TI Programmable 58/59

Aviation

Using the power of your *Solid State Software*™ module
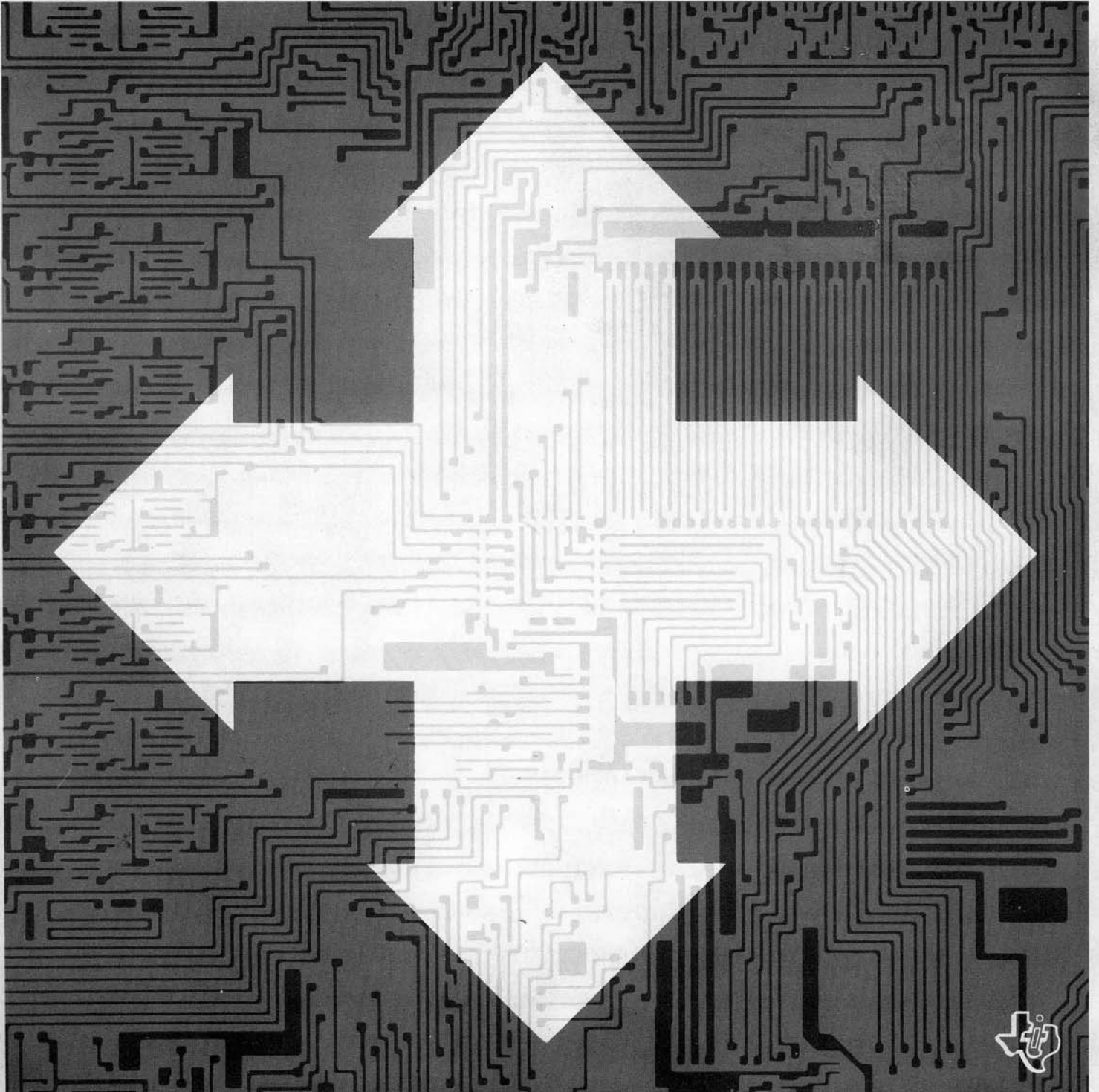
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CALCULATOR AVIATION

This Aviation Library will give the user increased calculating power for both preflight and in-flight situations. Along with ease of operation, both speed and accuracy will improve significantly over hand and slide rule computation. In addition, a few of its capabilities have never before been available without expensive avionics.

ATTENTION: **To the experienced user, the preflight programs will present no problem, but the in-flight programs are more demanding. The user *must* have a thorough grasp of the program's operation and limitations, and above all, of the situations to which it is applied, before actual in-flight use. This library does not pretend to provide knowledge; rather it provides the tools to more ably apply knowledge.**

It is highly recommended that the following easy steps be taken to ensure a safe working knowledge of each in-flight program: 1) Read the program explanation thoroughly. 2) Read the user instructions and work through the examples. 3) Create your own examples to more closely approximate your own particular situation. 4) Do an in-the-air trial run, preferably with a copilot (this may easily be done for several programs in the same flight). 5) Carefully evaluate each program for its usefulness in various situations.

On-board, the calcuator should be mounted to a knee-board or other solid surface, and the accessory 12 volt adaptor used. The pilot should develop a routine which integrates keystroke segments with hands-on flying. When properly developed, the great advantages of these 'tools' may be fully, safely, and easily realized.

USING THIS LIBRARY

Your calculator contains a removable *Solid State Software** module which places a large library with a variety of programs at your fingertips the instant you turn the calculator on. Each *Solid State Software* module contains up to 5000 program steps. Within seconds, you can replace the Master Library Module with an optional module, ranging from Applied Statistics to Aviation, to tailor your calculator to solve a series of professional problems with minimal effort. Your *Solid State Software* library does not take up valuable memory space needed for your own programs. In fact, you can call a library program as a subroutine from a program of your own without interruption.

After this brief introduction, you will find the description, user instructions, example problems and principal equations (when necessary) for each of the 23 programs in the Aviation Library. Each program is easily identified by the "AV" number in the upper corner of the page. This number corresponds with the call number you use to tell the calculator which program in the *Solid State Software* module you wish to use.

The primary reference point in this manual for each program is the User Instructions. These user instructions are also available for you in the handy pocket guide furnished with the library. The program description and sample problems should be used when you first run a program, to help you understand its full capabilities and limitations.

When using the *Solid State Software* programs as subroutines to your own programs, you will also want to check Register Contents for the program and check Program Reference Data provided in Appendix A.

*Trademark of Texas Instruments

CALCULATOR AVIATION

FLIGHT PLANNING

```
                    ┌─────────┐
                   (  START   )
                    └─────────┘
                         │
                         ▼
                    ╱ RNAV  ╲ ──── yes ──────────────────────────────────────► ┌────────┐
                    ╲available?╱                                                │ AV-22  │
                         │                                                      └────────┘
                         no
                         │
                         ▼
                  ╱ a great ╲ ── no ──►  ╱ (lat, long) ╲ ── no ──────►  ╱  to be  ╲ ── no ──► ┌────────┐
                  ╲circle route?╱        ╲of end points ╱               ╲updated inflight?╱    │ AV-02  │
                         │               ╲   known?   ╱                       │              └────────┘
                        yes                    │                             yes
                         │                    yes                             │
                         │                     ▼                              ▼
                         │              ┌─────────────┐                  ┌────────┐
                         │              │  AV-10 for  │                  │ AV-03  │
                         │              │course, distance│                └────────┘
                         │              └─────────────┘
                         ▼
                 ╱ great circle ╲ ── flown ──► ╱ allow for ╲ ── no ──┐
                 ╲  flown or     ╱             ╲   wind?   ╱          │
                 ╲approximated? ╱                   │                │
                         │                         yes               │
                      approx                        │                │
                         ▼                          ▼                │
                 ┌─────────────┐            ┌─────────────┐          │
                 │  AV-11 for  │            │  AV-07 for  │          │
                 │intermediate │            │average vector│          │
                 │  positions  │            └─────────────┘          │
                 └─────────────┘                   │                 │
                         │                          ▼                │
                         ▼                                           │
                 ╱ allow for wind? ╲ ── no ──┐                       │
                 ╲                 ╱          │                       │
                         │                    │                      │
                        yes                   ▼                      │
                         │              ╱ PC-100A ╲ ── no ──────────►┌────────┐
                         ▼              ╲available?╱                 │ AV-11  │
                 ┌─────────────┐              │                      └────────┘
                 │  AV-10 for  │             yes
                 │course, distance│           │
                 └─────────────┘              ▼
                         │              ┌────────┐
                         ▼              │ AV-04  │
                 ┌─────────────┐        └────────┘
                 │AV-07 or AV-08│
                 │ for effect of│
                 │ wind on leg  │
                 └─────────────┘
```

Specialized Programs

AV-19 }
AV-20 } for weight and balance

AV-23   for time zone conversions (long trips)

AV-05 }
AV-06 } for atmospheric conditions

AV-12   Line of sight distance and altitude

INFLIGHT PROGRAMS
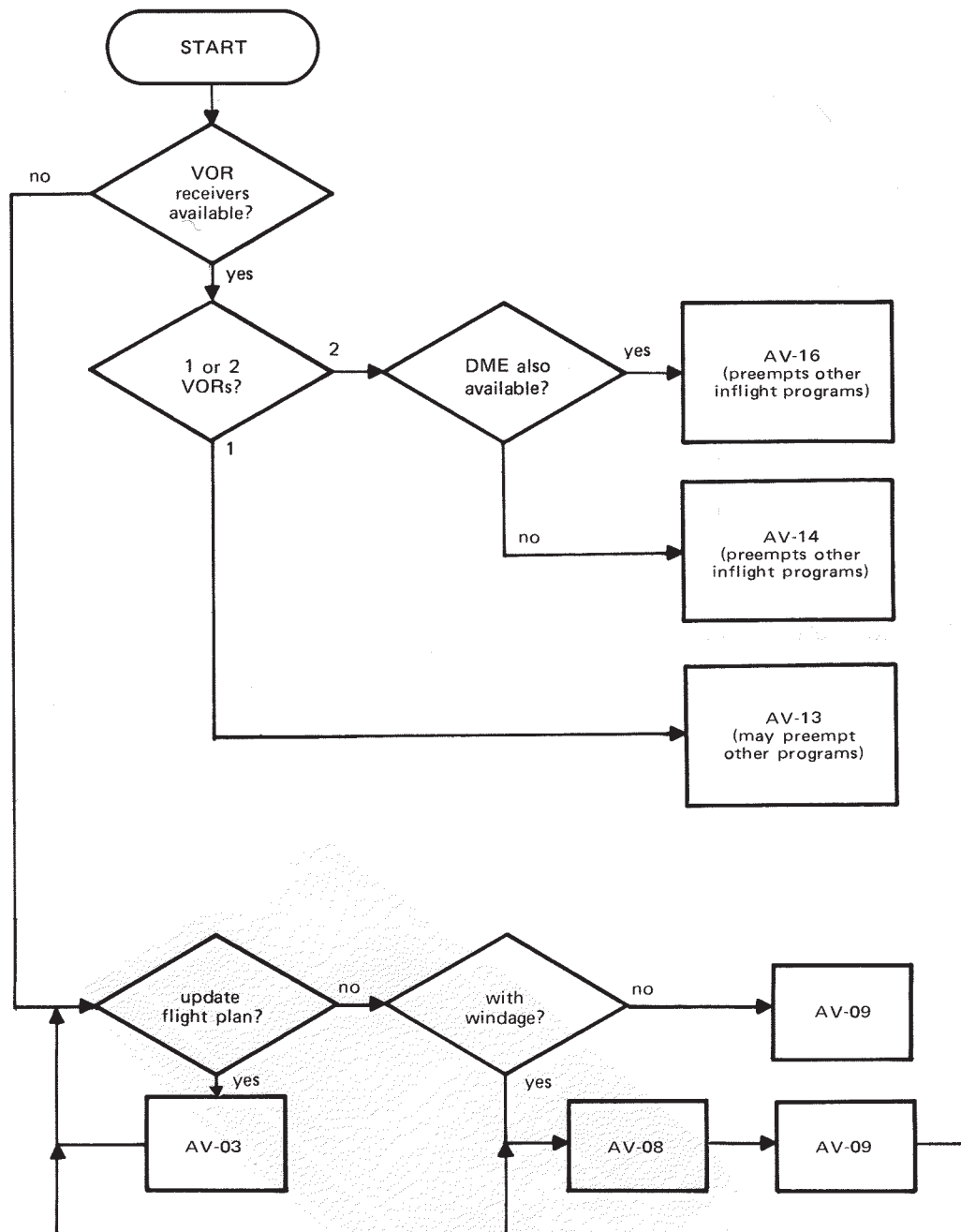
Specialized In-flight Programs

AV-12   DME speed correction

AV-17   Course correction when distance-off-course is known

AV-18   Rate of climb or descent

CALCULATOR AVIATION

REMOVING AND INSTALLING MODULES

The Master Library module is installed in the calculator at the factory, but can easily be removed or replaced with another. It is a good idea to leave the module in place in the calculator except when replacing it with another module. Be sure to follow these instructions when you need to remove or replace a module.

CAUTION

Be sure to touch some metal object before handling a
module to prevent possible damage by static electricity.

1. **Turn the calculator OFF.** Loading or unloading the module with the calculator ON may cause the keyboard or display to lock out. Also, shorting the contacts can damage the module or calculator.

2. Slide out the small panel covering the module compartment at the bottom of the back of the calculator. (See Diagram below.)

3. Remove the module. You may turn the calculator over and let the module fall out into your hand.

4. Insert the module, notched end first with the labeled side up into the compartment. The module should slip into place effortlessly.

5. Replace the cover panel, securing the module against the contacts.
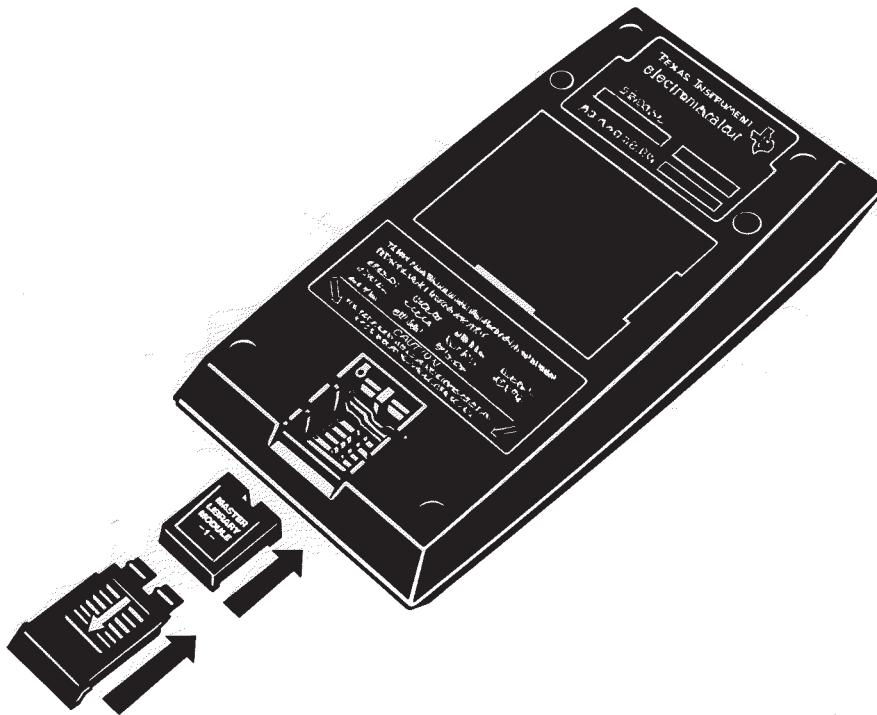
Don't touch the contacts inside the module compartment as damage can result.

RUNNING *SOLID STATE SOFTWARE* PROGRAMS

The Aviation Library contains a variety of useful programs. To help you get started in using the *Solid State Software* programs install your Aviation Library module and follow through a couple of brief examples with us:

First of all, to eliminate any possibility of having any pending operations or previous results interferring with your current program, turn your calculator off for a couple of seconds, and back on again. This off/on sequence is the assumed starting point for each example problem in this manual. Now press the key sequence [2nd] [Pgm] [0] [1] [SBR] [=] to call and run the *"diagnostic"* program. Notice the display goes blank except for a faint " [" at the far left which indicates that calculations are taking place. After about 15 seconds, "6." will appear in the display. This displayed number indicates that the Aviation Library Module is installed in the calculator and that the calculator and module are operating properly. If the display is flashing after the diagnostic, refer to "In Case of Difficulty" in the SERVICE INFORMATION Appendix of the Owner's Manual.

The diagnostic program is a highly specialized one that works internally to check the operation of your software library. Once you're sure things are working, you can continue with another program in the library.

Assume that you know the two legs of the flight you are about to take are 60 and 92 miles and you need to know the equivalent distances in nautical miles as well as the total distance. Program AV-21 is the appropriate program for this problem. Look through the nonmagnetic black and gold label cards* and find card AV-21 titled PILOT UNIT CONVERSIONS. Insert this card in the window above the top row of keys on your calculator. You can now see that the [D] key corresponds to nautical miles and the [E] key to statute miles. Now to solve the problem.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 21		Call Program 21
60	[E] [D]	52.13857451	Mi. → n. mi.
	[+]	52.13857451	
92	[E] [D]	79.94581425	Mi. → n. mi.
	[=]	132.0843888	Total distance in n. mi.

If you have the optional PC-100A printer** you may obtain a printed record of any input and output data that you wish. Programs AV-02 and AV-04 include instructions for printing your data. You may print anything else you wish by pressing [2nd] [Prt] on your calculator, or the PRINT key on the printer when the data you want printed is in the display.

To use the printer, mount your calculator on the PC-100A using the Calculator Mounting procedure in the PC-100A Owner's Manual. The switch called out in Step 2 should be set to "OTHER" for your calculator. Always turn the calculator and printer off before mounting or unmounting your calculator.

*The cards are supplied in a prepunched sheet. Carefully remove the individual cards from the sheet and insert them in the card carrying case for convenient storage.

**Note: The TI Programmable 58 and TI Programmable 59 will not operate on the PC-100 print cradle.

CALCULATOR AVIATION

Before you begin using the *Solid State Software* programs on your own, here are a few things to keep clearly in mind until you become familiar with your calculator.

1. Press [CLR] before running a program if you are not sure of the status of the calculator. (To be completely sure of calculator status, turn it off and on again — but remember that this clears the program memory.)

2. Some programs leave the calculator in a fix-decimal format (see Appendix A). In that event, you should press [INV] [2nd] [Fix] before running another program.

3. There is no visual indication of which *Solid State Software* program has been called. If you have any doubts, the safest method is to call the desired program with [2nd] [Pgm] mm, where mm is the two-digit program number. The calculator remains at this program number until another program is called, [RST] is pressed or the calculator is turned off.

4. A flashing display normally indicates an improper key sequence or that a numerical limit has been exceeded. When this occurs, always repeat the program sequence and check that each step is performed as directed by the User Instructions. Any unusual limits of a program are given in the User Instructions or related notes. The In Case of Difficulty portion of Appendix A in the Owner's Manual may be helpful in isolating a problem.

5. Some of the *Solid State Software* programs may run for several minutes depending on input data. If you desire to halt a running program, press the [RST] key. This is considered as an emergency halt operation which returns control to the main memory. A program must be recalled to be run again.

USING *SOLID STATE SOFTWARE* PROGRAMS AS SUBROUTINES

Any of the *Solid State Software* programs may be called as a subroutine to your own program in the main memory. Either of two program sequences may be used: 1) [2nd] [Pgm] mm (User Defined Key) or 2) [2nd] [Pgm] mm [SBR] (Common Label). Both send the program control to program mm, run the subroutine sequence, and then automatically return to the main program without interruption. Following [2nd] [Pgm] mm with anything other than [SBR] or a user-defined key is not a valid key sequence and can cause unwanted results.

It is very important to consider the Program Reference Data in Appendix A for any program called as a subroutine. You must plan and write your own program such that the data registers, flags, subroutine levels, parentheses levels, T-register, angular mode, etc., used by the called subroutine are allowed for in your program. In addition, a Register Contents section of each program description provides a guide to determine where data is or must be located to run this program.

A sample program that calls a *Solid State Software* program as a subroutine is provided in the *PROGRAMMING CONSIDERATIONS* section of the Owner's Manual.

If you need to examine and study the content of a *Solid State Software* program, you can download as described in the following paragraph.

DOWNLOADING *SOLID STATE SOFTWARE* PROGRAMS

If you need to examine a *Solid State Software* program, it can be downloaded into the main program memory.* This allows you to single step through a program in or out of the learn mode. It also allows using the program list or trace features of the optional printer. The only requirement for downloading a *Solid State Software* program is that the memory partition be set so there is sufficient space in the main program memory to receive the downloaded program. The key sequence to download a program is [2nd] [Pgm] mm [2nd] [Op] 09, where mm is the program number to be downloaded. This procedure places the requested program into program memory beginning at program location 000. The downloaded program writes over any instructions previously stored in that part of program memory. Remember to press [RST] before running or tracing the downloaded program.

Note that programs AV-02 and AV-04 may not be downloaded in the TI Programmable 58 due to their length. To download these programs in the TI Programmable 59, first repartition the calculator's storage area by pressing 5 [2nd] [Op] 17. The remainder of the programs in the Aviation Library Module may be downloaded with your calculator set at the partitioning established when you first turn it on.

PROGRAM DESIGN NOTES

Every program incoporates a form of initialization subroutine using the sequence [SBR] [CLR]. Depending on the program, initializing may cause 1) display and data registers to be cleared or loaded with the correct values; 2) flags to be set or reset; 3) the display mode to be "fixed" to some number of decimal places; 4) the selection of the degree mode for angular inputs.

Note that programs which must be run in the degree mode call for the selection of this mode in Step 2 of the User Instructions. This step is only intended to be a reminder as [SBR] [CLR] usually selects the degree mode when it is required. Naturally, if you perform a calculation in another mode while running one of these programs you must reselect the degree mode before continuing.

All directions (courses, headings, bearings, etc.) are entered and displayed in decimal degrees. Latitude and longitude are entered and displayed in the form DD.MMSSss (degrees. minutes seconds decimal seconds). Time may be in decimals, or HH.MMSS (hours. minutes seconds). All times are on the 24 hour clock. Dates are in MM.DD (month.day). Exceptions are noted in the User Instructions.

*Unless the library is a protected, special-purpose library.

AVIATION LIBRARY DIAGNOSTIC

This program performs the following functions separately.

1. Diagnostic/Library Module Check

2. Linear Regression Initialization

Diagnostic/Library Module Check

This routine checks the operation of your calculator and most of its functions, including conversion and statistics functions that are preprogrammed in the calculator, trigonometric functions, data register operations, program transfers, and comparisons. It also uses other navigation library programs to verify that the module is connected and operating correctly. If this diagnostic routine runs successfully, in approximately 15 seconds the number 6. will be displayed. If the calculator is attached to a PC-100A print cradle, the following will be printed:

```
                    AVIATION
                    6.
```
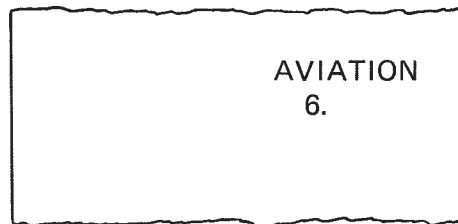
If there is a malfunction in the calculator or the *Solid State Software* module, a flashing number will be displayed. Refer to Appendix A of the Owner's Manual for an explanation of the various procedures to be followed when you have difficulties.

When you simply want to know which of your *Solid State Software* modules is in the calculator without physically looking at it, you can call the Library Module check portion of the routine directly. If the Aviation Library Module is in the calculator, the number 6. will be displayed. This number is unique to the Aviation Library (other optional libraries use other identifying digits).

Linear Regression Initialization

This routine initializes the calculator for linear regression by clearing data registers R_{01} through R_{06} and the T-register. It should be used whenever linear regression or other built-in statistics functions are to be started. You can also use the routine at any time to clear these registers selectively without disturbing any other registers.

```
┌─────────────────────────────────────────────────────────┐
│  ⚛  Solid State Software      TI ©1977                  │
│  AVIATION LIBRARY DIAGNOSTIC              AV-01          │
│         DIAGNOSTIC: [SBR] [=]                            │
│  LINEAR REGRESSION INITIALIZATION: [SBR] [CLR]          │
└─────────────────────────────────────────────────────────┘
```

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Diagnostic/Module Check			
1a	Select Program		[2nd] [Pgm] 01	
1b	Run Diagnostic		[SBR] [=]	6.[1]
	or			
1c	Library Module Check		[SBR] [2nd] [R/S]	6.[2]
	Initialize Linear Regression			
2a	Select Program		[2nd] [Pgm] 01	
2b	Initialize Linear Regression		[SBR] [CLR]	0.

NOTES:
1. This output is obtained if the calculator is operating properly.
2. The number 6. indicates the Aviation Library.
3. The Aviation Library programs are numbered 1 through 23. Program number 0 is the calculator's program memory.

Example 1: Diagnostic

PRESS	DISPLAY	OPTIONAL PRINTOUT
[2nd] [Pgm] 01		
[SBR] [=]	6.	AVIATION 6.

Example 2: Library Module Check

PRESS	DISPLAY	OPTIONAL PRINTOUT
[2nd] [Pgm] 01		
[SBR] [2nd] [R/S]	6.	AVIATION 6.

Example 3: Initialize Linear Regression

PRESS	DISPLAY
[2nd] [Pgm] 01	
[SBR] [CLR]	0.

