINT" YOU FORGOT TO LOWER THE FLAPS."
11525 PRINT" AS A RESULT THE AIRCRAFT COULD NOT DEVELOP SUFFICIENT LIFT."
11530 RETURN
11535 REM:TIME DELAY PAD
11540 FOR I=1 TO TQ
11545 NEXT I
11550 RETURN
11555 REM:CONVERT RTC TO TIME OF DAY IN SECONDS ABSOLUTE.
11560 J=7
11565 FOR I=0 TO 2
11570 TC$(I)=MID$(TV$,J,2)
11575 J=J-3
11580 TC(I)=VAL(TC$(I))
11585 TD=(3600*TC(2))+(60*TC(1))+TC(0)
11590 NEXT I
11595 RETURN
11600 REM:PLOTS VARIABLE ON REVERSE BACKGROUND
11605 PRINT@(YP,XP),CHR$(26);
11610 PRINT USING F$;V1;
11615 PRINT CHR$(25)
11620 RETURN
12000 REM:DEPARTURE ROUTINE
12010 IFF(7)=1GOTO12025ELSEF(7)=1
12015 GOSUB10340
12020 F(2)=0
12025 IFWH<>11GOTO12040ELSEAS=AS+5
12030 IFBR<>11GOTO12040ELSEAS=AS+5
12035 IFTR=4ANDAL>1800GOTO24ELSEGOTO12090
12040 IFAL<1200GOTO12090
12042 PRINT@(12,0),"********** FLIGHT ABORTED **********"
12044 PRINT:PRINT
12046 PRINT"YOU FAILED TO PERFORM CRUCIAL TRIM MANEUVERS FOLLOWING LIFTOFF."
12048 PRINT"THE PROPER TRIM SEQUENCE,WHICH MUST BE COMPLETED BELOW 1200 FEET,IS
AS FOLLOWS:"
12050 PRINT"    1-RAISE LANDING GEAR"
12052 PRINT"    2-RETRACT FLAPS"
12054 PRINT"    3-REDUCE THRUST"
12056 PRINT
12058 PRINT"---------- END OF PROGRAM ----------
12060 END
12090 GOSUB11130
12092 GOSUB11150
12094 GOSUB11170
12099 GOTO10310
13000 REM:END OF LISTING
```