AV-01

Register Contents

R_{00}		R_{05}	L.R. Init	R_{10}		R_{15}		R_{20}	
R_{01}	L.R. Init	R_{06}	L.R. Init	R_{11}		R_{16}		R_{21}	Used
R_{02}	L.R. Init	R_{07}		R_{12}		R_{17}			
R_{03}	L.R. Init	R_{08}		R_{13}		R_{18}			
R_{04}	L.R. Init	R_{09}		R_{14}		R_{19}			

FLIGHT PLAN WITH WIND

This program may be used to determine a flight plan for a trip of several legs with winds aloft. The wind triangle is solved using wind direction and velocity, magnetic compass variation, true airspeed, and true course to indicate magnetic heading and ground speed. The flying time, ETA, and fuel for each leg are computed, as are total time enroute and total fuel required.

The following equations are used:

$$TH = TC + \arcsin \left[\frac{WV}{TAS} \sin (WD - TC) \right]$$

$$MH = TH + Var$$

$$GS = TAS \cos (TH - TC) - WV \cos (WD - TC)$$

where

TH = true heading
TC = true course
MH = magnetic heading
Var = magnetic compass variation (+West, —East)
WD = wind direction (true)
WV = wind velocity
TAS = true airspeed
GS = ground speed
(all directions in degrees)

ETE = Dist/GS   Fuel = Burn × ETE

ETA = ETD + ETE   tF = Σ Fuel

   tt = Σ ETE

where

Dist = distance of leg
ETE = estimated time enroute for leg
ETA = estimated time of arrival
ETD = estimated time of departure
   tt = total time of flight
Burn = fuel flow (gal/hr or lbs/hr)
Fuel = fuel consumed for leg
   tF = total fuel consumed for all legs

The user should note that WD, WV, TAS, Burn and Var are assumed to be *average and constant* values for each leg, while in fact they may vary significantly and could seriously affect the accuracy of Fuel, GS (thus ETE), and MH. If, in the judgment of the pilot/navigator

AV-02

such variations warrant recalculating, the leg affected should be divided into two new legs at the point the variation occurs, and each recalculated for the new values. However, *this program is not designed for in-flight navigation,* hence changes affecting a leg actually being flown should be attempted only by a competent navigator.

NOTES:
1. Wind velocities greater than the true airspeed may yield incorrect results.
2. While this program does not require the use of the optional Print Cradle, the complexity of data output makes its use highly recommended. (No program changes are needed.)
3. Distances and speeds must be unit compatible throughout.

Solid State Software		TI © 1977
FLIGHT PLAN WITH WIND		AV-02
Var (+W,−E)	WD	WV	TAS ; Burn	ETD→tt ; tF
TC	Dist	→TH ; MH	→GS ; ETE	→Fuel ; ETA

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 02	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.0000[1]
4	Enter initial take-off time	ETD$_i$	[2nd] [E']	ETD[7]
				tt (HH.MMSS)
			[R/S]	tF (gal or lbs)
	For each leg			
5	Enter magnetic variation (+W, −E)	Var	[2nd] [A']	Var (deg)
6	Enter wind direction (true) in degrees	WD	[2nd] [B']	WD (deg)
7	Enter wind velocity	WV	[2nd] [C']	WV
8	Enter TAS and Burn (gal/hr or lbs/hr)[2] in that order[3]	TAS Burn	[2nd] [D'] [R/S]	TAS Burn
9	Enter true course	TC	[A]	TC (deg)
10	Enter distance of leg	Dist	[B]	Dist
11	Compute true heading and magnetic heading		[C]	TC (deg)[7]
				TH (deg)
			[R/S]	MH (deg)
12	Compute ground speed and estimated time enroute		[D] [R/S]	GS ETE (hrs)
13	Compute Fuel (for leg) and ETA		[E] [R/S]	Fuel (gal or lbs) ETA (hrs)
14	Enter estimated time of departure for next leg[5] and display total time and Fuel thus far	ETD[4]	[2nd] [E'] [R/S]	ETD[7] tt (HH.MMSS) tF (gal or lbs)
15	**For the next leg,** make appropriate changes in Steps 5-8[3], then go to Step 9 and continue.			

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NOTES: 1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed — see Introduction.)

2. Units (gal or lbs) must be consistent for correct tF.

3. To correct or change TAS or Burn, *both* must be reentered in the proper order.

4. Instruction [2nd] [E'] causes Fuel and ETE for leg to be added to cumulative totals (tt and tF). Therefore, do not perform this step until satisfied that the results are correct.

   If the incorrect value is inadvertently entered ([2nd] [E']), the leg must be recomputed as follows:

ENTER	PRESS
ETE from previous leg	[2nd] [D.MS] [STO] [1] [4]
ETA from previous leg	[2nd] [D.MS] [STO] [1] [6]
tt from previous leg	[2nd] [D.MS] [STO] [1] [2]
tF from previous leg	[STO] [1] [3]

   Go to Step 11 and continue.

5. Note that the ETA is already in the display register. Thus, if the flight will continue uninterrupted, simply press [2nd] [E']. To allow for layovers or time corrections, perform the needed calculations on the keyboard and continue (see Example).

6. Program leaves calculator in fix 4 mode.

7. Indicates ½ second pause in display.

Example: Prepare a flight plan for the following trip:
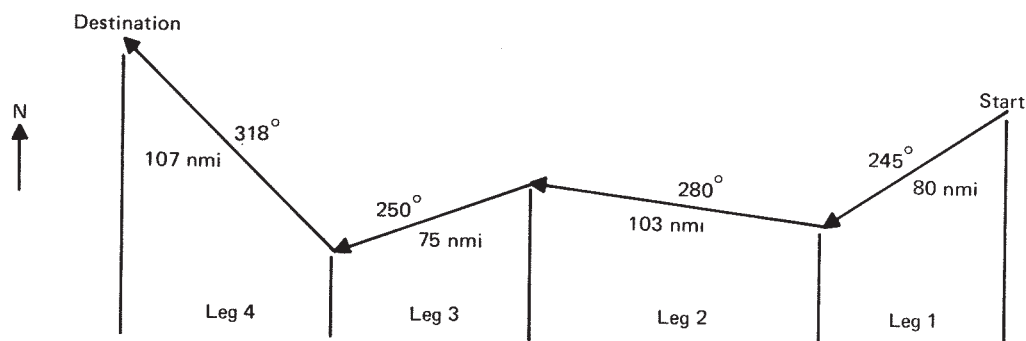
Courses indicated are true. Given meteorological and aircraft performance information, one can tabulate as follows:

	Var	WD	WV	TAS	Burn	TC	Dist
Leg 1	12°E	200°	28	115	14	245°	80
Leg 2	12.5°E	150°	15	118	14	280°	103
Leg 3	13°E	150°	18	115	14	250°	75
Leg 4	13.5°E	117°	22	118	14	318°	107

Takeoff time will be 12:50. The pilot will land after Leg 2 and spend 30 minutes on the ground.

AV-02

ENTER	PRESS	DISPLAY	PRINT	
	[2nd] [Pgm] 02		FLIGHT DATA	
	[SBR] [CLR]	0.0000		
12.5	[2nd] [E']	12.5000	12.5000	ETD
		0.0000	0.0000	TT
	[R/S]	0.0000	0.0000	TF
(Leg 1)				
12	[+/−] [2nd] [A']	−12.0000	−12.0000	VAR
200	[2nd] [B']	200.0000	200.0000	WD
28	[2nd] [C']	28.0000	28.0000	WV
115	[2nd] [D']	115.0000	115.0000	TAS
14	[R/S]	14.0000	14.0000	BURN
245	[A]	245.0000	245.0000	TC
80	[B]	80.0000	80.0000	DIST
	[C]	245.0000*		
		235.0863	235.0863	TH
	[R/S]	223.0863	223.0863	MH
	[D]	80.0000*	80.0000	DIST
		93.4838	93.4838	GS
	[R/S]	0.5121	0.5121	ETE
	[E]	11.9807	11.9807	FUEL
	[R/S]	13.4121	13.4121	ETA
	[2nd] [E']	13.4121*	13.4121	ETD
		0.5121	0.5121	TT
	[R/S]	11.9807	11.9807	TF
(Leg 2)				
12.5	[+/−] [2nd] [A']	−12.5000	−12.5000	VAR
150	[2nd] [B']	150.0000	150.0000	WD
15	[2nd] [C']	15.0000	15.0000	WV
118	[2nd] [D']	118.0000	118.0000	TAS
14	[R/S]	14.0000	14.0000	BURN
280	[A]	280.0000	280.0000	TC
103	[B]	103.0000	103.0000	DIST
	[C]	280.0000*		
		274.4118	274.4118	TH
	[R/S]	261.9118	261.9118	MH
	[D]	103.0000*	103.0000	DIST
		127.0810	127.0810	GS
	[R/S]	0.4838	0.4838	ETE
	[E]	11.3471	11.3471	FUEL
	[R/S]	14.2959	14.2959	ETA
	[+]			+LAYOVER
.30	[=]	14.5959		
	[2nd] [E']	14.5959*	14.5959	ETD
		1.3959	1.3959	TT
	[R/S]	23.3278	23.3278	TF

*Indicates ½ second pause in display.

ENTER	PRESS	DISPLAY	PRINT	
(Leg 3)				
13	[+/−] [2nd] [A']	−13.0000	−13.0000	VAR
150	[2nd] [B']	150.0000	150.0000	WD
18	[2nd] [C']	18.0000	18.0000	WV
115	[2nd] [D']	115.0000	115.0000	TAS
14	[R/S]	14.0000	14.0000	BURN
250	[A]	250.0000	250.0000	TC
75	[B]	75.0000	75.0000	DIST
	[C]	250.0000*		
		241.1329	241.1329	TH
	[R/S]	228.1329	228.1329	MH
	[D]	75.0000	75.0000	DIST
		116.7512	116.7512	GS
	[R/S]	0.3833	0.3833	ETE
	[E]	8.9935	8.9935	FUEL
	[R/S]	15.3832	15.3832	ETA
	[2nd] [E']	15.3832*	15.3832	ETD
		2.1831	2.1831	TT
	[R/S]	32.3213	32.3213	TF
(Leg 4)				
13.5	[+/−] [2nd] [A']	−13.5000	−13.5000	VAR
117	[2nd] [B']	117.0000	117.0000	WD
22	[2nd] [C']	22.0000	22.0000	WV
118	[2nd] [D']	118.0000	118.0000	TAS
14	[R/S]	14.0000	14.0000	BURN
318	[A]	318.0000	318.0000	TC
107	[B]	107.0000	107.0000	DIST
	[C]	318.0000*		
		321.8310	321.8310	TH
	[R/S]	308.3310	308.3310	MH
	[D]	107.0000*	107.0000	DIST
		138.2751	138.2751	GS
	[R/S]	0.4626	0.4626	ETE
	[E]	10.8335	10.8335	FUEL
	[R/S]	16.2458	16.2458	ETA
	[2nd] [E']	16.2458*	16.2458	ETD
		3.0457	3.0457	TT
	[R/S]	43.1547	43.1547	TF

Register Contents

R_{00}	Used	R_{05}	Var	R_{10}	Dist	R_{15}	Fuel
R_{01}		R_{06}	WV	R_{11}	Burn	R_{16}	ETD
R_{02}		R_{07}	WD	R_{12}	tt	R_{17}	GS
R_{03}		R_{08}	TAS	R_{13}	tF	R_{18}	TC
R_{04}		R_{09}	TH	R_{14}	ETE	R_{19}	

*Indicates ½ second pause in display.

FLIGHT PLAN AND VERIFICATION

This program is basically a simplified version of AV-02[1] (Flight Plan with Wind). Whereas AV-02 assumes an optimum cruising speed (TAS) and calculates ground speed, this program assumes groundspeed desired and calculates TAS needed. This allows the wind triangle to be solved by simple vector addition. The result is a program that will solve for true heading and true airspeed given true course desired and wind information.

Also incorporated is a routine to solve the time-speed-distance equation for any one unknown. Thus elapsed time enroute and estimated time of arrival can be predicted. Further, since the time-burn-fuel equation is analogous, it too can be solved for any one unknown.[2] In addition, the flight plan can be updated in-flight (Flight Verification).

Time-Speed-Distance and Fuel Consumption

Given two values of the following equations, the third can be calculated

$$\text{Dist} = \Delta t \times \text{GS} \qquad\qquad \text{Fuel} = \Delta t \times \text{Burn}$$

where

GS = ground speed
Dist = Distance traveled
Δt = time interval or elapsed time enroute
Burn = rate of fuel consumption (gal/hr or lbs/hr)
Fuel = total fuel consumed (gal or lbs)

See User Instructions, steps 4—7. Note that to directly calculate the fuel equations, user replaces GS with Burn, and Dist with Fuel.[2]

Flight Plan (pre-flight)

This routine calculates elapsed time enroute and estimated time of arrival given estimated time of departure, distance, and ground speed for each leg, as well as total time and total distance for all legs previous to the checkpoint. The following equations are used:

$$\text{ETA} = \text{ETD} + \Delta t \qquad\qquad tt = \Sigma \Delta t \qquad\qquad tD = \Sigma \text{Dist}$$

where

ETD = estimated time of departure for leg (either entered or carried over from previous leg)
Δt = elapsed time for leg (calculated from $\Delta t = \text{Dist/GS}$)
ETA = estimated time of arrival
tt = total time
tD = total distance

Time is entered and displayed in (HH.MMSS). Distance and speed must be unit compatible. (Usually nautical miles and knots).

Flight Verification

This routine may be used to update the flight plan as it is being flown. Given the actual time of arrival at a checkpoint, the actual groundspeed and leg time are computed. The corrected total time may be displayed. The following equation is used:

$$\Delta t = ATA - ATD$$

where

ATA = actual time of arrival.
ATD = actual time of departure.

True Heading and Airspeed

Given the wind direction and velocity, desired groundspeed and true course for each leg, this routine calculates the true course and true airspeed to fly needed to achieve that desired ground speed and course. The following equation is used:

$$\overrightarrow{TAS} = \overrightarrow{GS} + \overrightarrow{WV}$$

(see note 3)
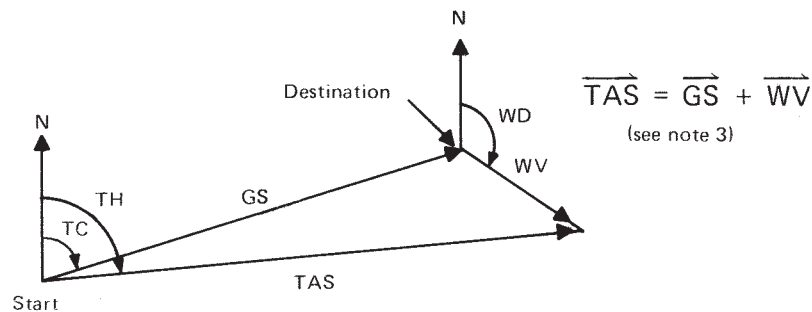
where

$\overrightarrow{TAS}$ = vector with magnitude TAS (true airspeed) and direction TH (true heading)

$\overrightarrow{GS}$ = vector with magnitude GS (ground speed) and direction TC (true course)

$\overrightarrow{WV}$ = vector with magnitude WV (wind velocity) and direction WD (wind direction)

Notes:

1. Unlike AV-02, this program contains no printer instructions. If the user desires, the PC-100A Print Cradle may be used, but it must be manually instructed to print the displayed result.
2. Note that GS and Dist *may not* be replaced by Burn and Fuel in the flight plan. After the totals for the legs are calculated, the total fuel consumed may be calculated by the following:
   total fuel = tt × Burn   *only if* Burn is constant.
   Otherwise each leg must be calculated separately and summed into an unused data register.
3. At first glance, the diagram would seem to be incorrect with $\overrightarrow{TAS}$ and $\overrightarrow{GS}$ interchanged and $\overrightarrow{WV}$ reversed. Yet it must be remembered that wind direction is that direction the wind is blowing *from*. Thus $\overrightarrow{WV}$ points *into* the wind.

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AV-03

	Solid State Software			TI © 1977
FLIGHT PLAN AND VERIFICATION				**AV-03**
	WD	WV	TC → TH;TAS	ATA → tD ; tt
ETD	Δt	GS/Burn	Dist/Fuel	→ETA

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 03	
2	Select degree mode		[2nd] [Deg]	
	Time-Speed-Distance or Time-Fuel-Burn[2] Do 4 or 5 or 6			
3	Initialize		[SBR] [CLR]	0.0000[1]
4	a. Enter time	Δt	[B]	0.0000
	b. Enter ground speed (or burn)	GS (or Burn)	[C]	0.0000
	c. Calculate distance (or fuel)		[D]	Dist (or Fuel)
5	a. Enter time	Δt	[B]	0.0000
	b. Enter distance (or fuel)	Dist (or Fuel)	[D]	0.0000
	c. Calculate ground speed (or burn)		[C]	GS (or Burn)
6	a. Enter ground speed (or burn)	GS (or Burn)	[C]	0.0000
	b. Enter distance (or fuel)	Dist (or Fuel)	[D]	0.0000
	c. Calculate time (Each value is stored and need not be reentered unless it has changed.)		[B]	Δt (HH.MMSS)
7	a. Display time (opt.)		[B] [B]	Δt (HH.MMSS)
	b. Display ground speed (opt.)		[C] [C]	GS
	c. Display distance (opt.) (in any order)		[D] [D]	Dist
	Flight Planning			
8	Initialize		[SBR] [CLR]	0.0000[1]
9	Enter take-off time[3]	ETD(HH.MMSS)	[A]	ETD (decimal hrs.)
10	Enter ground speed	GS	[C]	0.0000
11	Enter distance	Dist	[D]	0.0000
12	Calculate leg time		[B]	Δt (HH.MMSS)
13	Calculate ETA		[E]	ETA (HH.MMSS)
14	Calculate total distance and total time to checkpoint (For next leg, go to step 10)		[2nd] [E′] [R/S] [R/S]	ETA tD tt (HH.MMSS)
	Flight Verification			
15	Initialize		[SBR] [CLR]	0.0000[1]
16	Enter take-off time	ETD(HH.MMSS)	[A]	ETD (decimal hrs)
17	Enter anticipated ground speed	GS	[C]	0.0000
18	Enter distance	Dist	[D]	0.0000
19	Calculate ETA		[E]	ETA (HH.MMSS)
20	Enter actual time of arrival and calculate total distance and time flown	ATA (HH.MMSS)	[2nd] [E′] [R/S] [R/S]	ATA (HH.MMSS) tD tt (HH.MMSS)

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
21	Display actual leg time		[B] [B]	Δt
22	Display actual ground speed (For next leg, go to step 17)		[C] [C]	GS
	True Heading and Airspeed (Do 23 or 24 or 25)			
23	Enter ground speed	GS	[C]	0.0000
24	Perform Step 5			
25	Perform Steps 16, 18, 20			
26	Enter wind direction	WD	[2nd] [B']	WD
27	Enter wind velocity	WV	[2nd] [C']	WV
28	Enter true course and compute true heading and true airspeed	TC	[2nd] [D'] [R/S]	TH TAS

NOTES:

1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed — see Introduction.)

2. Replace GS with Burn and Dist with Fuel (see text).

3. Usually zero — this makes tt = the total elapsed time enroute. User may enter clock time (24 hr clock in HH.MMSS) if real-time ETA is desired for tt. Program will subtract 24 hrs if ETA is greater than 24 hrs. Note however, that program will yield incorrect results for leg times over 24 hrs.

4. Program leaves calculator in fix 4 mode.

Example 1: A pilot plans to fly 272 nautical miles at a ground speed of 95 knots. How long will his flight take? If the fuel flow is 12.5 gal/hr, how much fuel will he use?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 03		Select Program
	[SBR] [CLR]	0.0000	Initialize
95	[C]	0.0000	Enter GS
272	[D]	0.0000	Enter Dist
	[B]	2.5148	Δt (HH.MMSS)
12.5	[C]	0.0000	Enter Burn
	[D]	35.7895	Fuel (gal)

Example 2: Prepare a flight plan for the following flight:

	Ground speed (knots)	Distance (naut. mi.)
Leg 1	112	78
Leg 2	100	53
Leg 3	100	62

AV-03

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 03		Select Program
	[SBR] [CLR]	0.0000	Initialize
0	[A]	0.0000	Enter ETD
(Leg 1)			
112	[C]	0.0000	Enter GS
78	[D]	0.0000	Enter Dist
	[B]	0.4147	Δt (HH.MMSS)
	[E]	0.4147	ETA (HH.MMSS)
	[2nd] [E']	0.4147	calc totals
	[R/S]	78.0000	tD (opt'l)
	[R/S]	0.4147	tt (opt'l)
(Leg 2)			
100	[C]	0.0000	Enter GS
53	[D]	0.0000	Enter Dist
	[B]	0.3148	Δt (HH.MMSS)
	[E]	1.1335	ETA (HH.MMSS)
	[2nd] [E']	1.1335	calc totals
	[R/S]	131.0000	tD (opt'l)
	[R/S]	1.1335	tt (opt'l)
(Leg 3)			
62	[D]	0.0000	Enter Dist
	[B]	0.3712	Δt (HH.MMSS)
	[E]	1.5047	ETA (HH.MMSS)
	[2nd] [E']	1.5047	calc totals
	[R/S]	193.0000	tD
	[R/S]	1.5047	tt

Summary

	Δt	tD (nmi)	tt
Leg 1	:41:47	78	:41:47
Leg 2	:31:48	131	1:13:35
Leg 3	:37:12	193	1:50:47

Now we may update in-flight. Suppose an ATD of 13:18:00, and that the actual time of arrival at the first checkpoint is 13:58:12. Suppose further that the pilot circles for 10 minutes at checkpoint 2 to observe weather conditions.

ENTER	PRESS	DISPLAY	COMMENT
	[SBR] [CLR]	0.0000	Initialize
13.18	[A]	13.3000	ETD (decimal)
(Leg 1)			
112	[C]	0.0000	Enter GS (est.)
78	[D]	0.0000	Enter Dist
	[E]	13.5947	ETA (est.)
13.5812	[2nd] [E']	13.5812	ATA
	[R/S]	78.0000	tD (opt'l)
	[R/S]	0.4012	tt (opt'l)

20

ENTER	PRESS	DISPLAY	COMMENT
	[B] [B]	0.4012	Actual Δt
	[C] [C]	116.4179	Actual GS

We note that the actual ground speed was approximately 4 knots more than was estimated (probably due to wind). This information will help correct the ground speed estimate for the next leg. Since the second leg is in approximately the same direction, add 4 to GS for the next leg to improve the estimate (if leg is nearly 180° different, subtract 4, if nearly 90° different, leave unchanged). Suppose ATA was 14:29:02.

ENTER	PRESS	DISPLAY	COMMENT
(Leg 2)			
104	[C]	0.0000	Enter GS
53	[D]	0.0000	Enter Dist
	[E]	14.2847	ETA (HH.MMSS)
14.2902	[2nd] [E']	14.2902	ATA (HH.MMSS)
	[R/S]	131.0000	tD (opt'l)
	[R/S]	1.1102	tt (opt'l)
	[B] [B]	0.3050	Actual Δt
	[C] [C]	103.1351	Actual GS

The actual ground speed was very close to the estimate, so we may use the same GS for the third leg (with regard to direction as above). Add 10 minutes circling time to ATA above and use this value as the new ATD. Suppose ATA at third check point is 15:14:30.

(Leg 3)			
14.3902	[A]	14.6506	ETD (decimal)
62	[D]	0.0000	Enter Dist
	[E]	15.1506	ETA (HH.MMSS)
15.1430	[2nd] [E']	15.1430	ATA (HH.MMSS)
	[R/S]	193.0000	tD
	[R/S]	1.4630*	tt
	[B] [B]	0.3528	Actual Δt
	[C] [C]	104.8872	Actual GS

Summary

	ETA	ATA	tD (nmi)	Actual tt	Actual Δt	Actual GS (knots)
Leg 1	13:59:47	13:58:12	78	0:40:12	0:40:12	116
Leg 2	14:28:47	14:29:02	131	1:11:02	0:30:50	103
Leg 3	15:15:06	15:04:03	193	1:46:30*	0:35:28	105

Remarks

In the case of time used between legs, the program treats circling time exactly as if the pilot had landed. Therefore tt will be only the actual leg time flown. In the present case, the total flying time is tt + 10 min., or 1:56:30.

AV-03

Example 3: You wish to fly a leg with true course 040° for 62 nmi. The winds are from 125° at 22 knots. You will depart at 8:20 and wish to arrive at 8:55. What true heading and true airspeed should you fly?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 03		Select Program
	[SBR] [CLR]	0.0000	Initialize
8.2	[A]	8.3333	ETD (decimal)
62	[D]	0.0000	Dist
8.55	[2nd] [E']	8.5500	ATA
125	[2nd] [B']	125.0000	WD (deg)
22	[2nd] [C']	22.0000	WV
40	[2nd] [D']	51.4502	TC→TH (deg)
	[R/S]	110.4004	TAS (knots)

Register Contents

R_{00}	Used	R_{05}		R_{10}	Dist	R_{15}	ETA
R_{01}		R_{06}	WV	R_{11}	tD	R_{16}	ETD
R_{02}		R_{07}	WD	R_{12}	tt	R_{17}	GS
R_{03}		R_{08}	TAS	R_{13}	used	R_{18}	
R_{04}		R_{19}	TH	R_{14}	Δt	R_{19}	

LONG RANGE FLIGHT PLAN

This program *requires* the use of the accessory PC-100A Print Cradle.

There are two sections of this program: the first serves to enter way points and generates an overall picture of the flight; the second gives more detailed flight plan information.

Given the waypoints in order, the overall average ground speed, average Burn, fuel aboard at take-off, and ETD, this program will print the great circle distances between start and finish, ETE, ETA, fuel required, and fuel left on board.

Having completed the above, the user may then enter any of the following quantities for each leg as required: ground speed, Burn, fuel aboard (usually fuel left from preceding leg, or refueled quantity), and ETD. Then the following are printed for that leg:

1. great circle distance (Dist)
2. total distance flown thus far (tot Dist)
3. initial true course to fly a great circle route
4. ETE
5. ETA
6. estimated fuel required (EFR)
7. estimated fuel left aboard (EFL) at the end of the leg

These are computed from the following equations:

$$\text{Dist} = 60 \arccos \left[\sin L_s \sin L_d + \cos L_s \cos L_d \ \cos (\lambda_d - \lambda_s) \right]$$

$$TC_i = \arccos \left[\frac{\sin L_d - \sin L_s \cos (\text{Dist}/60)}{\sin (\text{Dist}/60) \cos L_s} \right] \qquad \text{tot Dist} = \Sigma \text{ Dist}$$

where

(L_s, λ_s) = latitude and longitude of starting point
(L_d, λ_d) = latitude and longitude of destination
$\quad$ Dist = great circle distance between above points
$\quad TC_i$ = initial true course of great circle route for leg i

If $[\sin (\lambda_d - \lambda_s) < 0]$, then the initial course is $(360° - TC_i)$.

Further:

$$\text{ETE} = \text{Dist} \div \text{GS} \qquad\qquad \text{ETA} = \text{ETD} + \text{ETE} \qquad (0 \leqslant \text{ETA} < 24)$$
$$\text{EFR} = \text{Burn} \times \text{ETE} \qquad\qquad \text{EFL} = \text{Fuel abd} - \text{EFR}$$

where

$\quad$ Fuel abd = fuel aboard craft (usable) at start of leg
$\quad\quad$ EFR = estimated fuel required (used)
$\quad\quad$ EFL = estimated fuel left
$\quad\quad$ Burn = rate of fuel flow

Remarks

This program computes the *great circle* distance from point to point. Since flying such a course requires an infinite number of heading changes, pilots generally follow a rhumbline course between points, which allows them to fly a constant heading. For most legs, the great circle distance is nearly equal to the rhumbline distance, and the initial great circle course is nearly equal to the rhumbline course. The difference increases (1) as the latitude increases, (2) as the difference of latitude between two points decreases, and (3) as the difference of longitude increases. It becomes quite large for two points widely separated on the same parallel of latitude far from the equator.*

Further, unless the waypoints lie approximately along the great circle route from start to destination, the initial values obtained in the first section of the program may differ greatly from the true values. In this case, ignore these outputs and proceed to compute the detailed leg plans. (Be sure to execute Steps 6 and 8.)

Limitation

Do not compute a path which passes directly over a pole. Start and destination of the entire trip or of any single leg may not be at diametrically opposite points of the earth.

*Reference: Bowditch, *American Practical Navigator,* Vol. II, Defense Mapping Agency Hydrographic Center, Pub. No. 9, 1975, p. 582.

⟨ఇ⟩ Solid State Software			TI ©1977	
LONG RANGE FLIGHT PLAN				AV-04
[print]→				
L_n, λ_n	GS	Fuel abd	Burn	ETD

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	PRINT
1	Select program		[2nd] [Pgm] 04	
2	Select degree mode		[2nd] [Deg]	
3	Initialize[1]		[SBR] [CLR]	0.0000
4	Enter coordinates in order:[2]			
	Latitude (+N, −S)	L_n (DD.MMSS)	[A]	WP # L_n
	Longitude (+W, −E)	λ_n (DDD.MMSS)	[A]	λ_n
	(Repeat Step 4 for each waypoint beginning with the origin)[3]			
5	Enter GS (average for entire trip): (knots)	GS	[B]	GS
6	Enter Fuel aboard at takeoff: (gal or lbs)	Fuel abd	[C]	Fuel abd
7	Enter Burn (gal or lbs/hr)[4]	Burn	[D]	Burn
8	Enter departure time (GMT) and print Dist, ETE, ETA, EFR, EFL[5]	ETD (HH.MMSS)	[E]	ETD (HH.MMSS) Dist (n.mi) ETE ETA EFR EFL

STEP	PROCEDURE	ENTER	PRESS	PRINT
	Do Steps 9-13 as required for each leg			
9	Enter new GS (knots)	GS	[B]	GS
10	Enter new Fuel aboard	Fuel abd	[C]	Fuel abd
11	Enter new Burn	Burn	[D]	Burn
12	Enter new ETD (GMT)	ETD (HH.MMSS)	[E]	ETD
13	Print Leg no., (L, λ) of end of leg, Dist, tot Dist, TC_i, ETE, ETA, EFR and EFL[6]		[2nd] [A']	Leg number L_n λ_n Dist tot Dist TC_i ETE ETA EFR EFL

NOTES:

1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed — see Introduction.)

2. To correct an entry before [A] is pressed press [CE]. If [A] is pressed following an incorrect entry return to Step 3. If you already recorded your data on magnetic cards, read the cards and go to Step 8.

3. The number of waypoints that may be entered depends upon the number of data registers available for program use as shown below.

Number of Registers	Maximum Number of Waypoints
20	4
30	9
40	14
50	19
60	24
70*	29
80*	34
90*	39
100*	44

See your Owner's Manual for complete instructions on partitioning your calculator's storage area.

* TI Programmable 59 only.

4. At this point you may record your data on magnetic cards if you own a TI Programmable 59. Press [INV] [2nd] [Fix] and then continue with the following:

To record bank 4 ($R_{00}-R_{29}$): enter 4 and feed in card
To record bank 3 ($R_{30}-R_{59}$): enter 3 and feed in card
To record bank 2 ($R_{60}-R_{89}$): enter 2 and feed in card
To record bank 1 ($R_{90}-R_{99}$): enter 1 and feed in card

See note 3 to determine which banks to record. Note that each bank must be recorded on a separate card side. (See your Owner's Manual for complete instructions.)

5. To change data entered in Steps 5-8 after [E] is pressed let n be the number of waypoints (including the origin) entered in Step 4. Now store $2n + 12$ in R_{00} and enter any data you wish to change before performing Step 8 again.

6. While tedious it is possible to recalculate a leg in the detailed flight plan. Enter the following data calculated in Step 13 for the leg previous to the one you wish to recompute.

Enter	Press
EFL for the *previous* leg	[STO] 06
Previous leg number	[STO] 05
Previous ETA	[2nd] [D.MS] [STO] 04
Previous tot Dist	[STO] 01
[(Prev leg no. + 1)×2] + 12	[STO] 00

Now continue with Step 9.

Example: Generate a flight plan given the following waypoints:

Waypoint #	Latitude	Longitude
0 (Origin)	49° 20′ 36″ N	123° 10′ 24″ W
1	48° 12′ N	120° 46′ W
2	47° 31′ N	114° 55′ W
3	45° 06′ N	110° 23′ 06″ W
4	43° 16′ 12″ N	104° 18′ W
5	40° 28′ N	101° 16′ 54″ W
6 (Destination)	38° 07′ 18″ N	96° 47′ 54″ W

ETD is 10:45, GS should be 230 knots, initial fuel aboard will be 50 gallons, and Burn should average 15 gal/hr.

ENTER	PRESS	DISPLAY	PRINT	
	[2nd] [Pgm] 04			
	[SBR] [CLR]	0.0000	LONG RANGE FLT PLAN	
			0.0000	WP
49.2036	[A]	1.000000	49.2036	LAT
123.1024	[A]	1.000000	123.1024	LON
			1.0000	WP
48.12	[A]	1.000000	48.1200	LAT
120.46	[A]	1.000000	120.4600	LON
			2.0000	WP
47.31	[A]	1.000000	47.3100	LAT
114.55	[A]	1.000000	114.5500	LON
			3.0000	WP
45.06	[A]	1.000000	45.0600	LAT
110.2306	[A]	1.000000	110.2306	LON
			4.0000	WP
43.1612	[A]	1.000000	43.1612	LAT
104.18	[A]	1.000000	104.1800	LON

ENTER	PRESS	DISPLAY	PRINT	
			5.0000	WP
40.28	[A]	1.000000	40.2800	LAT
101.1654	[A]	1.000000	101.1654	LON
			6.0000	WP
38.0718	[A]	1.000000	38.0718	LAT
96.4754	[A]	1.000000	96.4754	LON
230	[B]	230.0000	230.0000	GS
50	[C]	50.0000	50.0000	FUEL
15	[D]	15.0000	15.0000	BURN
10.45	[E]	2.0000	10.4500	ETD
			1316.8427	DIST
			5.4331	ETE
			16.2831	ETA
			85.8810	EFR
			−35.8810	EFL

Since the EFL is negative, the pilot must either take more aboard at the start, or refuel enroute. He decides to calculate further and then select the waypoint which would be the more advantageous for refueling.

The pilot estimates that on a take-off leg, GS will average 210 knots and Burn will average 17 gal/hr, while on a landing leg, GS will average 200 knots and Burn 13 gal/hr. Otherwise the average GS is 260 knots and Burn 14 gal/hr.

ENTER	PRESS	DISPLAY	PRINT	
(Leg 1 — a take-off leg)				
210	[B]	210.0000	210.0000	GS
17	[D]	17.0000	17.0000	BURN
	[2nd] [A']		1.0000	LEG
			48.1200	DLAT
			120.4600	DLON
			117.3063	DIST
			117.3063	TDST
			124.8755	TC
			0.3331	ETE
			11.1831	ETA
			9.4962	EFR
		0.0000	40.5038	EFL
(Leg 2)				
260	[B]	260.0000	260.0000	GS
14	[D]	14.0000	14.0000	BURN
	[2nd] [A']		2.0000	LEG
			47.3100	DLAT
			114.5500	DLON
			238.9895	DIST
			356.2958	TDST
			97.6975	TC
			0.5509	ETE
			12.1340	ETA
			12.8687	EFR
		0.0000	27.6351	EFL

Since only 27 gallons of fuel remain, the pilot will land to refuel at the next checkpoint.

ENTER	PRESS	DISPLAY	PRINT	
(Leg 3 — a landing leg)				
220	[B]	220.0000	220.0000	GS
13	[D]	13.0000	13.0000	BURN
	[2nd] [A']		3.0000	LEG
			45.0600	DLAT
			110.2306	DLON
			237.2134	DIST
			593.5092	TDST
			126.0127	TC
			1.0442	ETE
			13.1822	ETA
			14.0172	EFR
		0.0000	13.6180	EFL

The pilot plans to be on the ground for 55 minutes (adding this to ETA of 13.1822 gives an ETD of 14.1322), and will refuel to carry 60 gallons aboard for the remainder of the trip (that is, he will add an estimated 46.382 gallons to his tanks).

(Leg 4 — a take-off leg)				
210	[B]	210.0000	210.0000	GS
60	[C]	60.0000	60.0000	FUEL
17	[D]	17.0000	17.0000	BURN
14.1322	[E]	14.2228	14.1322	ETD
	[2nd] [A']		4.0000	LEG
			43.1612	DLAT
			104.1800	DLON
			283.8084	DIST
			877.3176	TDST
			110.6106	TC
			1.2105	ETE
			15.3427	ETA
			22.9750	EFR
		0.0000	37.0250	EFL
(Leg 5)				
260	[B]	260.0000	260.0000	GS
14	[D]	14.0000	14.0000	BURN
	[2nd] [A']		5.0000	LEG
			40.2800	DLAT
			101.1654	DLON
			215.5566	DIST
			1092.8742	TDST
			140.2607	TC
			0.4945	ETE
			16.2412	ETA
			11.6069	EFR
		0.0000	25.4181	EFL

ENTER	PRESS	DISPLAY	PRINT	
(Leg 6 — a landing leg)				
220	[B]	220.0000	220.0000	GS
13	[D]	13.0000	13.0000	BURN
	[2nd] [A']		6.0000	LEG
			38.0718	DLAT
			96.4754	DLON
			251.2140	DIST
			1344.0882	TDST
			122.6172	TC
			1.0831	ETE
			17.3243	ETA
			14.8445	EFR
		0.0000	10.5737	EFL

Register Contents

R_{00}	Pointer	R_{05}	Counter	R_{10}		R_{15}	λ_1	R_{20} and above
R_{01}	tot Dist	R_{06}	Fuel	R_{11}		R_{16}	L_2	are used similar
R_{02}	Used	R_{07}	Burn	R_{12}	L_0	R_{17}	λ_2	to $R_{12} - R_{19}$
R_{03}	Dist/60, ETE	R_{08}	GS	R_{13}	λ_0	R_{18}	L_3	
R_{04}	ETA, ETD	R_{09}	Dist	R_{14}	L_1	R_{19}	λ_3	

ATMOSPHERE, SPEED, TEMPERATURE, AND ALTITUDE

This program calculates atmospheric conditions given a known pressure altitude. If the aircraft recovery coefficient, calibrated airspeed, and indicated temperature are also known, then the program will calculate the mach number, true airspeed, true air temperature, and the density altitude. The calculations are limited to altitudes under 36,039 feet.

The standard sea level references (ICAO) are:

T_0 (temperature)   = 288.15 K   = 15.00°C

a_0 (speed of sound)   = 1116.4 ft/sec   = 661.5 knots

P_0 (atmospheric pressure) = 14.696 psi   = 29.92 in. Hg

ρ_0 (atmospheric density)   = 0.002376 lb sec^2/ft^4

Program outputs given pressure altitude are:

T (°C)   —   temperature in degrees Celsius

$\dfrac{a}{a_0}$ —   relative speed of sound

$\dfrac{P}{P_0}$ —   relative atmospheric pressure

$\dfrac{\rho}{\rho_0}$ —   relative atmospheric density

where T, a, P, and ρ are respectively the present temperature (°K), speed of sound, pressure, and density. These quantities are defined by the following equations:

$$T = T_0 - 0.001981 \ (\text{PALT}) \qquad\qquad \frac{P}{P_0} = \left(\frac{T}{T_0}\right)^{5.2563}$$

$$T(°C) = T - 273.15$$

$$\frac{a}{a_0} = \left(\frac{T}{T_0}\right)^{\frac{1}{2}} \qquad\qquad\qquad\qquad \frac{\rho}{\rho_0} = \left(\frac{P}{P_0}\right) \div \left(\frac{T}{T_0}\right)$$

Note also that under some conditions, further data can be approximated. For most aircraft, REC ≈ 0.8. And for small mach numbers (M) — (i.e., low and slow) — IT ≈ TAT. Thus density altitude can be approximated given only pressure altitude and indicated temperature.

The following abbreviations and units are used.

PALT	— pressure altitude (feet)
REC	— aircraft recovery coefficient.
IT	— indicated temperature (°K)
IT(°C)	— indicated temperature (°C)
TAT	— true air temperature (°K)
TAT(°C)	— true air temperature (°C)
CAS	— calibrated airspeed (knots)
TAS	— true airspeed (knots)
M	— mach number
DALT	— density altitude (feet) (see note 1 of User Instructions)

Given REC, CAS, and IT($^\circ$C), the following equations become useful:

$$IT = IT(^\circ C) + 273.15$$

$$TAT = (IT) \left[(REC) \left(\frac{1}{1 + 0.205\,M^2} - 1 \right) + 1 \right]$$

$$TAT(^\circ C) = TAT - 273.15$$

$$TAS = 39\,M\,\sqrt{TAT}$$

$$\frac{\rho}{\rho_0} = \frac{P}{P_0} \div \frac{TAT}{T_0}$$

$$DALT = 145426 \left[1 - \left(\frac{\rho}{\rho_0} \right)^{0.235} \right]$$

The mach number (airspeed/speed of sound for present conditions) is given by:

$$M^2 = 5\,[(Y + 1)^{0.286} - 1]$$

$$Y = \left(\frac{P_0}{P} \right) \left\{ \left[1 + 0.205 \left(\frac{CAS}{661.5} \right)^2 \right]^{3.5} - 1 \right\}$$

Reference: U.S. Standard Atmosphere, COESA, 1962.

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STD ATM; SPD; TEMP; ALT			AV-05
REC	→T(°C)	→a/a₀	→P/P₀	→ρ/ρ₀
PALT	IT(°C)	CAS→TAS;M	→TAT(°C)	→DALT

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 05	
2	Initialize		[SBR] [CLR]	0.00
	Standard Atmosphere Quantities			
3	Enter PALT (ft)	PALT	[A]	PALT (ft)
4	Calculate T(°C)		[2nd] [B′]	T(°C)
5	Calculate a/a_0		[2nd] [C′]	a/a_0
6	Calculate P/P_0		[2nd] [D′]	P/P_0
7	Calculate ρ/ρ_0		[2nd] [E′]	ρ/ρ_0
8	For a new case, go to step 3			
	TAS, M, TAT, and DALT			
9	Enter PALT (ft)	PALT	[A]	PALT
10	Enter REC	REC	[2nd] [A′]	REC
11	Enter IT(°C)	IT	[B]	IT (°C)
12	Enter CAS (knots) Calculate TAS (knots) and M	CAS	[C] [R/S]	TAS (knots) M
13	Calculate TAT (°C)		[D]	TAT (°C)
14	Calculate DALT (ft)		[E]	DALT (ft)[1]
15	For a new case, make changes as needed in steps 9-12.			
	DALT for low airspeeds			
16	Enter PALT (ft)	PALT	[A]	PALT (ft)
17	Enter TAT (°C) (≈IT) and calculate DALT.	TAT	[E]	DALT (ft)[1]

NOTES: 1. The density altitude is a function of air density. It is the altitude at which a given air density *(ρ)* would be encountered under standard atmospheric conditions. It is *not* the true altitude.

2. Accuracy degenerates for mach numbers greater than 1.

3. The program leaves the calculator in fix 2 mode.

Example 1: Assuming a standard atmosphere, what is the temperature ($^\circ$C), the present speed of sound, present pressure, and relative density, at a pressure altitude of 25,000 feet?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 05 [SBR] [CLR]	0.00	Initialize
25000	[A]	25000.00	PALT (ft)
	[2nd] [B']	-34.53	T ($^\circ$C)
	[2nd] [C']	0.91	a/a_0
	[X]		
661.5	[=]	601.98	a (knots)
	[2nd] [D']	0.37	P/P_0
	[X]		
29.92	[=]	11.10	P (in. Hg)
	[2nd] [E']	0.45	ρ/ρ_0

Example 2: For a pressure altitude of 27,000 feet, a recovery coefficient of 0.8, an indicated air temperature of 8°C, and a calibrated airspeed of 375 knots, find the mach number, true airspeed, true air temperature, and density altitude.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 05 [SBR] [CLR]	0.00	Initialize
27000	[A]	27000.00	PALT (ft)
.8	[2nd] [A']	0.80	REC
8	[B]	8.00	IT ($^\circ$C)
375	[C]	567.34	TAS (knots)
	[R/S]	0.92	M
	[D]	-25.53	TAT ($^\circ$C)
	[E]	28486.12	DALT (ft)

Example 3: Given a pressure altitude of 17,500 feet, an indicated temperature of -38°C, and a calibrated airspeed of 80 knots, what is the density altitude?

Since CAS is small with respect to speed of sound, -38°C can be entered as true air temperature.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 05 [SBR] [CLR]	0.00	Initialize
17500	[A]	17500.00	PALT (ft)
38	[+/−] [E]	15223.21	DALT (ft)

Register Contents

R_{00}		R_{05}		R_{10} PALT	R_{15}
R_{01}		R_{06}		R_{11} REC	R_{16}
R_{02}		R_{07}		R_{12} IT ($^\circ$C)	R_{17}
R_{03}		R_{08}		R_{13} M	R_{18}
R_{04}		R_{09}		R_{14}	R_{19}

PREDICTING FREEZING LEVELS
LOWEST USABLE FLIGHT LEVELS

This program contains two routines which operate independently.

Predicting Freezing Levels

This routine predicts the freezing level in feet above mean sea level, given a known temperature (°F or °C) and altitude (feet above MSL). The freezing level both in clear weather and in clouds is predicted from the following:

$$DFzL = ALT + 1000 \left(\frac{T(°C)}{2}\right)$$

$$WFzL = ALT + 1000 \left(\frac{T(°C)}{1.5}\right)$$

where

        ALT is the altitude in feet

        DFzL is the dry freezing level (clear weather) in feet

and   WFzL is the wet freezing level (clouds) in feet

Remarks

The values computed are estimates and may differ significantly from the actual freezing level (*especially* within 2000 feet above ground level where inversions are common). When in doubt it is best to calculate both DFzL and WFzL and use the lower value.

To execute this routine, use Steps 1-5 of the User Instructions.

Lowest Usable Flight Level

This routine computes the lowest usable flight level (LUFL) given the altimeter setting (ASET) according to the following:

        If ASET $\geq$ 29.92 (in Hg), then LUFL = 18,000 ft.

        If ASET $<$ 29.92 (in Hg), then LUFL = 18000 + 500 INT (60.82 − 2 (ASET))

where

        INT(x) is the integer function, yielding the integer part of x.

        (example − INT (2.1) = 2)

Remarks

To execute this routine, use Steps 1, 2, 7 of User Instructions.

	Solid State Software	TI © 1977		
FREEZE LEVEL; LOWEST FLIGHT LEVEL			AV-06	
T(°F)				
T(°C)	ALT	→DFzL	→WFzL	ASET→LUFL

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 06	
2	Initialize		[SBR] [CLR]	0.
	Freezing Levels:			
3	Enter temperature			
	If in °C	T (°C)	[A]	T (°C)
	If in °F	T (°F)	[2nd] [A′]	T (°C)
4	Enter altitude (ft)	ALT	[B]	ALT (ft)
5	Calculate freezing levels (in any order)		[C]	DFzL (ft)
			[D]	WFzL (ft)
6	For a new case, make changes as needed in Steps 3-4.			
	Lowest usable flight level:			
7	Enter altimeter setting (in Hg) and calculate LUFL	ASET	[E]	LUFL (ft)

NOTE: Both routines place calculator in fix 0 mode.

Example 1: If the air temperature is −7°C at 6500 feet, how high is the dry freezing level?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 06 [SBR] [CLR]	0.	Initialize
7	[+/−] [A]	−7.00	T (°C)
6500	[B]	6500.	ALT (ft)
	[C]	3000.	DFzL (ft)

Example 2: If the air temperature is 35° F at 1700 feet, what are the dry and wet freezing levels?

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 06 [SBR] [CLR]	0.	Initialize
35	[2nd] [A′]	1.67	T (°C)
1700	[B]	1700.	ALT (ft)
	[C]	2533.	DFzL (ft)
	[D]	2811.	WFzL (ft)

AV-06

Example 3: For altimeter settings of 29.92, 29.73, 30.12, and 29.11 (in Hg), find the corresponding lowest usable flight levels.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 06 [SBR] [CLR]	0.	Initialize
29.92	[E]	18000.	LUFL (ft)
29.73	[E]	18500.	LUFL (ft)
30.12	[E]	18000.	LUFL (ft)
29.11	[E]	19000.	LUFL (ft)

Register Contents

R_{00}	R_{05}	R_{10} T (°C)	R_{15}
R_{01}	R_{06}	R_{11} ALT	R_{16}
R_{02}	R_{07}	R_{12}	R_{17}
R_{03}	R_{08}	R_{13}	R_{18}
R_{04}	R_{09}	R_{14}	R_{19}

WIND COMPONENTS AND AVERAGE VECTOR

This program consists of two routines. Given a wind velocity and direction, an aircraft magnetic heading, and allowing for magnetic variation, the first routine calculates the tailwind and crosswind component vectors. And given several wind vectors along a flight path, the second routine calculates the approximate average wind vector for the entire flight path.

The tailwind (Tw) and crosswind (Cw) components are calculated using:

$$Tw = WV \cos (WD - MH - Var)$$

$$Cw = WV \sin (WD - MH - Var)$$

where a negative Tw indicates headwind and where

Cw = crosswind (+ Left, — Right)
WV = reported wind velocity
WD = reported wind direction
WH = aircraft magnetic heading
Var = magnetic compass heading (+ W, — E)

Note that surface winds reported by a control tower are magnetic, while all others are true. Therefore, when using this routine for take-off or landing, enter Var = 0. (See Examples 1 and 2.)

The approximate average wind vector is calculated by weighting each wind vector along the flight path in proportion to the distance it acts. Thus if $\vec{W}_i$ is a wind vector which acts along a distance D_i, then the total distance traveled is

$$\sum_{i=1}^{n} D_i$$

and the average wind vector is given by:

$$\vec{W}_{av} = \frac{\sum_{i=1}^{n} D_i \vec{W}_i}{\sum_{i=1}^{n} D_i}$$

The magnitude (WV_{av}) and the direction (WD_{av}) of $\vec{W}_{av}$ are displayed.

(See Example 3.)

	Solid State Software		TI ©1977	
WIND VECTORS				**AV-07**
Var (+W,−E)	WD	WV	MH	Dist
→Tw (+T,−H)	→Cw (+L,−R)		→WDav	→WVav

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 07	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.00[1]
	To calculate Tw and Cw			
4	Enter Var if applicable (see text)	Var	[2nd] [A']	Var
5	Enter wind direction	WD	[2nd] [B']	WD
6	Enter wind velocity	WV	[2nd] [C']	WV
7	Enter magnetic heading	MH	[2nd] [D']	MH
8	Calculate Tw		[A]	Tw (+ tail, − head)
9	Calculate Cw[2]		[B]	Cw (+ Lt, − Rt)
	To calculate an average vector do Step 3, then:			
10	Enter wind direction	WD	[2nd] [B']	WD
11	Enter wind velocity	WV	[2nd] [C']	WV
12	Enter distance	Dist	[2nd] [E']	Dist
13	To enter another wind vector, repeat Steps 10-12.			
14	Calculate WDav		[D]	WDav (deg)
15	Calculate WVav[3]		[E]	WVav

NOTES:
1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed − see Introduction.)
2. For another case, do Steps 4-7 as required for new values, then do Steps 8 and 9.
3. For a new case, do Step 3, then go to Step 10.
4. Program leaves calculator in fix 2 mode.

Example 1: An aircraft has a 210° magnetic heading at take-off. The control tower reports the wind as 22 knots and 260° (magnetic). What are the tailwind and crosswind components?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 07 [SBR] [CLR]	0.00	Initialize
0	[2nd] [A']	0.00	Var
260	[2nd] [B']	260.00	WD
22	[2nd] [C']	22.00	WV
210	[2nd] [D']	210.00	MH
	[A]	−14.14	Headwind (knots)
	[B]	−16.85	Rt. crosswind (knots)

Example 2: An aircraft is flying a magnetic heading of 300°. The winds aloft are reported as 35 knots at 110° (true). Magnetic variation is 15° East. What are the tailwind and crosswind components?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 07 [SBR] [CLR]	0.00	Initialize
15	[+/−] [2nd] [A']	−15.00	Var
110	[2nd] [B']	110.00	WD
35	[2nd] [C']	35.00	WV
300	[2nd] [D']	300.00	MH
	[A]	31.72	Tw
	[B]	−14.79	Rt. crosswind
	[A]	31.72	recall Tw

Example 3: Suppose the following wind conditions are reported along a flight path of 125° MH with Var = 13.5° E.

WV (knots)	WD°	Effective Along
30	145	50 (naut. mi.)
40	210	80
15	240	35

Compute the average wind vector along this path and then compute the component vectors.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 07 [SBR] [CLR]	0.00	Initialize
145	[2nd] [B']	145.00	WD
30	[2nd] [C']	30.00	WV
50	[2nd] [E']	50.00	Dist
210	[2nd] [B']	210.00	WD
40	[2nd] [C']	40.00	WV
80	[2nd] [E']	80.00	Dist
240	[2nd] [B']	240.00	WD
15	[2nd] [C']	15.00	WV
35	[2nd] [E']	35.00	Dist
	[D]	195.65	WD_{av}
	[E]	26.83	WV_{av}
	[2nd] [C']	26.83	Enter WV_{av}
	[D] [2nd] [B']	195.65	Enter WD_{av}
13.5	[+/−] [2nd] [A']	−13.50	Var
125	[2nd] [D']	125.00	MH
	[A]	−14.55	Headwind
	[B]	−22.54	Cw (Rt.)

Register Contents

R_{00}	Used	R_{05}	Var	R_{10}	WD_{av}	R_{15}	Used
R_{01}		R_{06}	WV	R_{11}	Dist	R_{16}	
R_{02}		R_{07}	WD	R_{12}	Cw	R_{17}	
R_{03}		R_{08}		R_{13}	tDist	R_{18}	
R_{04}		R_{09}	MH	R_{14}	Used	R_{19}	

THE WIND TRIANGLE

The wind triangle is a vector equation interrelating wind, air, and ground speed vectors.
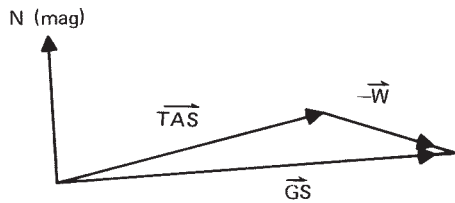
$$\vec{GS} = \vec{TAS} - \vec{W}$$

$$\text{or } (GS,MC) = (TAS,MH) - (WV,WD+Var)$$

where

$\vec{GS}$ is the vector with magnitude GS (ground speed) and direction MC (mag. course)

$\vec{TAS}$ is the vector with magnitude TAS (true air speed) and direction MH (mag. heading)

$\vec{W}$ is the vector with magnitude WV (wind velocity) and direction WD + Var (wind direction + mag. variation)

The true airspeed and magnetic heading are always entered. Then, given $\vec{W}$, $\vec{GS}$ will result. Or given $\vec{GS}$, $\vec{W}$ will result. By entering the leg distance and the times at the start and finish of the leg, the ground speed is automatically calculated and entered. Thus entering MC and $\vec{TAS}$ allows $\vec{W}$ to result. Further, if the magnetic wind direction is entered or desired, then Var should be entered as zero. If, however, the true wind direction is entered or desired, then the appropriate Var must be entered.

Note that if $\vec{TAS}$ and $\vec{GS}$ are given as average values over a flight path, the average wind vector for that path will result. (see AV1-06)

Remarks

This program can be used in conjunction with AV-09 (Dead Reckoning). See text of AV-09. Distance and speed units must be compatible within any one case; though knots and nautical miles are most often used.

	Solid State Software	TI © 1977
WIND TRIANGLE		**AV-08**

Var (+W,–E)	WD	WV	MH	TAS
[calc]→	MC	GS	Dist	t₁ , t₂

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 08	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.00^1
4	Enter magnetic variation[2]	Var (+W, –E)	[2nd] [A']	Var
5	Enter magnetic heading	MH (deg)	[2nd] [D']	MH
6	Enter true airspeed	TAS	[2nd] [E']	TAS
	To calculate wind direction and velocity:			
7	Enter magnetic course	MC (deg)	[B]	MC
	(Do Steps 8-10 or Step 11)			
8	Enter leg distance	Dist	[D]	Dist
9	Enter time at start of leg	t_1(HH.MMSS)	[E]	Ignore[3]
10	Enter time at end of leg[4]	t_2(HH.MMSS)	[E]	GS
11	Enter ground speed	GS	[C]	GS
12	Calculate wind direction		[A] [2nd] [B']	–1.00 WD (deg)
13	Calculate wind velocity		[A] [2nd] [C']	–1.00 WV
	To calculate magnetic course and ground speed:			
14	Enter wind direction	WD (deg)	[2nd] [B']	WD
15	Enter wind velocity	WV	[2nd] [C']	WV
16	Calculate magnetic course		[A] [B]	–1.00 MC (deg)
17	Calculate ground speed		[A] [C]	–1.00 GS

NOTES:

1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed – see Introduction.)
2. See text for proper usage.
3. Display shows Dist $\div$ ($R_{11} - t_1$).
4. To change t_1 or t_2, both must be reentered in proper order.
5. Program leaves calculator in fix 2 mode.

Example 1: You find that, in order to fly a magnetic course of 230°, you must fly a heading of 241°. From time 23:45:20 to time 0:11:38 a distance of 45 nmi has been flown. Given the magnetic variation of 11.5°E and a true airspeed of 105 knots, what is wind data for this leg?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 08 [SBR] [CLR]	0.00	Initialize
11.5	[+/−] [2nd] [A']	−11.50	Var
241	[2nd] [D']	241.00	MH
105	[2nd] [E']	105.00	TAS
230	[B]	230.00	MC
45	[D]	45.00	Dist
23.452	[E]	——	t₁ (ignore display)
.1138	[E]	102.66	t₂, display GS
	[A]	−1.00	calculate
	[2nd] [B']	330.33	WD
	[A]	−1.00	calculate
	[2nd] [C']	20.04	WV

Example 2: You are flying a heading of 178° at a true airspeed of 150 knots. The winds are reported as 32 knots at 263° (true), and the magnetic variation is 8.5° W. What is your groundspeed and magnetic course?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 08 [SBR] [CLR]	0.00	Initialize
8.5	[2nd] [A']	8.50	Var
263	[2nd] [B']	263.00	WD
32	[2nd] [C']	32.00	WV
178	[2nd] [D']	178.00	MH
150	[2nd] [E']	150.00	TAS
	[A]	−1.00	calculate
	[B]	166.13	MC
	[A]	−1.00	calculate
	[C]	155.27	GS

Register Contents

R_{00}	Used	R_{05}	Var	R_{10}	Dist	R_{15}	Used
R_{01}		R_{06}	WV	R_{11}	t	R_{16}	
R_{02}		R_{07}	WD	R_{12}		R_{17}	GS
R_{03}		R_{08}	TAS	R_{13}		R_{18}	TC
R_{04}		R_{09}	MH	R_{14}	Used	R_{19}	MC

DEAD RECKONING

Given the latitude, longitude, and time at the starting position, along with the true course and ground speed, this program calculates the latitude and longitude of the aircraft at a later time by dead reckoning. The following are applied:
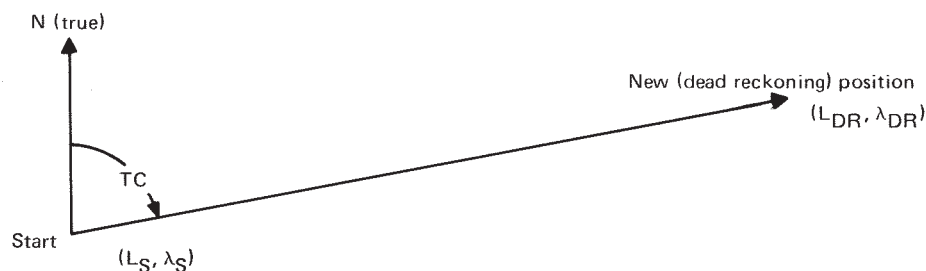
$$L_{DR} = \left(\frac{\Delta t \times GS \times \cos(TC)}{60} \right) + L_S$$

If TC = 90° or 270°,

then

$$\lambda_{DR} = \lambda_S - \left(\frac{\Delta t \times GS \times \sin(TC)}{60 \cos L_S} \right)$$

otherwise

$$\lambda_{DR} = \lambda_S - \frac{180}{\pi} \left[\tan(TC) \times \left(\ln \tan(45° + \tfrac{1}{2} L_{DR}) - \ln \tan(45° + \tfrac{1}{2} L_S) \right) \right]$$

where

TC = true course
L_S = latitude of start
λ_S = longitude of start
Δt = time between positions
t_S = time at start
t_{DR} = time at dead reckoning position
L_{DR} = latitude of dead reckoning position
λ_{DR} = longitude of dead reckoning position

Limitations: The flight path may not cross a pole.
The program loses accuracy within 0.5° of a pole.

The effects of wind may be taken into account by using this program in conjunction with AV-08 (Wind Triangle). First use AV-08 to compute the magnetic course and ground speed. (This will place true course and ground speed in the appropriate registers for the Dead Reckoning program.) Then select the Dead Reckoning program and perform steps 3—6 and 9—11 (see Example 2).

The user will note that the single keystroke [A] transfers the calculated dead reckoning position to the starting position for a new leg, thus greatly simplifying multiple-leg calculations (see Example 1).

⟨TI⟩ Solid State Software	TI ©1977				
DEAD RECKONING					**AV-09**
ts	λs(+W,−E)			tDR	→λDR(+W,−E)
[DR→S]	Ls(+N,−S)	TC		GS	→LDR(+N,−S)

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 09	
2	Select degree mode		[2nd] [Deg]	
3	Initialize[1]		[SBR] [CLR]	0.0000
4	Enter time at start	t_S (HH.MMSS)	[2nd] [A']	t_S (decimal)
5	Enter starting latitude (+N, −S)	L_S (DD.MMSS)	[B]	L_S (decimal)
6	Enter starting longitude (+W, −E)	λ_S (DDD.MMSS)	[2nd] [B']	λ_S (decimal)
7	Enter true course	TC	[C]	TC
8	Enter ground speed	GS (knots)	[D]	GS
9	Enter time of dead reckoning position[2]	t_{DR} (HH.MMSS)	[2nd] [D']	t_{DR} (decimal)
10	Compute latitude (+N, −S)		[E]	L_{DR} (DD.MMSS)
11	Compute longitude (+W, −E)[3,4]		[2nd] [E']	λ_{DR} (DDD.MMSS)
12	DR → S (if required)[5]		[A]	0.0000

NOTES: 1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed — see Introduction.)

2. Steps 4-9 may be performed in any order.

3. Steps 10 and 11 may be performed in either order.

4. To compute a new position at a later time along the same course and speed, go to Step 9 and continue.

5. To use (L_{DR}, λ_{DR}) as the starting position for a new leg, do Step 12, then go to Step 7 and continue.

6. Program leaves calculator in fix 4 mode.

Register Contents

R_{00}	Used	R_{05}	Var	R_{10}	Dist	R_{15}	t_{DR}
R_{01}	L_S	R_{06}		R_{11}		R_{16}	Used
R_{02}	λ_S	R_{07}		R_{12}		R_{17}	GS
R_{03}	L_{DR}	R_{08}		R_{13}		R_{18}	TC
R_{04}	λ_{DR}	R_{08}		R_{14}	t_s	R_{19}	

Example 1: At 23:10:00 your aircraft is at 35° 17′ S, 176° 32′ W. You fly a true course of 282° at a groundspeed of 250 knots until 3:10:00 the next day. Then you change course to 170° and groundspeed is reduced to 200 knots. What is your position at 4:15:00?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 09 [SBR] [CLR]	0.0000	Initialize
23.1	[2nd] [A′]	23.1667	t_S (decimal)
35.17	[+/−] [B]	−35.2833	L_S
176.32	[2nd] [B′]	176.5333	λ_S
282	[C]	282.0000	TC
250	[D]	250.0000	GS
3.1	[2nd] [D′]	3.1667	t_{DR} (decimal)
	[E]	−31.4905	L_{DR} (DD.MMSS)
	[2nd] [E′]	−163.5359	λ_{DR} (DDD.MMSS)
	[A]	0.0000	DR $\overset{\rightarrow}{}$ s
170	[C]	170.0000	TC
200	[D]	200.0000	GS
4.15	[2nd] [D′]	4.2500	t_{DR} (decimal)
	[E]	−35.2228	L_{DR} (DD.MMSS)
	[2nd] [E′]	−164.3909	λ_{DR} (DDD.MMSS)

Example 2: You have been flying a magnetic heading of 247° at a true airspeed of 100 knots. Your position at 5:15 was 35° 31′ N, 95° 12′ W. The winds are reported as 173° (true) at 34 knots. Magnetic variation is 10° E. What is your position at 6:00?

Use AV-08 (Wind Triangle)

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 08 [SBR] [CLR]	0.00	Initialize
10	[+/−] [2nd] [A′]	−10.00	Var
173	[2nd] [B′]	173.00	WD
34	[2nd] [C′]	34.00	WV
247	[2nd] [D′]	247.00	MH
100	[2nd] [E′]	100.00	TAS
	[A]	−1.00	Calculate
	[B]	266.32	MC
	[A]	−1.00	Calculate
	[C]	102.20	GS

Use Dead Reckoning Program

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 09 [SBR] [CLR]	0.0000	Initialize
5.15	[2nd] [A′]	5.2500	t_S (decimal)
35.31	[B]	35.5167	L_S (decimal)
95.12	[2nd] [B′]	95.2000	λ_S (decimal)
6	[2nd] [D′]	6.0000	t_{DR} (decimal)
	[E]	35.3926	L_{DR} (DD.MMSS)
	[2nd] [E′]	96.4541	λ_{DR} (DDD.MMSS)

RHUMBLINE NAVIGATION

This program calculates the rhumbline course between two points on the earth's surface. The rhumb line connecting two points is that one which makes the same oblique angle to all meridians. While not always the shortest route, flying a rhumbline course has the advantage of allowing the pilot to maintain a single course. (See text Note of AV-04.)

Inputs for the program are the latitude and longitude of two points (start and destination), and magnetic variation. Outputs are the true course, magnetic course, distance along the rhumb line, and cumulative distance for several legs. The single keystroke [A] causes the destination coordinates for the present leg to become the start coordinates for the succeeding leg, thus facilitating multiple-leg computations. The following equations are used:
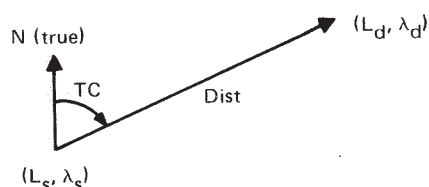
$$\tan TC = \left[\frac{\pi\,(\lambda_s - \lambda_d)}{180\,\left(\ln \tan\,(45 + \tfrac{1}{2} L_d) - \ln \tan\,(45 + \tfrac{1}{2} L_s)\right)} \right]$$

$$MC = TC + Var \qquad\qquad tot\ Dist = \Sigma\ Dist$$

$$Dist = \begin{cases} 60\,|(\lambda_d - \lambda_s)\cos L_s\,| & \text{if } \cos TC = 0 \\[2ex] 60\,\left|\dfrac{L_d - L_s}{\cos TC}\right| & \text{otherwise} \end{cases}$$

where

L_s = latitude of start	MC = magnetic course
λ_s = longitude of start	TC = true course
L_d = latitude of destination	Var = magnetic variation
λ_d = longitude of destination	Dist = distance of leg

Limitations: A flight path may not cross a pole.
Program loses accuracy near the poles, or for legs shorter than about 3 miles.

	Solid State Software	TI ©1977
RHUMBLINE NAVIGATION		AV-10
Var (+W,−E)	λ_s (+W,−E)	λ_d (+W,−E)	[calc]→	→ tot Dist
[d→s]	L_s (+N,−S)	L_d (+N,−S)	→TC ; MC	→Dist

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 10	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.00[1]
4	Enter mag. variation (if needed)[2]	Var (deg)	[2nd] [A']	Var
5	a. Enter latitude of start[3] b. Enter longitude of start[2]	L_s(DD.MMSS) λ_s(DDD.MMSS)	[B] [2nd] [B']	L_s (deg) λ_s (deg)
6	a. Enter latitude of destination[3] b. Enter longitude of destination[2]	L_d(DD.MMSS) λ_d(DDD.MMSS)	[C] [2nd] [C']	L_d (deg) λ_d (deg)
7	Calculate results		[2nd] [D']	0.00
8	a. Display true course b. Display magnetic course (optional)		[D] [R/S]	TC (deg) MC (deg)
9	Display distance		[E]	Dist (n. mi.)
10	Display total distance[4]		[2nd] [E']	tot Dist
11	For multiple legs, make (L_d, λ_d) the new (L_s, λ_s), then do Steps 4, 6−10.		[A]	0.00

NOTES: 1. Initialization selects degree mode. (Step 2 is seldom needed — see Introduction.)

2. (+W, −E).

3. (+N, −S).

4. Steps 8-10 may be performed in any order.

5. Program leaves calculator in fix 2 mode.

Example 1: You wish to fly between the following points:
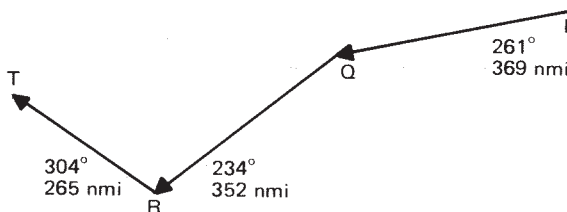
	L		λ		
P	33° 20' 16''	N	171°	W	start
Q	32° 25'	N	178° 13' 56''	W	
R	29°	N	176° 12' 42''	E	
T	31° 27'	N	171° 58'	E	destination

Find the distance and true course for each leg, and total distance.

AV-10

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 10 [SBR] [CLR]	0.00	Initialize
(Leg PQ)			
33.2016	[B]	33.34	L_s
171	[2nd] [B']	171.00	λ_s
32.25	[C]	32.42	L_d
178.1356	[2nd] [C']	178.23	λ_d
	[2nd] [D']	0.00	Calculate
	[D]	261.38	TC (decimal)
	[E]	368.59	Dist (n. mi.)
(Leg QR)			
	[A]	0.00	$d \xrightarrow{} s$
29	[C]	29.00	L_d
176.1242	[+/−] [2nd] [C']	−176.21	λ_d
	[2nd] [D']	0.00	Calculate
	[D]	234.42	TC (decimal)
	[E]	352.33	Dist
	[2nd] [E']	720.92	tot Dist
(Leg RT)			
	[A]	0.00	$d \xrightarrow{} s$
31.27	[C]	31.45	L_d
171.58	[+/−] [2nd] [C']	−171.97	λ_d
	[2nd] [D']	0.00	Calculate
	[D]	303.74	TC (decimal)
	[E]	264.63	Dist
	[2nd] [E']	985.55	tot Dist

Example 2: A pilot must fly from (32° 20′ N, 111° W) to (32° 25′ N, 108° 35′ W). The magnetic variation is 13° E. Find his true course, magnetic course, and distance flown.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 10 [SBR] [CLR]	0.00	Initialize
13	[+/−] [2nd] [A']	−13.00	Var
32.2	[B]	32.33	L_s
111	[2nd] [B']	111.00	λ_s
32.25	[C]	32.42	L_d
108.35	[2nd] [C']	108.58	λ_d
	[2nd] [D']	0.00	Calculate
	[D]	87.66	TC (decimal)
	[R/S]	74.66	MC (decimal)
	[E]	122.56	Dist (n. mi.)

Register Contents

R_{00}	Used	R_{05}	Var	R_{10}	Used	R_{15}	
R_{01}	L_s	R_{06}	TC	R_{11}	Used	R_{16}	
R_{02}	λ_s	R_{07}	$\lambda_s - \lambda_d$	R_{12}		R_{17}	
R_{03}	L_d	R_{08}	Dist	R_{13}		R_{18}	
R_{04}	λ_d	R_{09}	tot Dist	R_{14}		R_{19}	

GREAT CIRCLE FLYING

A great circle is defined as "the line of intersection of the earth's surface and a plane through the center of the earth." Since only one plane passes through any two points on the surface of the earth and the center of the earth, only one great circle passes through any two points on the surface (unless they are 180° opposed). The equator and meridians are great circles. But the practical benefit is that the great circle route between two points is the shortest possible (all other things being equal). However, to fly a great circle requires continual course changes. Thus, it is usually best to approximate a great circle route by flying several rhumbline courses between intermediate points along the great circle route.

This program, given the coordinates of start and destination, calculates: 1) the great circle distance between them, 2) the initial true course to fly if the route is to be attempted, and 3) the vertex, or the point with the highest latitude (north or south) along the great circle route. Of even greater interest is the program's ability to calculate any intermediate point along the route given the longitude at which that point is to be calculated.[1] (For instance, it may be feasible to change course at 1° increments of longitude.)
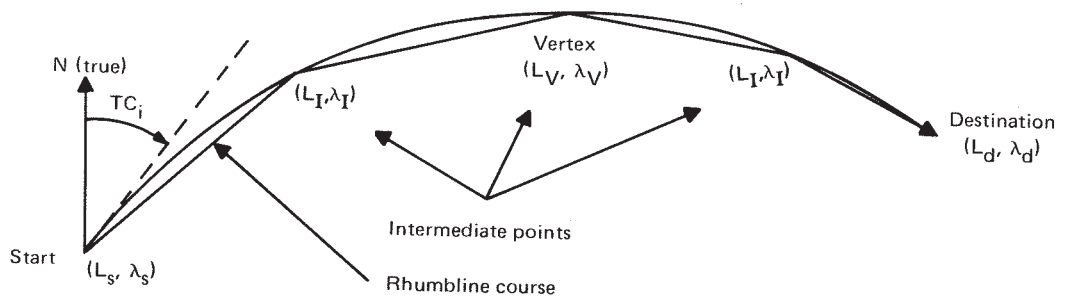
The following equations are used:

$$\text{Dist} = 60 \ \text{arccos} \ [\sin L_s \sin L_d + \cos L_s \cos L_d \cos (\lambda_d - \lambda_s)]$$

$$TC_i = \text{arccos} \left[\frac{\sin L_d - \sin L_s \cos (\text{Dist}/60)}{\sin (\text{Dist}/60) \cos L_s} \right] \quad \begin{array}{l} [\text{if } \sin (\lambda_d - \lambda_s) < 0 \\ \quad \text{then } (360° - TC_i) \text{ is used}] \end{array}$$

$$L_I = \text{arctan} \left[\frac{\tan L_d \sin (\lambda_I - \lambda_s) - \tan L_s \sin (\lambda_I - \lambda_d)}{\sin (\lambda_d - \lambda_s)} \right]$$

$$\lambda_v = \lambda_s - \text{arctan} \left(\frac{1}{\tan TC_i \sin L_s} \right)$$

where

L_s = latitude of start
λ_s = longitude of start
L_d = latitude of destination
λ_d = longitude of destination
Dist = great circle distance between start and destination

TC_i = initial true course for great circle route
L_I = latitude of intermediate point
λ_I = longitude of intermediate point
L_v = latitude of vertex
λ_v = longitude of vertex

Limitations: This program will not work if the great circle defined by start and destination is a meridian (passes through the poles). That is, λ_s may not equal λ_d. Nor may start and destination be at diametrically opposite points on the earth. Coordinates of the vertex cannot be calculated if the starting point lies on the equator.

Notes:

1. The most efficient means of flying a rhumbline approximation is to obtain a series of intermediate points along the great circle route, and then use these in AV1-09 (Rhumbline Navigation) to obtain more complete information.
2. Only one of the vertices is computed. The other is at $(- L_v, \lambda_v + 180°)$.
3. The great circle crosses the equator at $\lambda_v + 90°$ and at $\lambda_v - 90°$.

Reference: Bowditch, *American Practical Navigator*, Defense Mapping Agency Hydrographic Center, 1975, pp. 443, 582-3.

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GREAT CIRCLE FLYING				**AV-11**
λ_s (+W,−E)	λ_d (+W,−E)		→TC$_i$	
L$_s$ (+N,−S)	L$_d$ (+N,−S)	λ→L ($_I$ or $_v$)	→Dist	→λ_v

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 11	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.0000[1]
4	Enter starting latitude	L$_s$ (+N, −S) (DD.MMSS)	[A]	L$_s$ (deg)
5	Enter starting longitude	λ_s (+W, −E) (DDD.MMSS)	[2nd] [A′]	λ_s (deg)
6	Enter latitude of destination	L$_d$ (+N, −S) (DD.MMSS)	[B]	L$_d$ (deg)
7	Enter longitude of destination	λ_d (+W, −E) (DDD.MMSS)	[2nd] [B′]	λ_d (deg)
8	Compute Dist		[D]	Dist (n. mi.)
9	Compute TC$_i$		[2nd] [D′]	TC$_i$ (deg)
	To calculate coordinates of vertex, do Steps 10 and 11			
10	Compute longitude of vertex		[E]	λ_v (DDD.MMSS)[3]
11	Compute latitude of vertex		[C]	L$_v$ (DD.MMSS)
	To compute latitude corresponding to an intermediate longitude, do Step 12			
12	Enter longitude	λ_I (DDD.MMSS)	[C]	L$_I$ (DD.MMSS)
	(Repeat for each intermediate point)			
13	For another case, go to Step 4			

NOTES: 1. Initializaiton selects degree mode. (Step 2 is seldom needed − see Introduction.)

2. Program leaves calculator in fix 4 mode.

3. If $\lambda_v > 180$ use $\lambda_v - 360$.

Example: Find the great circle distance and initial true course
from 30° 23' 40" S, 18° 08' 17" W
to 35° 17' 36" S, 175° 49' 30" E.
Also find the coordinates of a vertex, and the latitude of the point on the circle at 150° W.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 11 [SBR] [CLR]	0.0000	Initialize
30.234	[+/−] [A]	−30.3944	L_s
18.0817	[2nd] [A']	18.1381	λ_s
35.1736	[+/−] [B]	−35.2933	L_d
175.493	[+/−] [2nd] [B']	−175.8250	λ_d
	[D]	6780.6524	Dist (n. mi.)
	[2nd] [D']	192.3553	TC_i
150	[C]	−74.1609	$\lambda_I \rightarrow L_I$
	[E]	101.4850	λ_v
	[C]	−79.2151	L_v

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	L_s	R_{06}	TC	R_{11}		R_{16}	
R_{02}	λ_s	R_{07}	λ_I	R_{12}		R_{17}	
R_{03}	L_d	R_{08}	Dist/60	R_{13}		R_{18}	
R_{04}	λ_d	R_{09}		R_{14}		R_{19}	

LINE-OF-SIGHT DISTANCE AND ALTITUDE
DME SPEED CORRECTION

As suggested by the title, this program consists of two routines each independent of the other. They are considered separately.

Line-of-Sight Distance and Altitude

Given the altitude of a transmitter station (Trans), the maximum altitude of the terrain between the transmitter and an aircraft (Terr), and the aircraft altitude (ALT), (all in feet above mean sea level), this routine calculates the line-of-sight distance from the aircraft to the station (Dist) (in nautical miles) when the aircraft is at the minimum altitude required to receive the signal. Conversely, given Terr, Trans, and Dist, the routine calculates the minimum ALT needed to receive the signal.
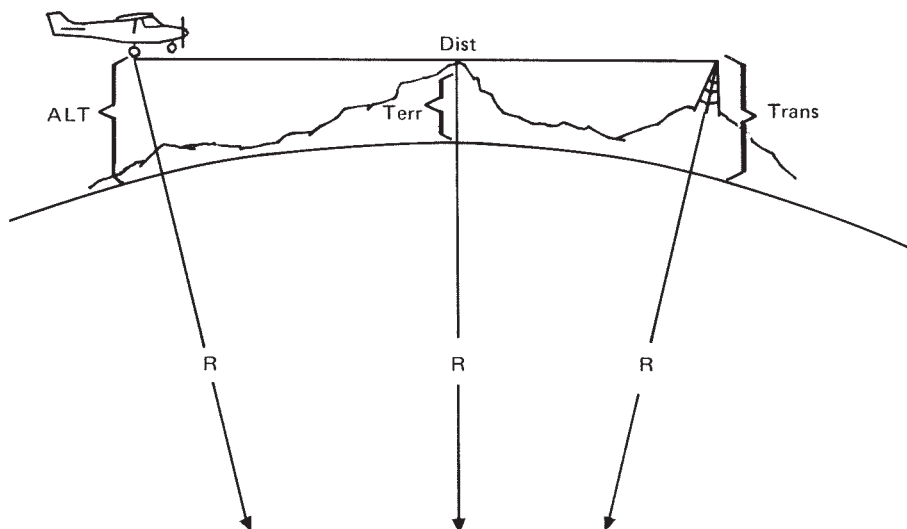
The following equations are used:

$$\text{Dist} = \sqrt{(R + ALT)^2 - (R + Terr)^2} + \sqrt{(R + Trans)^2 - (R + Terr)^2}$$

$$\text{ALT} = \sqrt{(R + Terr)^2 + \left(\text{Dist} - \sqrt{(R + Trans)^2 - (R + Terr)^2}\right)^2} - R$$

where:

R = earth's radius = 3440 n. mi. = 2.090144×10^7 feet

The formulas assume that the radial from the center of the earth to the point of highest terrain is perpendicular to the line-of-sight. If this is not actually the case, then Dist calculated will be slightly shorter than the actual distance, or ALT will be slightly higher than necessary. In any event, this routine yields the *worst case result.*

Limitations: *Display will flash if Terr > ALT or Trans.* Refraction of radio waves is not accounted for; in most cases, this will be significant. (See Example 1)

DME Speed Correction

Given the magnetic course (MC), the DME speed indicator reading (DMEsp), and the radial to or from the DME station (R_{DME}), this routine computes the ground speed (GS). The DME speed indicator measures the component of the aircraft ground velocity vector in the direction of the radial between aircraft and station:
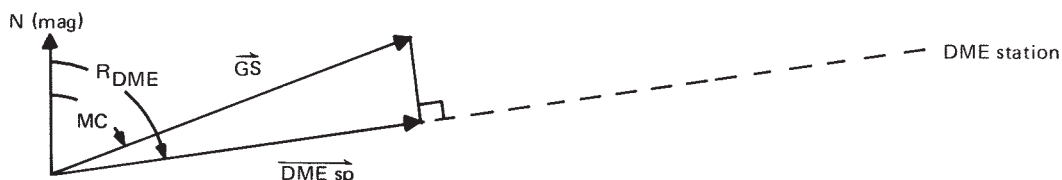
where:

$\vec{GS}$ is the vector with magnitude GS and direction MC

and $\vec{DMEsp}$ is the vector with magnitude DMEsp and direction R_{DME}.

The solution is given by:

$$GS = \frac{DMEsp}{|\cos(R_{DME} - MC)|}$$

One may correct for the altitude of the aircraft if desired, although this is not necessary unless the station is very close or the aircraft very high.

$$GS' = \frac{GS\sqrt{\Delta h^2 + Dist_{DME}^2}}{Dist_{DME}}$$

where:

GS' = ground speed corrected for altitude (knots)

Δh = difference between aircraft and station altitude (feet above MSL)

and $Dist_{DME}$ = distance from aircraft to station (n. mi.) (See Example 2)

Limitations: A magnetic course perpendicular to R_{DME}, that is MC = $R_{DME} \pm 90°$, will cause display to flash. For accurate results, $|R_{DME} - MC|$ should be less than 60°.

LINE OF SIGHT; DME SPEED AV-12

MC	R$_{DME}$	DME$_{SP}$ → GS	Dist$_{DME}$	Δh → GS'
Terr	Trans	ALT	Dist	[calc]→

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 12	
2	Select degree mode[1]		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.
	For all line-of-sight distance or altitude:			
4	Enter altitude of terrain (MSL)	Terr (ft)	[A]	Terr
5	Enter transmitter altitude (MSL)	Trans (ft)	[B]	Trans
	To calculate line-of-sight distance given ALT:			
6	Enter aircraft altitude (MSL)	ALT (ft)	[C]	ALT
7	Compute line-of-sight distance		[E] [D]	Dist (n. mi.)
	To calculate ALT given line-of-sight distance:			
8	Enter line-of-sight distance	Dist (n. mi.)	[D]	Dist
9	Compute minimum altitude required		[E] [C]	ALT (ft)
	To compute ground speed from DME speed reading:			
10	Enter magnetic course	MC (deg)	[2nd] [A']	MC
11	Enter radial to (or from) the DME station	R$_{DME}$ (deg)	[2nd] [B']	R$_{DME}$
12	Enter DMEsp and calculate ground speed	DMEsp (knots)	[2nd] [C']	GS (knots)
	To correct for aircraft altitude:			
13	Enter distance to DME station	Dist$_{DME}$ (n. mi.)	[2nd] [D']	Dist$_{DME}$
14	Enter difference between aircraft and DME station altitude and compute corrected ground speed	Δh (ft)	[2nd] [E']	GS' (knots)

NOTES: 1. Step 2 is necessary if you have selected another angular mode since turning on your calculator.

2. Program places calculator in fix 0 mode.

Example 1: An omnidirectional broadcasting antenna is 5700 feet above MSL. The terrain between your flight path and the antenna is 5500 feet above MSL at its highest point. Above what altitude must you fly to be assured of receiving the transmission as far as 90 n. mi. away?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 12 [SBR] [CLR] †	0.	Initialize
5500	[A]	5500.	Terr
5700	[B]	5700.	Trans
90	[D]	90.	Dist
	[E] [C]	10459.	ALT (ft)

The line-of-sight altitude is 10,459 ft., but your aircraft is only capable of a 9,000-foot ceiling. At this altitude, what is the maximum distance you might expect to receive transmission?

*5500	[A]	5500.	Terr
5700	[B]	5700.	Trans
9000	[C]	9000.	ALT
	[E] [D]	78.	Dist

*(This procedure is identical to the solution of the following problem: A pilot begins to receive signals from a station at 9000 ft. Given the above Terr and Trans, what is his approximate distance from the station?)

Example 2: An aircraft flying a magnetic course of 215° is receiving signals from a DME station bearing 172°, with an indicated DME speed of 117 knots. What is his (uncorrected) ground speed?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 12 [SBR] [CLR] †	0.	Initialize
215	[2nd] [A′]	215.	MC
172	[2nd] [B′]	172.	R_{DME}
117	[2nd] [C′]	160.	DMEsp → GS

The aircraft is 12,000 ft. above MSL and 4 n. mi. from the station. Find the corrected ground speed.

4	[2nd] [D′]	4.	$Dist_{DME}$
12000	[2nd] [E′]	178.	$\Delta h → GS'$

Register Contents

|							
R_{00}	ALT	R_{05}		R_{10}	Dist	R_{15}	Terr
R_{01}		R_{06}		R_{11}	$(R + ALT)^2$	R_{16}	Trans
R_{02}		R_{07}		R_{12}	$(R + Terr)^2$	R_{17}	GS
R_{03}		R_{08}		R_{13}	$(R + Trans)^2$	R_{18}	MC
R_{04}		R_{09}		R_{14}	R_{DME}	R_{19}	6076

†Make sure your calculator is in the degree mode.

POSITION AND NAVIGATION BY ONE VOR

The radial from the VOR to the aircraft is read at time t_1, and again at time t_2. Then given the windage, magnetic heading, true airspeed, and the radial and distance from the VOR to the aircraft's destination, this program computes the distance from the VOR to the aircraft at t_2, and the magnetic course and distance from the aircraft to the destination at t_2.

The ground speed is computed using windage, magnetic heading, and true airspeed, and may in turn be used to determine ETA (or a different value may be used if desired).

The following equations are used:

$$\overrightarrow{GS} = \overrightarrow{TAS} - \overrightarrow{W}$$
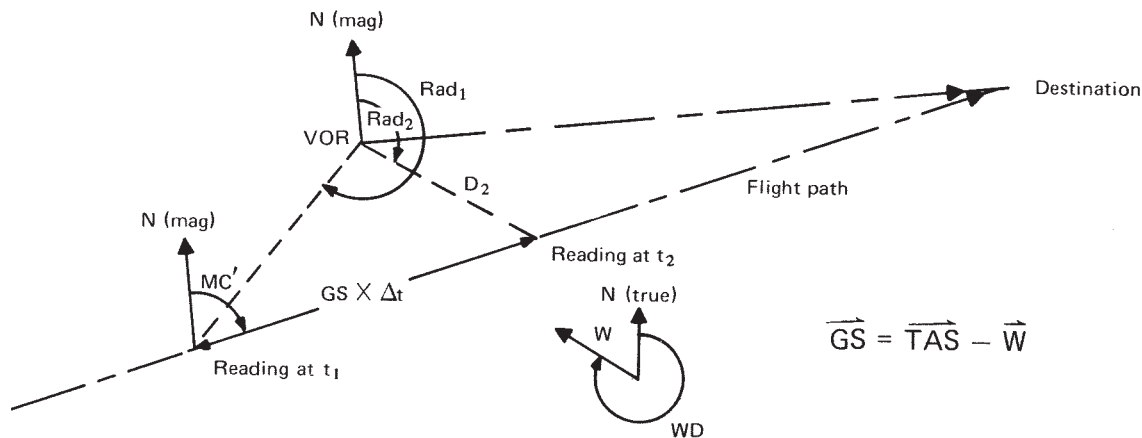
where

$\overrightarrow{GS}$ = the vector with magnitude GS (ground speed) and direction MC' (magnetic course from t_1 to t_2)

$\overrightarrow{TAS}$ = the vector with magnitude TAS (true airspeed) and direction MH (magnetic heading from t_1 to t_2)

$\overrightarrow{W}$ = the vector with magnitude WV (wind velocity) and direction WD (wind direction true) + Var (magnetic variation)

$$D_2 = \left| \frac{(GS \times \Delta t) \times \sin(MC' - Rad\ 1)}{\sin(Rad\ 2 - Rad\ 1)} \right|$$

where
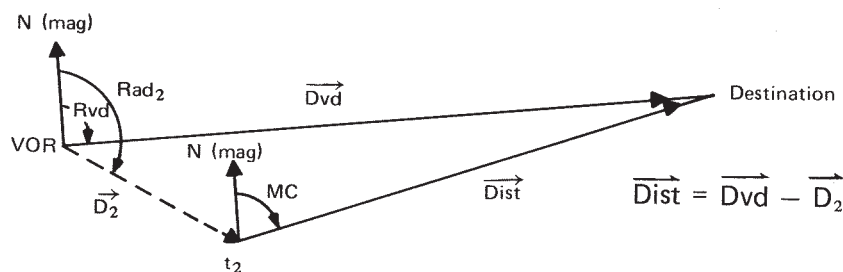
D_2 = distance of aircraft from VOR at t_2

$\Delta t = t_2 - t_1$

Rad 1 = radial from VOR to aircraft at t_1

Rad 2 = radial from VOR to aircraft at t_2

$GS \times \Delta t$ = distance from t_1 to t_2

Once D_2 has been computed (or found with a DME), the magnetic course and distance to the destination may be determined as follows:

$$\overrightarrow{Dist} = \overrightarrow{Dvd} - \overrightarrow{D_2}$$

where

$\overrightarrow{Dist}$ = vector with magnitude Dist (distance from t_2 to destination) and direction MC (magnetic course from t_2 to destination)

$\overrightarrow{Dvd}$ = vector with magnitude Dvd (distance from VOR to destination) and direction Rvd (radial from VOR to destination)

$\overrightarrow{D_2}$ = vector with magnitude D_2 and direction Rad 2

Limitation:

1. Due to the inherent error in determining VOR radials, the difference between Rad 1 and Rad 2 should be *at least* 10° for accurate results. Time should be determined to the nearest second.

2. Δt must be less than 24 hours.
   (ETA − t_2) must be less than 24 hours.

AV-13

	Solid State Software	TI ©1977
POSITION/NAVIGATION — ONE VOR		AV-13

Var (+W,−E)	WD , WV	RVD , DVD	MH	TAS
t₁ , t₂	Rad 1 , Rad 2	→D₂	D₂→MC; Dist	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 13	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.0000[1]
4[2]	Enter magnetic variation (+W, −E)	Var (deg)	[2nd] [A′]	Var
5	Enter wind direction and velocity (in that order)[3]	WD (deg) WV	[2nd] [B′] [2nd] [B′]	Prev WD Prev WV
6[4]	Enter the radial and distance from the VOR to the destination (in that order)	Rvd (deg) Dvd	[2nd] [C′] [2nd] [C′]	Prev Rvd Prev Dvd
7	Enter magnetic heading	MH (deg)	[2nd] [D′]	MH
8	Enter true airspeed	TAS	[2nd] [E′]	TAS
9	Enter time of first radial reading[3]	t₁ (HH.MMSS)	[A]	t₁ (hours)
10	Enter radial from the VOR to the aircraft[3] (first reading)	Rad 1 (deg)	[B]	Rad 1
11	Enter time of second radial reading[3]	t₂ (HH.MMSS)	[A]	t₂ (hours)
12	Enter radial from the VOR to the aircraft[3] (second reading)	Rad 2 (deg)	[B]	Rad 2
13	Compute distance between VOR and aircraft at t₂		[C]	D₂
14a[4]	With D₂ in the display, press [D] to display magnetic course to destination. If D₂ is not in display, key it in and press [D]	D₂	[D]	MC (deg)
14b	Calculate distance to destination		[R/S]	Dist
14c	Calculate ground speed		[R/S]	GS
14d	Enter GS (if different from 14c) and calculate ETA	GS (optional)	[R/S]	ETA
15	For a new case where the old second reading is the new first reading, go to Step 11 and continue.			

NOTES:
1. Initialization uses [CMs] and selects degree mode. (Step 2 is seldom needed — see Introduction.)
2. If DME is available, then it may be used to measure the distance to the VOR. In this case, only Steps 11, 12, and 14 need be performed to obtain desired results.
3. To change either WD or WV, *both* must be reentered in that order. The same applies for the following data pairs: Rvd and Dvd, t₁ and t₂, Rad 1 and Rad 2.
4. If only D₂ is desired, Steps 6 and 14 may be omitted.
5. Program leaves calculator in fix 4 mode.

Example 1: You are piloting an aircraft and receiving a signal from one VOR. The windage is 197° true at 23 knots. Magnetic variation is 14°E. You have determined the radial from the VOR to your destination as 057° and distance as 72 n. mi. Your magnetic heading is 042° at 124 knots. At 9:27:11, the radial from the VOR is 172°. At 10:04:27, the radial is 092°.

First, find your distance from the VOR at 10:04:27; then find magnetic course and distance to destination, your ground speed, and ETA.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 13 [SBR] [CLR]	0.0000	Initialize
14	[+/−] [2nd] [A′]	−14.0000	Var
197	[2nd] [B′]	0.0000[1]	WD
23	[2nd] [B′]	0.0000[1]	WV
57	[2nd] [C′]	0.0000[1]	Rvd
72	[2nd] [C′]	0.0000[1]	Dvd
42	[2nd] [D′]	42.0000	MH
124	[2nd] [E′]	124.0000	TAS
9.2711	[A]	9.4531[2]	t_1
172	[B]	172.0000	Rad 1
10.0427	[A]	10.0742[2]	t_2
92	[B]	92.0000	Rad 2
	[C]	62.6771	D_2
	[D]	356.8829	MC to destination
	[R/S]	41.4628	Dist to destination
	[R/S]	142.6108	GS
	[R/S]	10.2154	ETA at destination

REMARKS:

1. The previous value entered will be displayed. Usually, the display should be ignored.
2. t_1 and t_2 are displayed as decimal hours.

Example 2: You have a DME aboard, and you are receiving a signal from one VOR. The radial from the VOR to your destination is 123° and distance is 84 n. mi. You estimate ground speed will be 120 knots for the remainder of the flight. (AV-12 is useful here.)

At 14:00:00, the radial from the VOR is 220°, and the DME indicates that its distance is 32 n. mi. What is the magnetic course and distance to your destination, and ETA?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 13 [SBR] [CLR]	0.0000	Initialize
123	[2nd] [C′]	0.0000[1]	Rvd
84	[2nd] [C′]	0.0000[1]	Dvd
14	[A]	14.0000[2]	t
220	[B]	220.0000	Rad
32	[D]	103.1333	D_2 → MC to dest.
	[R/S]	93.4621	Dist to destination
	[R/S]	0.0000[1]	Previous GS
120	[R/S]	14.4644	GS → ETA

REMARKS:

1. The previous value entered will be displayed. Usually, the display should be ignored.
2. t_1 and t_2 are displayed as decimal hours.

Register Contents

R_{00}	Used	R_{05}	Var	R_{10}	Rad 1	R_{15}	t
R_{01}		R_{06}	WV	R_{11}	Rad 2	R_{16}	
R_{02}		R_{07}	WD	R_{12}		R_{17}	GS
R_{03}	Dvd	R_{08}	TAS	R_{13}	Used	R_{18}	
R_{04}	Rvd	R_{09}	MH	R_{14}	Δt	R_{19}	

AREA NAVIGATION

The Area Navigation package consists of three programs: Area Nav Load Module (AV-15); VOR Area Nav (AV-16); and DME Area Nav (AV-14). The Load Module program is used to load position information into your calculator's data registers for use in the VOR and DME Area Nav programs. The Load Module can handle numerous* waypoints which may be VOR's or other geographic fixes, and can 1) load the data registers directly, or 2) store the information on a blank Flight Data card. These Flight Data cards are particularly useful in that several may be recorded for a large area, and simply reading one will load the data registers with the information necessary to navigate in that section of the area.

The VOR and DME Area Nav programs do the real work of the set. While similar, the choice between them is based on the type of equipment you have. Both use the same input data, and both programs compute distance to go, magnetic course, GS, and ETA to a specified waypoint.

ATTENTION!

Particular care must be taken by the pilot to ensure that he is thoroughly familiar with the operation of these programs before inflight use, especially in single-pilot or IFR situations. Mounting the calculator to a knee-board or a solid base is advisable, and key entries should be made in small segments with adequate attention to other aviation and navigation tasks between keystrokes. Use of the accessory 12-volt charger is highly recommended.

Area Nav Load Module

The programs are based on prestored geographical positions (referred to as 'waypoints') which may be navigational aids (VOR, ADF Radio Beacon, etc.), fixes (intersections, landmarks, obstacles, etc.), or other geographical locations (airports, towns, etc. . . .) that may be located relative to each other. Each waypoint is stored so that it may be referred to by a number designation (0, 1, 2, . . ., N*). The radials supplied by on-board VOR receivers give the pilot a means of accurately locating his aircraft in relation to those points, and by extension, in relation to other waypoints.

The general method is based on selection of an arbitrary point (waypoint "0" with coordinates (0, 0)) as the origin of a network of other defined waypoints (numbered 1–N). These waypoints are defined by their magnetic bearing and distance from either waypoint 0 or any previously defined waypoint (see Remark 1).

To use the Load Module, select suitable charts which cover the area of interest and choose the navigational aids you wish to store as waypoints. At least two of these must be VOR stations. (Actually, one or both could be radio beacons if ADF readings were used and converted to *magnetic bearing from the station.*) It is desirable to define waypoints for departure, destination, and

---

*The actual number of waypoints that the load module may handle depends upon the partitioning of your calculator. See remark for more information.

alternate airports. Select a waypoint near the center of the area to be identified as "0", and others to be assigned number 1 - N as desired. Select the Load Module program (AV-15) and load the network as follows:

Enter number of waypoint to be loaded	Press [A] (Load FIX)
Enter number of waypoint used as a reference	Press [B] (from FIX)
Enter magnetic bearing from reference to new waypoint	Press [C] (RAD)
Enter distance between waypoints	Press [D] (Dist)

Repeat for each waypoint. Note that the reference point for each new fix must already have been defined to the calculator. Fix 0 is always assumed as (0, 0), thus it *must* be the reference for the first waypoint entered. The second waypoint entered may reference either fix 0 or the first point entered, etc. . . .The location of any waypoint may be changed at any time before recording the data on magnetic cards. However, movement of the origin requires redefining all other positions.

If you have a TI Programmable 59 and if the network is one you might use frequently, it may then be stored on a blank magnetic card, creating a Flight Data card. This data card may then be read into memory at any time without even having to select the Load Module program.

By recording several Flight Data cards, "blocks" of waypoints may be used to describe a long route. A new block would then be loaded as the aircraft left the previous one. At least one VOR should be common to adjacent blocks.

Be sure to label each Flight Data card; for instance, a card accompanying the example used in this section could be labeled:

Pens made especially for writing on mylar or acetate should work well. Most others will smear.

Recording a network on a blank card does not affect the data registers (which will still be used). Thus, whether or not a Flight Data card is recorded, you may continue by immediately selecting the required navigation program.

If a waypoint needs to be "moved" while navigating, the Load Module may be reselected for that purpose. Then, once the data has been changed you may reselect the appropriate navigation program and continue normally.

Remark: The load module operates as follows: Bearing and distance are converted to cartesian (x, y) coordinates. Each waypoint entered is assigned a number $(0 - N)$ which the program uses to assign the (x, y) coordinates of that waypoint to 2 data registers. The registers are found by:

x_n in register $13 + 2n$ (eg. x_5 in R_{23})

y_n in register $12 + 2n$ (eg. y_5 in R_{22})

Note that the number of waypoints that may be entered depends upon the number of data registers available for program use as shown below.

Number of Registers	Maximum Number of Waypoints
20	4
30	9
40	14
50	19
60	24
70*	29
80*	34
90*	39
100*	44

See your Owner's Manual for complete instructions on partitioning your calculator's storage area.

To Use Flight Data Card

If you have entered your flight data and recorded it on a magnetic card or cards you may simply read this data into your calculator's data memory when it is needed for the VOR or DME Area Nav program. To do this simply press [CLR] and feed the card into the card slot. Once the card is read the number in the display indicates which bank was read. See your Owner's Manual for complete instructions on using magnetic cards.

*TI Programmable 59 only.

AV-14, 15, 16

	Solid State Software		TI ©1977	
AREA NAV—LOAD MODULE			AV-15	
Load FIX #	from FIX #	Rad	Dist	

USER INSTRUCTIONS

| STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 15	
2	Initialize[1]		[SBR] [CLR]	0.
	For each waypoint, do Steps 3-6			
3	Enter number of waypoint to be entered	n	[A]	n.
4	Enter number of waypoint to be used as reference[2]	m	[B]	m.
5	Enter radial *from* m to n in degrees	Rad	[C]	Rad
6	Enter distance from m to n	Dist	[D]	Dist
	(For new waypoint, go to 3)			
	To record waypoints on a magnetic card, do Steps 7-9			
7a	Record data registers $R_{00}-R_{29}$ on a magnetic card	4 Card (Bank 4)	[2nd] [Write]	4.
7b[4]	Record data registers $R_{30}-R_{59}$ on a magnetic card if needed[3].	3 Card (Bank 3)	[2nd] [Write]	3.
	Label recorded card (see text).			
8	Initialize Load Module program for new network *or* go to VOR or DME Area Nav program			

NOTES:
1. Initialization uses [CMs] and selects degree mode.
2. Must be "0" or a waypoint already entered.
3. Step 7b is needed only if you are working with more than nine waypoints.
4. Registers $R_{60}-R_{89}$ (bank 2) and $R_{90}-R_{99}$ (bank 1) may be recorded similarly. See the preceding table to determine how many banks you need to record. (Note that each bank must be recorded on a separate card side.)

SAMPLE FLIGHT CHART

ALL COURSES MAGNETIC
ALL DISTANCES NAUT. MILES
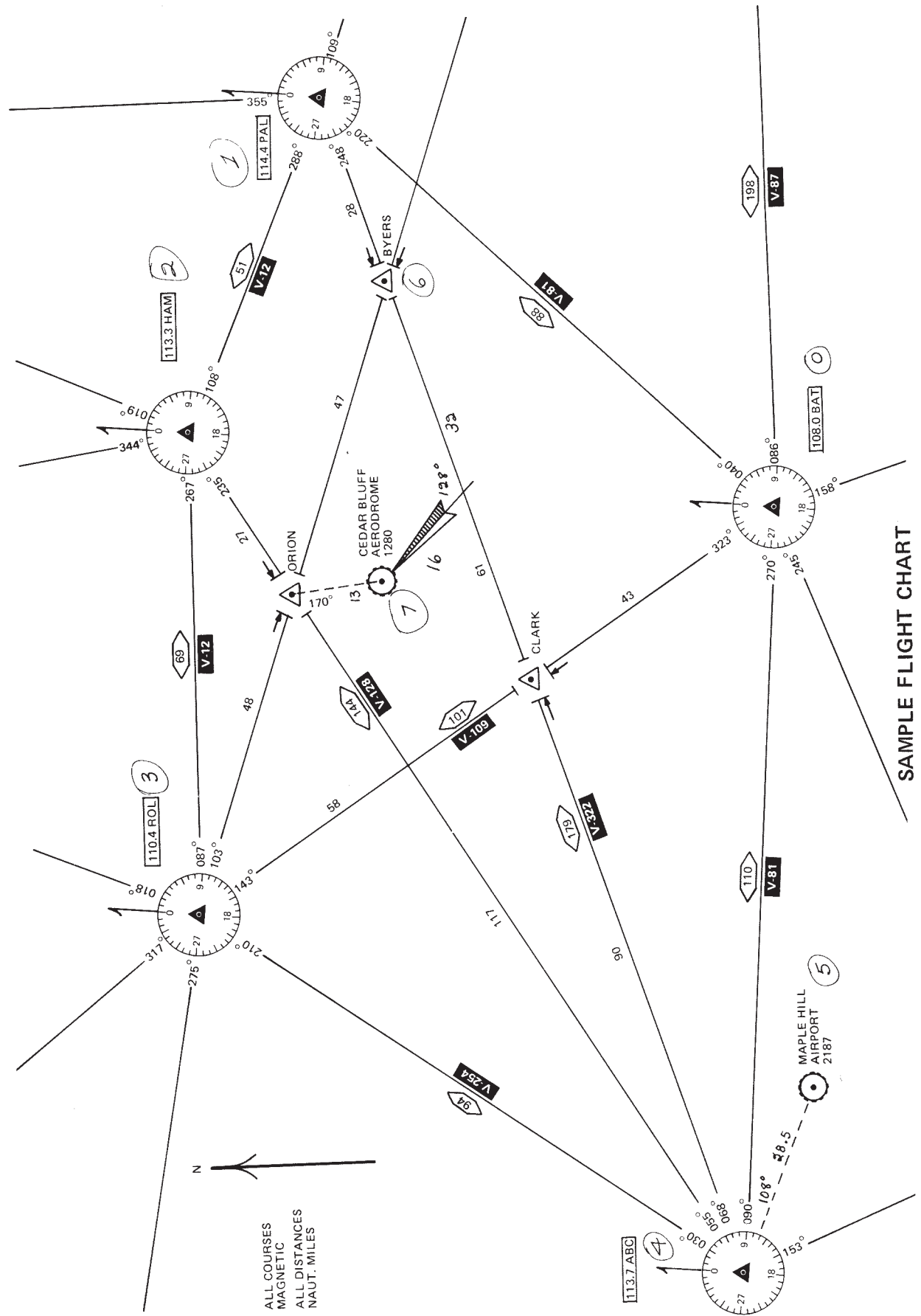
Example: Store the network shown on the accompanying Sample Flight Chart in your calculator's data registers for use in the Area Nav programs. (Several possible methods.)

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 15 [SBR] [CLR]		Initialize
1	[A]	0.	Load FIX #1
0	[B]	1.	from FIX #0
40	[C]	40.	Radial 040°
88	[D]	88.	Distance 88 n. mi.
2	[A]	2.	Load FIX #2
1	[B]	1.	from FIX #1
288	[C]	288.	Radial 288°
51	[D]	51.	Dist 51 n. mi.
3	[A]	3.	Load FIX #3
2	[B]	2.	from FIX #2
267	[C]	267.	Radial 267°
69	[D]	69.	Dist 69 n. mi.
4	[A]	4.	Load FIX #4
0	[B]	0.	from FIX #0
270	[C]	270.	Radial 270°
110	[D]	110.	Dist 110 n. mi.
5	[A]	5.	Load FIX #5
4	[B]	4.	from FIX #4
108*	[C]	108.	Radial 108°
28.5*	[D]	28.5	Dist 28.5 n. mi.

(to enter #7, define Orion intersection as #6 temporarily, then after loading #7 from Orion, redefine #6 as Byers intersection)

6	[A]	6.	Load FIX #6 (temp.)
2	[B]	2.	from FIX #2
235	[C]	235.	Radial 235°
27	[D]	27.	Dist 27 n. mi.
7	[A]	7.	Load FIX #7
6	[B]	6.	from FIX #6
170*	[C]	170.	Radial 170°
13*	[D]	13.	Dist 13 n. mi.
6	[A]	6.	Load FIX #6
1	[B]	1.	from FIX #1
248	[C]	248.	Radial 248°
28	[D]	28.	Dist 28 n. mi.

*not on chart, but found by plotting.

To record this network on a magnetic card, press [4] [2nd] [Write] and insert the card in the card slot. (This data is used in later examples.)

To read the card, press [CLR] and feed the card into the card slot.

Register Contents

R_{00}	P/R	R_{05}		R_{10}		R_{15}	x_1	R_{20} and above
R_{01}	y pointer	R_{06}		R_{11}		R_{16}	y_2	are used similar
R_{02}	x pointer	R_{07}		R_{12}	y_0	R_{17}	x_2	to $R_{12} - R_{19}$
R_{03}	Used	R_{08}		R_{13}	x_0	R_{18}	y_3	
R_{04}				R_{09}		R_{14}	y_1	R_{19}	x_3	

AREA NAV USAGE SEQUENCE
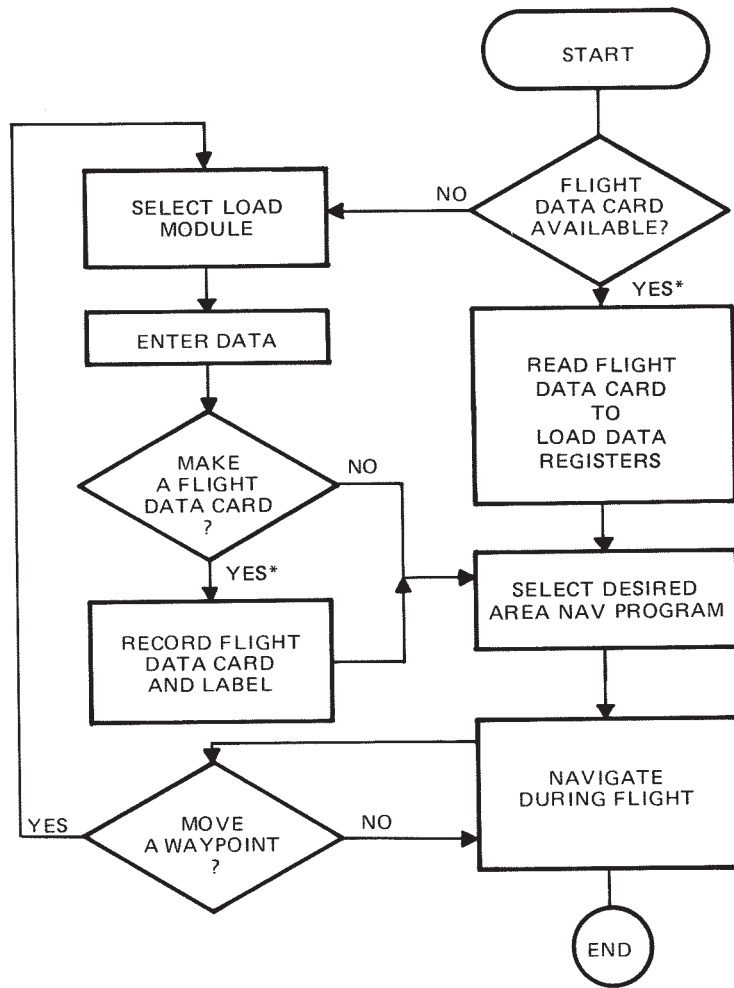
*TI Programmable 59 only.

VOR Area Nav

Once the network data is in place, the VOR Area Nav program may be used. Knowing the radials from 2 defined VOR's, the program calculates the position of the aircraft relative to #0, and thus relative to each defined network point. By entering the number of the waypoint in question, the pilot may find the distance and magnetic course from his present position to that waypoint. Then, entering the time of the VOR readings and estimated ground speed, ETA to that waypoint is calculated.

Another important feature is the "Add miles" instruction. This instruction directly changes the distance used in ETA calculations. For instance, if the flight plan includes two legs to a destination, then direct distance to the destination and resulting ETA calculation will not be correct. But calculating the distance to the leg intersection, then adding the distance of the second leg will give correct distance and ETA results (see Example).

In addition, any undefined point may be treated as an aircraft position provided the radials to two defined points are known. This allows the user to find distance and magnetic course to a defined point from an undefined one (see Example).

References:

1. The VOR Area Nav program operates as follows (see also Reference of Load Module section): Each defined waypoint (n) is already stored by the Load Module as (x_n, y_n) relative to waypoint #0, with the y-axis aligned to magnetic north (see Reference 2). The two radials from an aircraft position to two defined VOR's are defined by:

   line A from VOR A to aircraft $-\#y_A = m_A x_A + y_{iA}$

   line B from VOR B to aircraft $-\#y_B = m_B x_B + y_{iB}$

   where m is the slope of the line, and y_i is the y-intercept
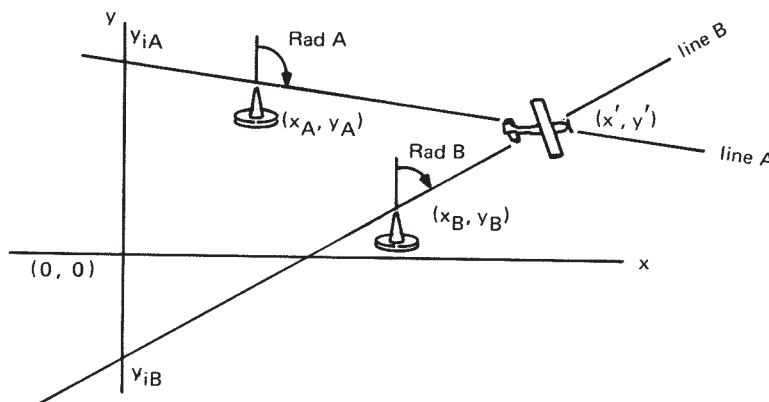
$$m = \tan(90 - Rad)$$

$$y_i = y - x \tan(90 - Rad)$$

m and y_i are calculated and stored in intermediate registers, then used to calculate the aircraft position (x', y'):

$$x' = \frac{y_{iB} - y_{iA}}{m_B - m_A}$$

$$y' = m_A x' + y_{iA}$$

Distance to #n $= \sqrt{(x_n - x')^2 + (y_n - y')^2}$

Magnetic Course to #n $= 90 - \arctan\left(\dfrac{y_n - y'}{x_n - x'}\right)$ if $(y_n - y') > 0$

$= 270 - \arctan\left(\dfrac{y_n - y'}{x_n - x'}\right)$ if $(y_n - y') < 0$

ETA = Dist/GS + time of reading

2. The program uses a cartesian coordinate system aligned to magnetic north at the "0" waypoint. Change in magnetic variation over the network will thus induce some error, though generally less than other errors. To correct for this error:

    Correction factor = (Variation at "0") − (Variation at station being received; +W, −E)

    Corrected radial   = (Radial measured) + (Correction factor)

    The correction factors may be marked beside the isogonic lines of the chart for ready reference.

3. Non-linearity in the VOR grid due to terrain, etc., will cause errors. This is usually apparent when the ends of straight airways (published IFR routes) on the chart are not reciprocal course $(x \neq y - 180°)$. In such a case, the VOR nearest the flight path should be used. Plotting should be done with care.

4. Two VOR readings 180° different (or identical) may not be used in this program. (For instance, in the sample chart, a pilot flying V-322 may not use #1 *and* #4). Further, error increases drastically with VOR readings approaching 0° or 180° difference. In such cases, use of another VOR is advisable.

5. It is sometimes desirable to locate an aircraft position exactly at a defined waypoint. To do so, simple enter two separate bearings from the same waypoint. The following uses waypoint #4 and bearings of 010° and 100°.

4	[2nd]	[A']
10	[2nd]	[B']
4	[2nd]	[A']
100	[2nd]	[C']

    Any two bearings not differing by 0° or 180° may be used.

6. A slight offset of 6.8×10^{-7} degrees allows magnetic bearing inputs of 0°, 180°, or 360° from a VOR.

	Solid State Software		TI © 1977	
VOR AREA NAV				**AV-16**
from FIX #	Rad A	Rad B	GS→	→GS
t of read'g	# → Dist to	→ ETA	→MC	Add mi

USER INSTRUCTIONS

| STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Load data using Load Module program or Flight Data card			
2	Select VOR Area Nav program (A and B).		[2nd] [Pgm] 16	
3	Initialize		[SBR] [CLR]	
4	Enter estimated ground speed[2].	GS	[2nd] [D']	GS.0000
5	Enter time of reading[1].	t (HH.MMSS)	[A]	t of reading (decimal hrs)
6a[3]	Enter waypoint number of first VOR.	n	[2nd] [A']	0.0000
6b	Enter radial from first VOR.	Rad A	[2nd] [B']	0.0000
7a[3]	Enter waypoint number of second VOR.	m	[2nd] [A']	0.0000
7b	Enter radial from second VOR.	Rad B	[2nd] [C']	0.0000
8[4]	Calculate distance to waypoint #W	W	[B]	Dist to #W
9	Calculate magnetic course to waypoint #W		[D]	MC (decimal degrees)
10[5]	Change distance (if needed)	± miles	[E]	Dist to ± miles
11	Calculate ETA to last distance displayed		[C]	ETA (HH.MMSS)
12a	Compute actual GS to waypoint in Step 7		[2nd] [E']	GS
12b	Enter calculated GS for use in additional ETA calculations if desired	GS	[2nd] [D']	GS
13	For a new reading, perform Steps 5, 6 and/or 7 as needed and continue.			

NOTES:

1. Use 24 hour clock. Program resets time at midnight. t of reading may be entered at any time before ETA is calculated.

2. Use units compatible with distance units (usually naut. miles and knots). GS may be entered at any time before ETA is calculated, and need not be reentered unless changed.

3. Step 6a and b, and Step 7a and b must be performed in that order. Steps 6 and 7 may be performed in either order or separately (see example). All bearings should be entered in whole degrees.

4. Step 8 must be performed before Steps 9, 10, or 11. Magnetic course is calculated to the last waypoint number entered before [B] is pressed.

5. Enter a negative value if distance is desired to a point *closer* to you (along your flight path) than waypoint #W in Step 8. Enter a positive value otherwise.

6. Program leaves calculator in fix 4 mode.

7. Initialization selects degree mode.

SAMPLE FLIGHT CHART

ALL COURSES
MAGNETIC
ALL DISTANCES
NAUT. MILES
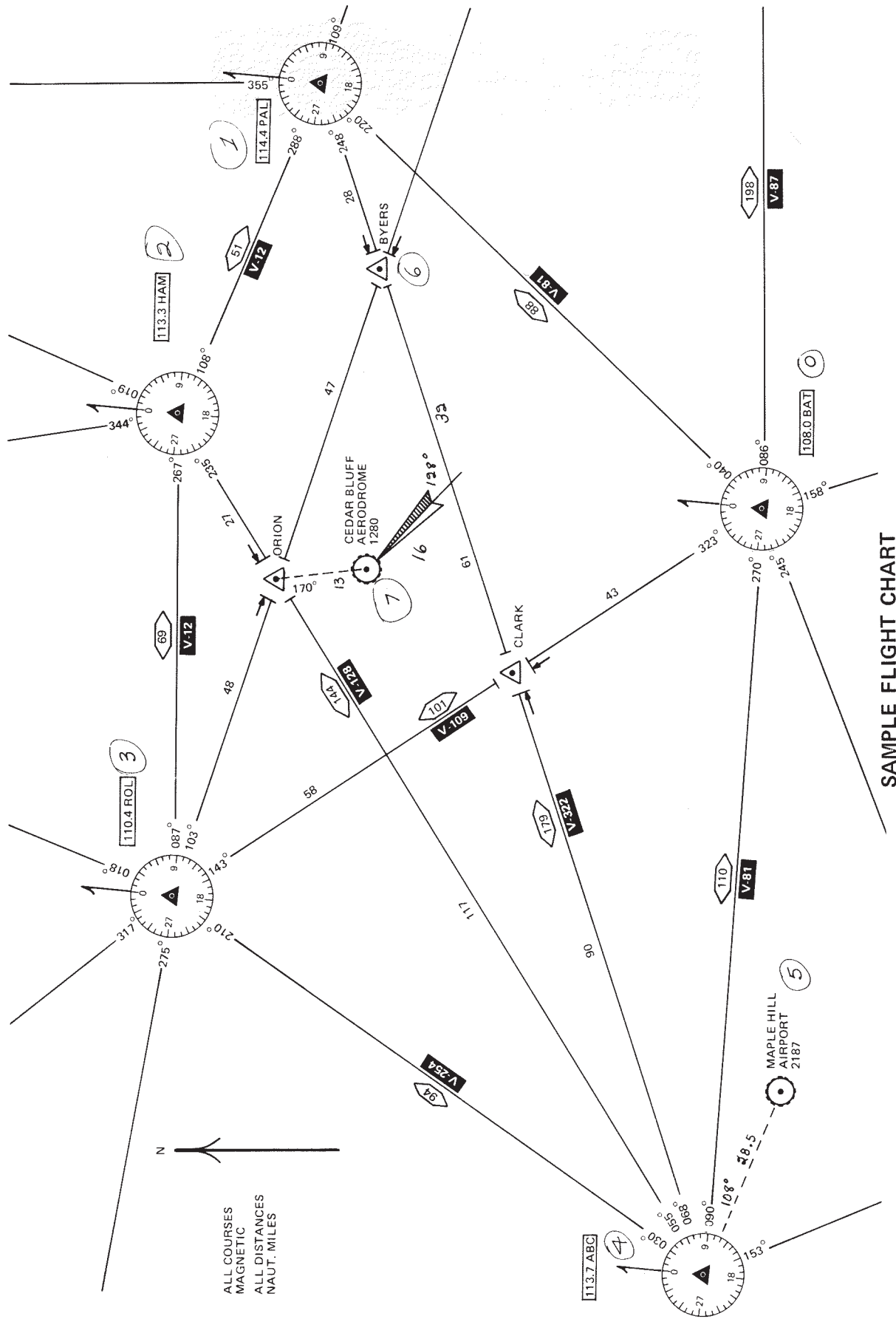
Example: Suppose that a pilot wishes to fly from Maple Hill Airport to Cedar Bluff Aerodome using the waypoint data entered in the Load Module program example. At departure (08:42) his readings are:

VOR ABC (#4) = 108°
VOR BAT (#0) = 264°

His estimated ground speed is 140 knots.

Load the waypoint data using the Load Module program example or the Flight Data card for that example if you recorded one. * Now continue with the following.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 16 [SBR] [CLR]		Initialize
140	[2nd] [D′]	140.	est. ground speed
8.42	[A]	8.7	time of reading
4	[2nd] [A′]	0.0000	from FIX #4
108	[2nd] [B′]	0.0000	Radial A
0	[2nd] [A′]	0.0000	from FIX #0
264	[2nd] [C′]	0.0000	Radial B
7	[B]	95.5682	Dist to #7
	[D]	48.2651	MC to #7
	[C]	9.2257	ETA at #7

At 08:50,   VOR ABC (#4) = 084°
VOR BAT (#0) = 273°

ENTER	PRESS	DISPLAY	COMMENT
8.5	[A]	8.8333	t of reading
4	[2nd] [A′]	0.0000	from FIX #4
84	[2nd] [B′]	0.0000	Rad A
0	[2nd] [A′]	0.0000	from FIX #0
273	[2nd] [C′]	0.0000	Rad B
7	[B]	79.9969	Dist to #7
	[D]	50.3591	MC to #7
	[C]	9.2417	ETA at #7

It is apparent that the aircraft is drifting left off course, so trial heading of 52° is taken. At intersection with V-322, assume he will turn and follow the airway to intercept the Cedar Bluff localizer.

*There is no need to load this data if you haven't disturbed your calculator's data registers since running the last example.

At 9:00, pilot intercepts V-322 and turns to 068°.

VOR ABC (#4) = 068°
VOR BAT (#0) = 289°

What is his ETA at Clark intersection?

ENTER	PRESS	DISPLAY	COMMENT
9	[A]	9.0000	t of reading
4	[2nd] [A']	0.0000	from FIX #4
68	[2nd] [B']	0.0000	Rad A
0	[2nd] [A']	0.0000	from FIX #0
289	[2nd] [C']	0.0000	Rad B
6	[B]	97.1024	Dist to Byers (#6)
61	[+/−] [E]	36.1024	Dist to Clark
	[C]	9.1528	ETA at Clark

The distance to the intersection of the Cedar Bluff localizer with V-322 can also be calculated. Since a course flown along the localizer is 308°, the bearing to that intersection from #7 is 128° (= 308° − 180°). The radial defining V-322 is the 248° radial from VOR PAL (#1).

1	[2nd] [A']	0.0000	from FIX #1
248	[2nd] [B']	0.0000	Rad A
7	[2nd] [A']	0.0000	from FIX #7
128	[2nd] [C']	0.0000	Rad B
6	[B]	32.0005	Dist to Byers
7	[B]	16.1572	Dist to Cedar Bl.

The pilot pencils in these figures on the flight chart. Now he calculates the distance and ETA from his last position to the localizer intercept. (This requires reentry of Rad B.)

0	[2nd] [A']	0.0000	from FIX #0
289	[2nd] [C']	0.0000	Rad B
6	[B]	97.2251	Dist to Byers
32	[+/−] [E]	65.2251	Dist to intercept
	[C]	9.2757	ETA at intercept

To obtain the ETA at Cedar Bluff, he adds the distance along the localizer course.

16.2	[E]	81.4251	Dist to Cedar Bl.
	[C]	9.3454	ETA at Cedar Bl.

At 9:16, the aircraft passes through Clark intersection and the pilot switches to VOR PAL (#1), receiving a 248° reading. (This has already been entered in the previous calculations.) Yet now the pilot decides to fly direct to Cedar Bluff. What course should he fly and what is his ETA?

ENTER	PRESS	DISPLAY	COMMENT
9.16	[A]	9.2667	t of reading
0	[2nd] [A']	0.0000	from FIX #0
323	[2nd] [C']	0.0000	Rad B
7	[B]	24.9775	Dist to Cedar Bl.
	[D]	33.9299	MC to Cedar Bl.
	[C]	9.2642	ETA at Cedar Bl.

The pilot comes to 034° for a direct approach. He is on final approach to Cedar Bluff at 9:27, proving that his last ground speed estimate was quite accurate.

This example has shown a very condensed exercise of the capabilities of this program. Only extensive ground practice will guarantee their full realization in-flight. (Leave the waypoint data in your calculator's data registers for use in the next example.)

GS Calculation

Another feature of the VOR Area Nav program is that in addition to calculating magnetic course, this program calculates ground speed from the elapsed time and the distance flown between readings.

The following equation is used:

$$GS = \frac{Dist - Dist'}{t - t'}$$

where:

GS = ground speed (calculated) t = time of last reading

$Dist$ = last distance calculated t' = time of previous reading

$Dist'$ = previous distance calculated

Limitations: Ground speed calculations do not allow for midnight. Incorrect values will result for the first calculation after 24:00:00, but subsequent results will be correct.

SAMPLE FLIGHT CHART

ALL COURSES
MAGNETIC

ALL DISTANCES
NAUT. MILES
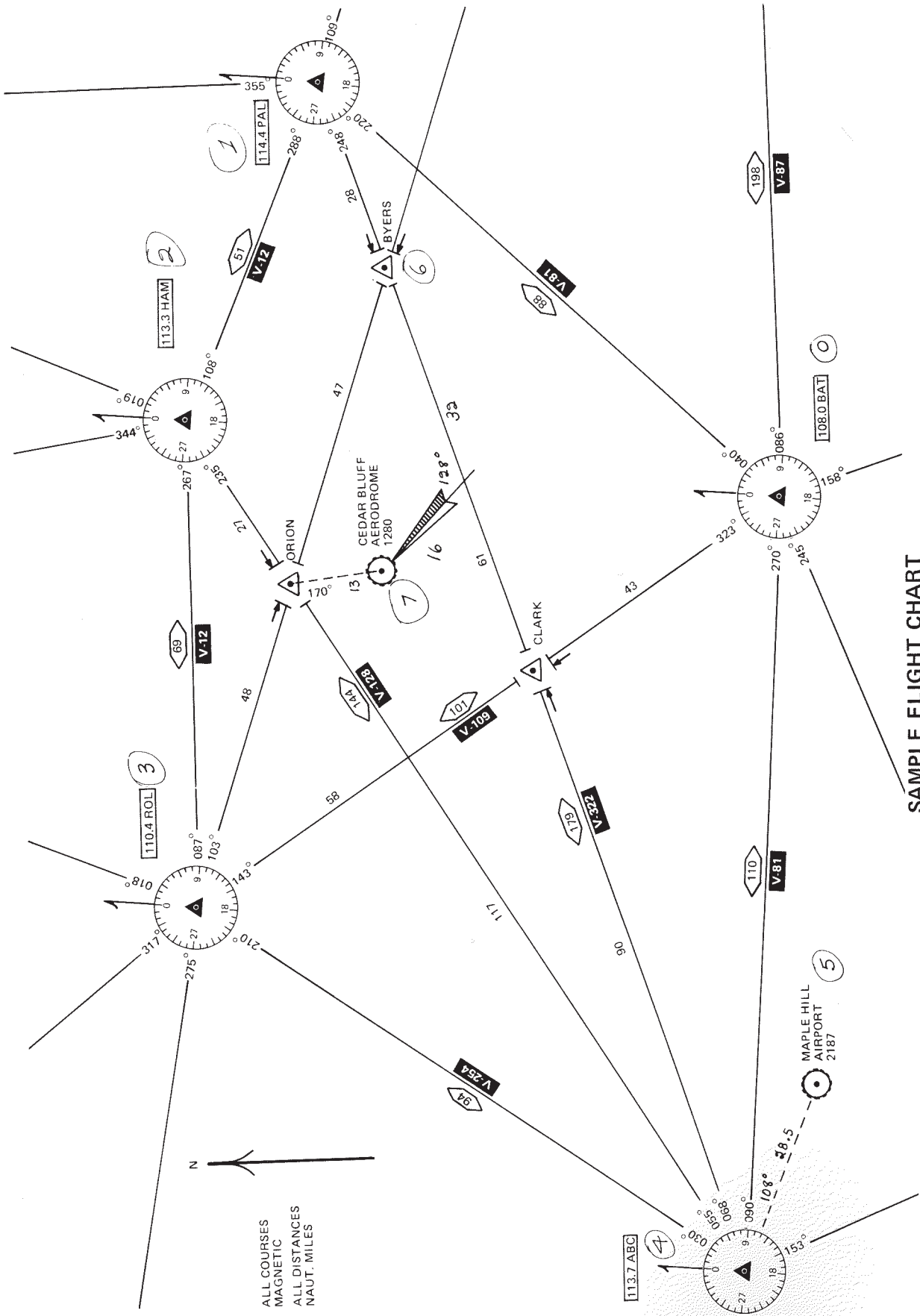
Example: You are flying southwest on V-322 between VOR PAL and BYERS intersection, enroute to VOR ABC (see accompanying sample flight chart).

At 23:30:00, estimated ground speed is 120 knots, and

VOR PAL (#1) = 248°
VOR HAM (#2) = 120°

How far is BYERS, and what is your estimate for VOR ABC?

Load the waypoint data using the Load Module program example or the Flight Data card for that example if you recorded one*. Now continue with the following.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 16 [SBR] [CLR]		Initialize
120	[2nd] [D']	120.	est. GS
23.3	[A]	23.5	t of reading
1	[2nd] [A']	0.0000	from FIX #1
248	[2nd] [B']	0.0000	Rad A
2	[2nd] [A']	0.0000	from FIX #2
120	[2nd] [C']	0.0000	Rad B
6	[B]	14.5440	Dist to Byers (#6)
4	[B]	166.2336	Dist to ABC (#4)
	[C]	0.5307	ETA at ABC

Now initialize the ground speed calculation routine by pressing [2nd] [E']. The display (−7.0738) is meaningless at this point since two position entries are required for results.

At 23:40:00, VOR HAM (#2) = 150°. (VOR PAL is the same.)

ENTER	PRESS	DISPLAY	COMMENT
23.4	[A]	23.6667	t of reading
2	[2nd] [A']	0.0000	from FIX #2
150	[2nd] [C']	0.0000	Rad B
4	[B]	145.2286	Dist to #4
	[C]	0.5237	ETA at #4
	[2nd] [E']	126.0300	calculate GS

The calculated ground speed is approximately 126 knots. Enter this as your new estimate.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [D']	126.0300	est. GS
	[C]	0.4908	new ETA at #4

At 23:50:00, VOR HAM (#2) = 184°.

ENTER	PRESS	DISPLAY	COMMENT
23.5	[A]	23.8333	t of reading
2	[2nd] [A']	0.0000	from FIX #2
184	[2nd] [C']	0.0000	Rad B
4	[B]	124.6325	Dist to #4
	[C]	0.4920	ETA at #4
	[2nd] [E']	123.5769	calculate GS

*There is no need to load this data if you haven't distrubed your calculator's data registers since running the last example

AV-14, 15, 16

At 0:00:00, VOR − HAM (#2) = 206°.

ENTER	PRESS	DISPLAY	COMMENT
125	[2nd] [D′]	125.0000	est. GS
0	[A]	0.0000	t of reading
2	[2nd] [A′]	0.0000	from FIX #4
206	[2nd] [C′]	0.0000	Rad B
4	[B]	104.2131	Dist to #4
	[C]	0.5001	ETA at #4
	[2nd] [E′]	−0.8568*	calculate GS

*Ignore the calculated ground speed, since it does not allow for midnight. However, this step is necessary to initialize the routine for subsequent calculations. At CLARK intersection, you tune to VOR ROL for the remainder of the flight.

At 0:10:00, VOR ROL (#3) = 150°.

ENTER	PRESS	DISPLAY	COMMENT
.1	[A]	0.1667	t of reading
3	[2nd] [A′]	0.0000	from FIX #3
150	[2nd] [C′]	0.0000	Rad B
4	[B]	83.1450	Dist to #4
	[C]	0.4954	ETA at #4
	[2nd] [E′]	126.4087	calculate GS

The flight continues in like manner. At 0:49:00, you are over VOR ABC; thus, your estimate of 125 knots is very close to your actual GS. (Note: The same waypoint data is used in the next example.)

This program requires more extensive ground practice than is possible within the scope of this example.

Register Contents

R_{00}	Pointer	R_{05}	Dist	R_{10}	Dist′	R_{15}	x_1	R_{20} and above
R_{01}	y_{iB}	R_{06}	$y′-y_B$	R_{11}	$t′$	R_{16}	y_2	are used similar
R_{02}	m_B	R_{07}	$x′$	R_{12}	y_0	R_{17}	x_2	to $R_{12}-R_{19}$
R_{03}	y_{iA}	R_{08}	t	R_{13}	x_0	R_{18}	y_3	
R_{04}	m_A	R_{09}	GS	R_{14}	y_1	R_{19}	x_3	

The contents of these registers may be recalled at any time without disrupting program operation.

DME Area Nav

This area navigation program is also compatible with the Area Nav Load Module program (AV-15). The operation of this program is identical to that of VOR Area Nav except that position is determined by radial and DME distance from a single VORTAC station. Corrections for slant range, altitude, and close proximity to the VORTAC are ignored in the solution. A reduction in the number of keystrokes and reduced position error due to the Rho-Theta versus Theta-Theta approach used in VOR Area Nav are two advantages of this program.

Waypoint data is stored in the calculator's data registers by the Area Nav Load Module program as explained earlier. Aircraft position is then determined by

$$x' = x_{FIX} + r \cos \theta \qquad \text{and} \qquad y' = y_{FIX} + r \sin \theta$$

where:

$$r = \text{DME distance}$$
$$\theta = 90 - r \text{ radial}$$
$$(x_{FIX}, y_{FIX}) = \text{the coordinates of the waypoint (VORTAC) from which the DME distance and bearing are obtained.}$$

The remaining calculations are the same as those described for VOR Area Nav.

	Solid State Software		TI ©1977	
DME AREA NAVIGATION				**AV-14**
from FIX #	Rad	DME	GS →	→ GS
Time	# → Dist to	→ ETA	→ MC	Add mi

USER INSTRUCTIONS

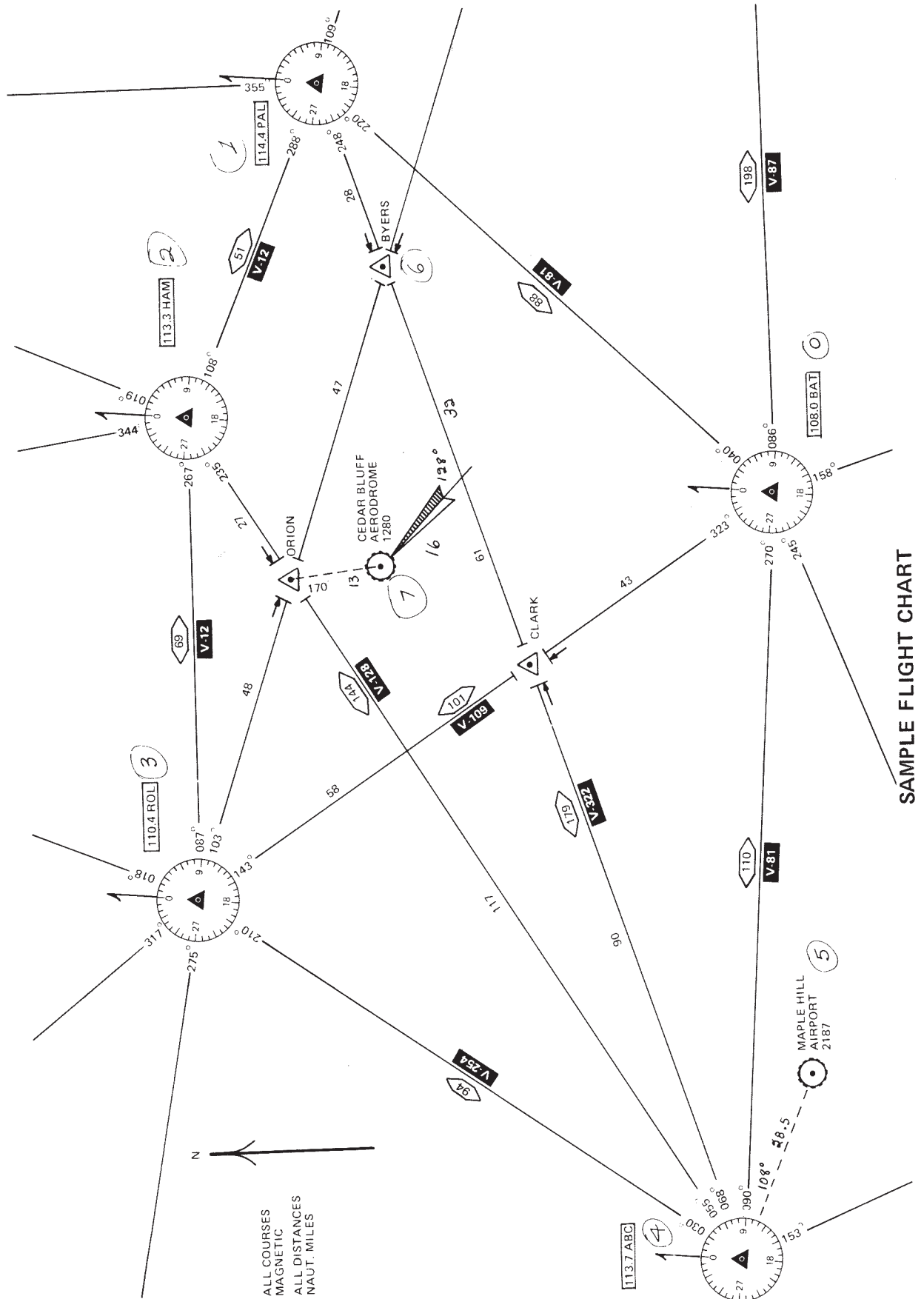| STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Load data using Load Module program or Flight Data card			
2	Select DME Area Nav program		[2nd] [Pgm] 14	
3	Initialize		[SBR] [CLR]	
4	Enter estimated ground speed[2]	GS	[2nd] [D′]	GS.0000
5	Enter time of DME reading[1]	t(HH.MMSS)	[A]	t (decimal hrs)
6a[3]	Enter VORTAC waypoint number	WP #	[2nd] [A′]	0.0000
6b	Enter radial from VORTAC	Rad	[2nd] [B′]	Radial
6c	Enter DME distance measured along above radial	DME	[2nd] [C′]	Distance
7[4]	Calculate distance to desired waypoint	WP #	[B]	Dist to WP
8	Calculate magnetic course to above waypoint		[D]	Mc (decimal degrees)
9[5]	Change distance (if needed)	± miles	[E]	Dist to ± miles
10	Calculate ETA to last distance displayed		[C]	ETA (HH.MMSS)
11a	Compute GS to waypoint in Step 7		[2nd] [E′]	GS[6]
11b	Enter calculated GS for use in additional ETA calculations if desired	GS	[2nd] [D′]	GS
12	For a new reading, perform Steps 5 and 6 and continue			

NOTES:

1. Use 24 hour clock. Program resets time at midnight. t of reading may be entered at any time before ETA is calculated.

2. Use units compatible with distance units (usually naut. miles and knots). GS may be entered at any time before ETA is calculated, and need not be reentered unless changed.

3. Steps 6a, b, and c should be performed in that order. All bearings should be entered in whole degrees.

4. Step 7 must be performed before 8, 9, or 10. MC is calculated to the last waypoint entered before pressing [B].

5. Enter a negative value if distance is desired to a point *closer* to you (along your flight path) than waypoint in Step 7. Enter a positive value otherwise.

6. Ignore this result on the first entry as it only initializes storage for subsequent entries. No valid GS estimate may be made with less than 2 observations made at different times. You may also ignore other GS calculations if they appear to be off.

7. Initialization selects degree mode.

8. Program leaves calculator in fix 4 mode.

SAMPLE FLIGHT CHART

114.4 PAL

355

109°

220°

248°

286°

① 1

② 2

113.3 HAM

V-12

51

BYERS

28

⑥ 6

198

V-87

I8A

88

108.0 BAT

⑩ 0

086°

158°

040°

323°

270°

245°

019°

344

267°

235°

108°

27

ORION

CEDAR BLUFF
AERODROME
1280

128°

16

170

13

⑦ 7

61

47

33

43

V-12

69

48

V-128

I4A

V-109

101

CLARK

110.4 ROL

③ 3

087°

103

018°

143°

317°

275°

210°

58

V-322

179

V-81

110

90

III

117

MAPLE HILL
AIRPORT
2187

⑤ 5

108°

28.5

V-254

94

N

ALL COURSES
MAGNETIC

ALL DISTANCES
NAUT. MILES

113.7 ABC

④ 4

090°

055

030

060°

153°

Example 1: Suppose that a pilot using the sample flight chart makes the following observations:

TIME	VORTAC	RAD	DME
12:15	ROL (#3)	180°	75 n. mi.

Using an estimated GS of 140 knots compute the distance, magnetic course and ETA for Maple Hill (#5).

First load the waypoint data using the Load Module program example or the Flight Data card for that example if you recorded one. (There is no need to load this data if you haven't disturbed your calculator's data registers since running the last example.) Now continue with the following.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 14 [SBR] [CLR]		Initialize
140	[2nd] [D']	140.	est. ground speed
12.15	[A]	12.25	time of reading
3	[2nd] [A']	0.0000	from FIX #3
180	[2nd] [B']	180.0000	Radial from #3
75	[2nd] [C']	75.0000	DME Dist from #3
5	[B]	25.7863	Dist to #5
	[D]	238.7751	MC to #5
	[C]	12.2603	ETA at #5

Example 2: Using the sample flight chart, assume that a pilot makes the following observations:

TIME	VORTAC	RAD	DME
12:22	ABC (#4)	068°	25 n. mi.

Using an estimated GS of 140 knots determine the distance and ETA to the Clark intersection. Note that since the Clark intersection is not a defined waypoint, Byers (#6) and the Add Miles function are used to complete the example

First load the waypoint data using the Load Module program example or the Flight Data card for that example if you recorded one. (There is no need to load this data if you haven't disturbed your calculator's data registers since running the last example.) Now continue with the following.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 14 [SBR] [CLR]		Initialize
140	[2nd] [D']	140.	est. ground speed
12.22	[A]	12.36666667	time of reading
4	[2nd] [A']	0.0000	from FIX #4
68	[2nd] [B']	68.0000	Radial from #4
25	[2nd] [C']	25.0000	DME Dist from #4
6	[B]	126.6897	Dist to Byers (#6)
61*	[+/−] [E]	65.6897	Add mi. → Dist to Clark
	[C]	12.5009	ETA at Clark

*Obtained from chart.

Example 3: Suppose that a pilot using the sample flight chart is flying from ABC to PAL on a direct route via Clark and Byers. Suppose that the estimated ground speed of his plane is 100 knots. However, he is also flying with a strong tailwind and chooses to fly at a high altitude to pick up the favoring winds. Due to his altitude he is able to read ROL (#3) along the entire course and makes these observations:

TIME	VORTAC	RAD	DME
12:00	ROL (#3)	210°	94 n. mi.
12:30	ROL (#3)	143°	58 n. mi.
12:50	ROL (#3)	103°	95 n. mi.

Update the ground speed and ETA at PAL at each of these observations.

First load the waypoint data using the Load Module program example or the Flight Data card for that example if you recorded one. (There is no need to load this data if you haven't disturbed your calculator's data registers since running the last example.) Now continue with the following.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 14 [SBR] [CLR]		Initialize
100	[2nd] [D']	100.	est. ground speed
12	[A]	12.	time of reading
3	[2nd] [A']	0.0000	from FIX #3
210	[2nd] [B']	210.0000	Radial from #3
94	[2nd] [C']	94.0000	DME Dist from #3
1	[B]	178.4014	Dist to PAL (#1)
	[D]	67.1567	MC to #1
	[C]	13.4702	ETA at #1
	[2nd] [E']	−14.8668	Initialize GS calculation (ignore first result)
12.30	[A]	12.5000	time of reading
3	[2nd] [A']	0.0000	from FIX #3
143	[2nd] [B']	143.0000	Radial from #3
58	[2nd] [C']	58.0000	DME Dist from #3
1	[B]	89.3009	Dist to PAL (#1)
	[D]	67.5013	MC to #1
	[C]	13.2335	New ETA at #1 (Note difference!)
	[2nd] [E']	178.2009	Computed GS
	[2nd] [D']	178.2009	Accept new GS
	[C]	13.0004	New ETA at PAL

ENTER	PRESS	DISPLAY	COMMENT
12.50	[A]	12.8333	time of reading
3	[2nd] [A']	0.0000	from FIX #3
103	[2nd] [B']	103.0000	Radial from #3
95	[2nd] [C']	95.0000	DME Dist from #3
1	[B]	26.5004	Dist to PAL (#1)
	[D]	69.6361	MC to #1
	[C]	12.5855	New ETA at #1
	[2nd] [E']	188.4016	Computed GS
	[2nd] [D']	188.4016	Update GS
	[C]	12.5826	New ETA at PAL

Register Contents

R_{00}	Pointer	R_{05}	Dist to WP	R_{10}	Dist'	R_{15}	x_1	R_{20} and above
R_{01}	y'	R_{06}		R_{11}	t'	R_{16}	y_2	are used similar
R_{02}	x'	R_{07}		R_{12}	y_0	R_{17}	x_2	to $R_{12} - R_{19}$
R_{03}	Radial	R_{08}	t	R_{13}	x_0	R_{18}	y_3	
R_{04}	DME Dist	R_{09}	GS	R_{14}	y_1	R_{19}	x_3	

COURSE CORRECTION

This program calculates the corrected magnetic course and the distance to go for an aircraft that has strayed a known distance off course.
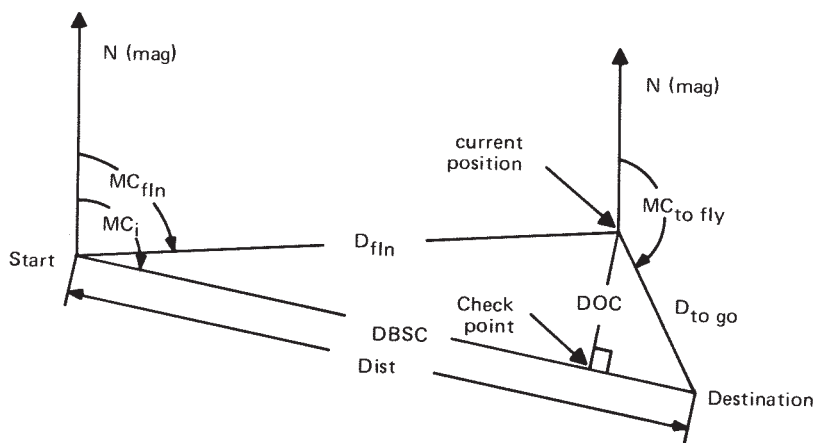
$$DBSC = \sqrt{D_{fln}^2 - DOC^2}$$

if D_{fln} is known

$$MC_i = MC_{fln} + \arctan\left(\frac{DOC}{DBSC}\right) \qquad D_{to\ go} = \sqrt{(Dist - DBSC)^2 + DOC^2}$$

$$MC_{to\ fly} = MC_i + \arcsin\left(\frac{DOC}{D_{to\ go}}\right) \qquad 0 \leqslant MC_{to\ fly} < 360°$$

where

Dist = distance from start to destination

DOC = distance off course (+ left, − right of intended course) (see Note 2)

D_{fln} = distance actually flown to current position (see Note 2)

DBSC = distance from start to checkpoint

$D_{to\ go}$ = distance to go from current position to destination

MC_i = intended magnetic course

MC_{fln} = magnetic course actually flown to current position

$M_{to\ fly}$ = magnetic course to fly from current position to destination

Remarks:

1. All distances may be in any unit of length, but units must be uniform within any one case.

2. DOC and D_{fln} *must* be relative to a "current position" which is *perpendicular* to checkpoint. If this is not directly known, then it must be estimated. The error of this estimation will not be multiplied at the destination, but will be retained.

Limitations: Program assumes a flat earth, thus calculations over large distances or near the poles will yield inaccurate results. Program does not compensate for windage, which may cause considerable error.

AV-17

		D_{fln}	MC_{fln}	→$D_{to\ go}$
Solid State Software			TI ©1977	
COURSE CORRECTION				AV-17
DOC(+L,−R)	Dist	DBSC	MC_i	→$MC_{to\ fly}$

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 17	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.00[1]
4	Enter distance off course (+L, −R)[2]	DOC	[A]	DOC
5	Enter distance from start to destination	Dist	[B]	Dist
	Perform Step 6 OR 7			
6	Enter distance between start and checkpoint	DBSC	[C]	DBSC
7	Enter distance flown[2]	D_{fln}	[2nd] [C']	DBSC
	Perform Step 8 OR 9			
8	Enter intended course	MC_i (deg)	[D]	MC_i (deg)
9	Enter actual course	MC_{fln} (deg)	[2nd] [D']	MC_i (deg)
10	Calculate corrected course		[E]	$MC_{to\ fly}$ (deg)
11	Calculate distance remaining		[2nd] [E']	$D_{to\ go}$
12	For a new problem, go to Step 4			

NOTES:
1. Initialization uses [CMs] key and selects degree mode. (Step 2 is seldom needed — see Introduction.)
2. See text Remarks.
3. Program leaves calculator in fix 2 mode.

Example 1: You had planned to fly 274 n. mi. at 138° to your destination, but you are now 21.5 n. mi. to the right of a checkpoint. If you have actually flown 213 n. mi., what is your new magnetic course and distance to your destination?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 17 [SBR] [CLR]	0.00	Initialize
21.5	[+/−] [A]	−21.50	DOC (− right)
274	[B]	274.00	Dist
213	[2nd] [C']	211.91	D_{fln} → DBSC
138	[D]	138.00	MC_i (deg)
	[E]	118.90	$MC_{to\ fly}$ (deg)
	[2nd] [E']	65.71	$D_{to\ go}$

Example 2: A trip is planned of 402 n. mi. at an MC_i of 35°. But the apprentice navigator makes an unfortunate error, and you actually fly a course of 55°. This is discovered at checkpoint one which is 248 n. mi. along your original route. If you are 91 n. mi. off course (to the right), what is your $MC_{to\ fly}$ and $D_{to\ go}$?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 17 [SBR] [CLR]	0.00	Initialize
91	[+/−] [A]	−91.00	DOC
402	[B]	402.00	Dist
248	[C]	248.00	DBSC
35*	[D]	35.00	MC_i*
	[E]	4.42	$MC_{to\ fly}$
	[2nd] [E]	178.88	$D_{to\ go}$

*Since MC_{fln} is also known, this step may be replaced by:

55	[2nd] [D′]	34.85	$MC_{fln} \rightarrow MC_i$

Register Contents

R_{00}		R_{05}		R_{10} DOC	R_{15}
R_{01}		R_{06}		R_{11} Dist	R_{16}
R_{02}		R_{07}		R_{12} DBSC	R_{17}
R_{03}		R_{08}		R_{13} MC_i	R_{18}
R_{04}		R_{09}		R_{14}	R_{19}

RATE OF CLIMB
TURN PERFORMANCE

As suggested by the title, this program contains two routines which operate independently.

Rate of Climb

Given the true airspeed and altitude change (+ or −), this routine can calculate the rate of climb (+ or −) if the ground distance over which the altitude change occurs is specified. Conversely, the distance can be calculated if the rate of climb is specified. The following equations are used in these calculations.
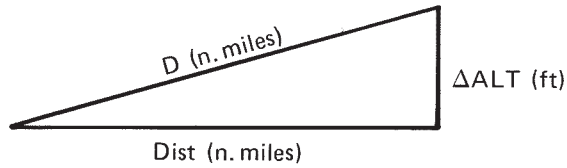
$$\text{Dist} = \left[D^2 - \left(\frac{\Delta\text{ALT}}{6076} \right)^2 \right]^{\frac{1}{2}}$$

$$\text{ROC} = \frac{\text{TAS}\,(\Delta\text{ALT})}{60\left[\text{Dist}^2 + \left(\frac{\Delta\text{ALT}}{6076} \right)^2 \right]^{\frac{1}{2}}}$$

$$D = \frac{\text{TAS}\,(\Delta\text{ALT})}{60\ \text{ROC}}$$

where

TAS = true air speed in knots

ROC = rate of climb in ft/min (+ or −)

LIMITATION: This routine assumes constant airspeed is maintained throughout the change of altitude.

Turn Performance

Given the true airspeed, bank angle, and normal stall speed, this routine computes the G-force, turn diameter, time to complete a 360° turn, and the stall speed in the turn. The turn performance indicators are computed from the following equations.

LIMITATIONS: All values assume turns with no vertical accelerations. The calculated stall speed may differ drastically from actual stall speed in turbulence, rain, etc.
Program assumes bank angle is for a no-slip turn.

$$\text{G-force} = 1/\cos (\text{Bank})$$
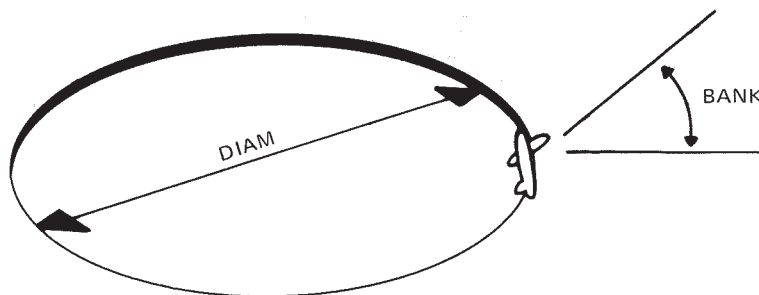
$$\text{Diam} = \text{TAS}^2 / 34208 \tan (\text{Bank})$$

$$t = 0.0055 \, \text{TAS}/\tan (\text{Bank})$$

$$\text{Stall} = \text{Nstall} \times \sqrt{\text{G-force}}$$

where

Bank = bank angle in degrees

Diam = turn diameter in n. miles

TAS = true airspeed in knots

t = time to complete 360° turn (minutes)

Nstall = normal stall speed (knots)

Stall = stall speed in turn (knots)

G-force = force in direction of turn radius expressed in parts of a G
(the gravitational constant)

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 18	
2	Select degree mode		[2nd] [Deg]	
3	Initialize		[SBR] [CLR]	0.0000[1,2]
	Rate of Climb			
4	Enter ΔALT in feet[5]	ΔALT	[2nd] [A']	0.0000
5	Enter TAS in knots	TAS	[2nd] [B']	0.0000
6	If Dist is known	Dist (n. miles)	[A]	0.0000
	Calculate ROC[3,5]		[B]	ROC (ft/min)[5]
7	If ROC is known[5]	ROC (ft/min)	[B]	0.0000
	Calculate Dist[4]		[A]	Dist (n. miles)
8	For a new case, go to Step 4			
	Turn Performance			
9	Enter TAS in knots	TAS	[2nd] [B']	0.0000
10	Enter Bank ∠ in degrees	Bank ∠	[2nd] [C']	0.0000
11	Enter Nstall in knots	Nstall	[2nd] [D']	0.0000
12	To calculate G-force		[2nd] [E']	G-force
13	To calculate Diam		[C]	Diam (n. miles)
14	To calculate t		[D]	t (HH.MMSS)
15	To calculate Stall		[E]	Stall (knots)
16	For a new case, make changes as needed in Steps 9–11 and calculate new values.			

NOTES:

1. Initialization use [CMs] and selects degree mode. (Step 2 is seldom needed — see Introduction.)
2. The program places the calculator in the fix 4 mode. To return to normal mode press [2nd] [fix] [9].
3. 0.0000 must be in the display before calculating ROC.
4. 0.0000 must be in the display before calculating Dist.
5. + if climb, − if descent.

Example 1: A pilot wishes to gain 4,000 feet in altitude over a horizontal distance of 12 nautical miles. What rate of climb is required if his true airspeed is 95 knots?

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 18		
	[SBR] [CLR]	0.0000	Initialize
4000	[2nd] [A']	0.0000	ΔALT (ft)
95	[2nd] [B']	0.0000	TAS (knots)
12	[A]	0.0000	Dist (n. mi.)
	[B]	526.9853	ROC (ft/min)

Example 2: An aircraft is descending at a rate of 700 feet per minute. What is the distance required to lose 3,200 feet in altitude if the true airspeed is 111 knots?

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 18		Select Program
	[SBR] [CLR]	0.0000	Initialize
3200	[+/−] [2nd] [A′]	0.0000	ΔALT (ft)
111	[2nd] [B′]	0.0000	TAS (knots)
700	[+/−] [B]	0.0000	ROC (ft/min)
	[A]	8.4407	Dist (n. mi.)

Example 3: Calculate the G-force, diameter of turn, time required for a 360° turn, and stall speed in a 40° bank with a true airspeed of 105 knots and a normal stall speed of 55 knots.

ENTER	PRESS	DISPLAY	COMMENTS
	[2nd] [Pgm] 18		Select Program
	[SBR] [CLR]	0.0000	Initialize
105	[2nd] [B′]	0.0000	TAS (knots)
40	[2nd] [C′]	0.0000	Bank (deg)
55	[2nd] [D′]	0.0000	Nstall (knots)
	[2nd] [E′]	1.3054	G-force
	[C]	0.3841	Diam (n. mi.)
	[D]	0.0041	t (HH.MMSS)
	[E]	62.8399	Stall (knots)

Register Contents

R_{00}		R_{05}		R_{10} ΔALT	R_{15}
R_{01}		R_{06}		R_{11} Dist	R_{16}
R_{02}		R_{07}		R_{12} ROC	R_{17}
R_{03}		R_{08} TAS		R_{13} Bank	R_{18}
R_{04}		R_{09}		R_{14} Nstall	R_{19}

GENERAL WEIGHT AND BALANCE

This program computes the total weight, total moment, and center of gravity of an aircraft given the weight and either moment or moment arm of each item. Conversions from gallons to pounds of fuel, and from pounds to kilograms are available.

The following equations are used:

$$\text{Mmt} = \text{Mmt arm} \times \text{Wt}$$

$$\text{C of G} = \frac{\text{tot Mmt}}{\text{tot Wt}}$$

$$\text{tot Wt} = \Sigma \ \text{Wt}$$

$$\text{tot Mmt} = \Sigma \ \text{Mmt}$$

where

Mmt = moment

Wt = weight

C of G = center of gravity in distance from reference point

tot = total

Any unit system may be used, but units must be compatible throughout for correct results.

	Solid State Software	TI ©1977
GENERAL WEIGHT AND BALANCE		**AV-19**

del Lst Pr	Mmt	gas gal → lbs	lbs → kgs	del Nxt Pr
Wt	Mmt Arm	→ tot Wt	→ tot Mmt	→ C of G

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 19	0
2	Initialize		[SBR] [CLR]	0.00
3	Enter weight of item	Wt	[A]	Wt
	Do 4a OR 4b			
4a	Enter moment arm	Mmt arm	[B]	Mmt
4b	Enter moment	Mmt	[2nd] [B']	Mmt
5	To delete pair just entered (3 and 4)[1]		[2nd] [A']	0.00
6	Repeat Steps 3 and 4 for each data pair			
7	Compute total weight, total moment, and center of gravity (any order)		[C] [D] [E]	tot Wt tot Mmt C of G
8	To delete any pair: then, perform Steps 3 and 4 for deleted pair		[2nd] [E']	0.00
9	For a new case, go to Step 2			
10	To convert gallons of fuel to pounds of fuel	Gal (fuel)	[2nd] [C']	Lbs (fuel)
11	To convert pounds to kilograms	Lbs	[2nd] [D']	Kg

NOTES: 1. Step 5 causes the last pair to be deleted. If a mistake is made in Steps 3 and 4, do not perform Step 5 until both Steps 3 and 4 are completed.

2. Program leaves calculator in fix 2 mode.

3. Initialization uses [CMs] instruction.

Example: Find the total weight, total moment, and center of gravity for an aircraft loaded as follows. If these quantities exceed aircraft limits, change loading and recompute.

Item	Weight (lbs)	Moment arm (in)	Moment (in-lbs)
Empty aircraft	1400		18,000
Fuel	[22 gal]	30	
Oil	15		−450
Pilot	180	12.15	
Passenger 1	130	38	
Passenger 2	215	65	
Baggage	32	70	

Aircraft limits are:

Wt = 2,500 lbs   C of G (max) = 22 in

Mmt = 43,000 in-lbs   C of G (min) = 12 in

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 19 [SBR] [CLR]	0.00	Initialize
1400	[A]	1400.00	Empty Wt
18000	[2nd] [B']	18000.00	Mmt
22	[2nd] [C']	132.00	Gal → lbs
	[A]	132.00	Fuel Wt
30	[B]	3960.00	Mmt
15	[A]	15.00	Oil Wt
450	[+/−] [2nd] [B']	−450.00	Mmt
180	[A]	180.00	Pilot Wt
12.15	[B]	2187.00	Mmt
130	[A]	130.00	Pass. 1 Wt
38	[B]	4940.00	Mmt
2215	[A]	2215.00	(Mistake)
65	[B]	143975.00	
	[2nd] [A']	0.00	Delete last pr.
215	[A]	215.00	Pass. 2 Wt
65	[B]	13975.00	Mmt
32	[A]	32.00	Baggage Wt
70	[B]	2240.00	Mmt
	[C]	2104.00	tot Wt
	[D]	44852.00	tot Mmt
	[E]	21.32	C of G

The total moment is too large, so we must move weight forward. Exchange passengers and recompute

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [E']	0.00	Delete next pr.
130	[A]	130.00	(Pass. 1 Wt)
38	[B]	4940.00	(Mmt)
	[2nd] [E']	0.00	Delete next pr.
215	[A]	215.00	(Pass. 2 Wt)
65	[B]	13975.00	(Mmt)
215	[A]	215.00	Pass. 2 Wt
38	[B]	8170.00	Mmt
130	[A]	130.00	Pass. 1 Wt
65	[B]	8450.00	Mmt
	[D]	42557.00	tot Mmt
	[E]	20.23	C of G

Weight and balance are now acceptable.

Register Contents

R_{00}		R_{05}		R_{10} Wt	R_{15}
R_{01}		R_{06}		R_{11} Mmt	R_{16}
R_{02}		R_{07}		R_{12} tot Wt	R_{17}
R_{03}		R_{08}		R_{13} tot Mmt	R_{18}
R_{04}		R_{09}		R_{14}	R_{19}

CUSTOMIZED WEIGHT AND BALANCE

This program is a customized version of AV-19 *(General Weight and Balance)*, calculating total weight, total moment, and center of gravity for an aircraft with as many as 3 rows of seats, 2 fuel tanks, and 2 baggage compartments. The program requires the pilot to enter the constants relevant to his aircraft directly into the data registers. These include the moment arms for each row of seats, tanks, and baggage compartments, as well as the empty weight and empty moment. Most aircraft manuals include a table of moment arms; if not, they can be derived from the loading diagram (see note below).

> Empty weight = ("licensed empty weight" + weights of oil, unusable fuel, manuals, etc. . . .)
>
> Empty moment = ("licensed empty moment" + moments due to oil, unusable fuel, manuals, etc. . . .)

Other applicable formulas are shown in AV-19.

If you own a TI Programmable 59 you may prepare a customized Constant Card once you have loaded your constants into data memory. To prepare the Constant Card, see User Instructions and Example 1. Once the Constant Card has been recorded, it can be used to store these constants into the proper data registers whenever you need to compute weight and balance for that particular aircraft. First, load the Constant Card. This stores the constants into the appropriate registers. Then select this program and proceed according to the User Instructions.

To recompute weight and balance with new inputs, or to change inputs at any time, only those inputs need be reentered. (Example—to change a value already entered for Fuel 1, simply enter new value and press [STO] **01** just as you would for the initial value.)

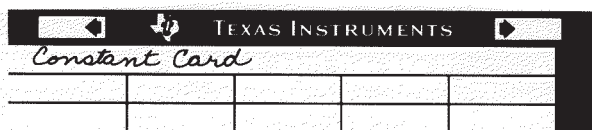**Remark:** Example of determination of moment arm from loading diagram.
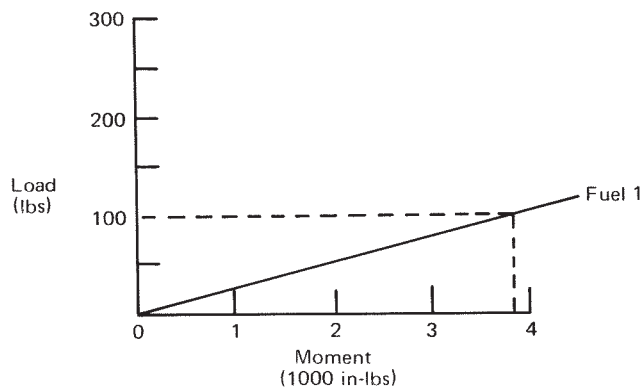
A moment of 3800 in-lbs of fuel corresponds to a load of 100 lbs.

$$\text{Moment arm} = \frac{\text{Moment}}{\text{Load}}$$

$$= \frac{3800}{100} = \boxed{38 \text{ in}}$$

Remark: While inches, pounds, and inch-pounds are standard units, any other compatible unit system may be used, such as centimeters, kilograms, and centimeter-kilograms.

```
┌─────────────────────────────────────────────────┐
│  ◄   ⬢  TEXAS INSTRUMENTS   ►                     │
│ ─────────────────────────────────────────        │
│ Constant Card                                     │
│ ─────────────────────────────────────────        │
│          │      │      │      │                   │
└─────────────────────────────────────────────────┘
```

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Initialize		[CLR] [2nd] [CMs]	0.
2	Enter Fuel 1 moment arm[1]	Mmt arm (in)	[STO] [0] [1]	
3	Enter Fuel 2 moment arm	Mmt arm (in)	[STO] [0] [2]	
4	Enter Bag 1 moment arm	Mmt arm (in)	[STO] [0] [3]	
5	Enter Bag 2 moment arm	Mmt arm (in)	[STO] [0] [4]	
6	Enter Fr Row moment arm	Mmt arm (in)	[STO] [0] [5]	
7	Enter Rr Row moment arm	Mmt arm (in)	[STO] [0] [6]	
8	Enter Mid Row moment arm	Mmt arm (in)	[STO] [0] [7]	
9	Enter Empty Moment	Empty Mmt (in-lbs)	[STO] [0] [8]	
10	Enter Empty Weight	Empty Wt (lbs)	[STO] [0] [9]	
	To Record Constant Card[2]			
11	Select floating point mode[3]		[INV] [2nd] [Fix]	
12	Record data on Constant Card	4 Feed in card	[2nd] [Write]	4.
13	Test card — turn calculator off, then on. Load card	Feed in card	[CLR]	0. 4.
	Recall R_{01} through R_{09} and compare with appropriate figures			
	Example		[RCL] [0] [1]	Fuel 1 Mmt arm

NOTES:
1. Simply skip the step for any moment arm which is not applicable. But note that each register assignment *must* correspond to its proper moment arm (as shown in Steps 2-10) to yield correct results. Registers 01–09 *are not* available to the user even if that step is skipped.

2. TI Programmable 59 only.

3. A magnetic card may not be recorded when the calculator is in a fix decimal mode.

Example 1: Load these constants into the appropriate data registers:

Length of moment arms (in)

Fuel 1	38
(no second fuel tank)	
Bag 1	42
Bag 2	110
Fr Row	48
Rr Row	97
Mid Row	73

Empty Mmt	72142 in-lbs
Empty Wt	2714 lbs

ENTER	PRESS	DISPLAY	COMMENT
	[CLR] [2nd] [CMs]	0.	
38	[STO] [0] [1]	38.	Fuel 1
42	[STO] [0] [3]	42.	Bag 1
110	[STO] [0] [4]	110.	Bag 2
48	[STO] [0] [5]	48.	Fr Row
97	[STO] [0] [6]	97.	Rr Row
73	[STO] [0] [7]	73.	Mid Row
72142	[STO] [0] [8]	72142.	Empty Mmt
2714	[STO] [0] [9]	2714.	Empty Wt.

If you have a TI Programmabe 59 , record this on a magnetic card (remember to select the floating point mode if necessary). Press [4] [2nd] [Write] and feed in card. The constants are now recorded on the card and should be checked as indicated in Step 13.

The next step is to enter the actual weight (fuel, baggage, and passengers) carried on the aircraft as described below.

Solid State Software		TI ©1977		
CUSTOMIZED WEIGHT AND BALANCE			AV-20	
Fuel 2	Bag 2	Fr Row	Rr Row	Mid Row
Fuel 1	Bag 1	→ tot Wt	→ tot Mmt	→ C of G

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Load Constant Card **OR**		[CLR] (feed card)	4.
2	Load data registers manually[3]			
3	Select program		[2nd] [Pgm] 20	
4	Initialize		[SBR] [CLR]	0.00
5	Enter Fuel 1 (gal)[2]	Fuel 1	[A]	Fuel 1
6	Enter Fuel 2 (gal)	Fuel 2	[2nd] [A']	Fuel 2
7	Enter Bag 1 (lbs)	Bag 1	[B]	Bag 1
8	Enter Bag 2 (lbs)	Bag 2	[2nd] [B']	Bag 2
9	Enter Fr Row (lbs)	Fr Row	[2nd] [C']	Fr Row
10	Enter Rr Row (lbs)	Rr Row	[2nd] [D']	Rr Row
11	Enter Mid Row (lbs)	Mid Row	[2nd] [E']	Mid Row
12	Calculate tot Wt		[C]	tot Wt (lbs)
13	Calculate tot Mmt		[D]	tot Mmt (in-lbs)
14	Calculate C of G		[E]	C of G (in)
15	For a new case, do the steps (among Steps 5–11) to make desired changes, then go to Step 12.			

NOTES:
1. Do not attempt to enter any value which is not applicable to the aircraft described on the Constant Card. Note that program automatically converts gallons to pounds for Step 5 and 6. Do not enter pounds.

2. Program leaves calculator in fix 2 mode.

3. See the last set of User Instructions.

Example 2: Compute the weight and balance for the aircraft in the last example, given the following data:

Fuel 1	35 gal
Bag 1	32 lbs
Bag 2	17 lbs
Pilot and passenger (Fr Row)	270 lbs
Passenger (Rr Row)	170 lbs
Passenger (Mid Row)	140 lbs

Repeat example 1 or read the Constant Card if you recorded one.

ENTER	PRESS	DISPLAY	COMMENT
	[CLR]	0.	
Feed in Card		4.	

Now enter the data given above.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 20 [SBR] [CLR]	0.00	Initialize
35	[A]	35.00	Fuel 1
32	[B]	32.00	Bag 1
17	[2nd] [B']	17.00	Bag 2
270	[2nd] [C']	270.00	Fr Row
170	[2nd] [D']	170.00	Rr Row
140	[2nd] [E']	140.00	Mid Row
	[C]	3553.00	tot Wt
	[D]	123006.00	tot Mmt
	[E]	34.62	C of G

Register Contents

R_{00}	Used	R_{05}	Fr Row Ma	R_{10}	Fuel 1	R_{15}	Rr Row
R_{01}	Fuel 1 Ma	R_{06}	Rr Row Ma	R_{11}	Fuel 2	R_{16}	Mid Row
R_{02}	Fuel 2 Ma	R_{07}	Mid Row Ma	R_{12}	Bag 1	R_{17}	tot Wt
R_{03}	Bag 1 Ma	R_{08}	Empty Mmt	R_{13}	Bag 2	R_{18}	tot Mmt
R_{04}	Bag 2 Ma	R_{09}	Empty Wt	R_{14}	Fr Row	R_{19}	Used

PILOT UNIT CONVERSIONS

This program converts between various measures of length, between degrees Fahrenheit and Celsius, between gallons (U.S.) and pounds of gasoline, between liters and gallons, and between pounds and kilograms. The following conversion factors are used:

$$1 \text{ foot} = 0.3048 \text{ meters}$$
$$1 \text{ kilometer} = 1,000 \text{ meters}$$
$$1 \text{ nautical mile} = 1,852 \text{ meters}$$
$$1 \text{ statute mile} = 1,609.344 \text{ meters}$$
$$1 \text{ gallon (U.S.) of gasoline} = 6 \text{ pounds of gasoline}$$
$$1 \text{ liter} = 0.26417786 \text{ gallons (U.S.)}$$
$$1 \text{ pound} = 0.453592 \text{ kilograms}$$
$$^\circ C = 5/9 \, (^\circ F - 32)$$

The user defined keys are assigned as follows:

A	meters	A'	$^\circ F \rightarrow \,^\circ C$
B	feet	B'	gallons of gas → pounds of gas
C	kilometers	C'	liters → gallons (U.S.)
D	nautical miles	D'	pounds → kilograms
E	statute miles	E'	← [INV]

To convert between units of length, key in the length and press the user defined key corresponding to the units which the length is expressed in. Then press the user defined key corresponding to the unit of length which is desired. The length expressed in the new units will be displayed (see Example 1).

Use the second function of the user defined key [A' — D'] to make other conversions. To convert in the direction indicated on the card (for example, $^\circ F$ to $^\circ C$ is shown on the card as $^\circ F \rightarrow \,^\circ C$), simply enter the number and press the second function of the key. And to convert in the opposite direction (for example, $^\circ C \rightarrow \,^\circ F$), enter the number and press [2nd] [E'], (← [INV]) before pressing the appropriate key (see Example 2).

Other conversions are available from programs ML-24 and ML-25 in the Master Library Module supplied with your calculator.

Remarks:

1. Conversions can be performed without affecting keyboard calculations in progress. However, data registers R_{15} and R_{16} must be reserved for conversions.

2. Most answers will be correct to at least 5 significant figures.

AV-21

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 21	
2	Initialize		[SBR] [CLR]	0.
3	Enter number to be converted (if not already in display)	nnn		nnn
	To convert units of length			
4	Press key corresponding to units of number in display		([A] – [E])	nnn
5	Press key corresponding to units desired		([A] – [E])	xxx
	To convert other units			
6	Press key corresponding to conversion desired, or [2nd] [E′] if the inverse of that key is desired	OR	([2nd] [A′] – [D′]) [2nd] [E′] ([2nd] [A′] – [D′]	xxx xxx
7	**For a new case, do Steps 3–5 OR 3 and 6**			

NOTE: To correct an entry or incorrect user defined key push, press [SBR] [CLR] and start over.

Example 1: Convert 7.2 meters to feet.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 21 [SBR] [CLR]	0.	Initialize
7.2	[A]	7.2	meters
	[B]	23.62204724	feet

Convert 6,000 feet to nautical miles, then to kilometers.

ENTER	PRESS	DISPLAY	COMMENT
6000	[B]	6000	feet
	[D]	0.9874730022	nautical miles
	[D]	0.9874730022	
	[C]	1.8288	kilometers

Example 2: Convert 410°F to °C.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 21 [SBR] [CLR]	0.	Initialize
410	[2nd] [A']	210	°F → °C

Convert 25 pounds of gasoline to liters.

ENTER	PRESS	DISPLAY	COMMENT
25	[2nd] [E'] [2nd] [B']	4.166666667	Gal gas
	[2nd] [E'] [2nd] [C']	15.77220236	liters

Register Contents

R_{00}	R_{05}	R_{10}	R_{15}	Used
R_{01}	R_{06}	R_{11}	R_{16}	Used
R_{02}	R_{07}	R_{12}	R_{17}	
R_{03}	R_{08}	R_{13}	R_{18}	
R_{04}	R_{09}	R_{14}	R_{19}	

RNAV FLIGHT PLANNING

The RNAV Flight Planning program facilitates planning flights for RNAV equipped aircraft that require radial/DME distance to establish waypoints. The program provides waypoint rhumbline navigation with the capability to determine the latitude and longitude of a point on the rhumbline track given the leg distance down the track. This calculated position is stored and indexed for use in the computation of the magnetic radial and DME distance from a way-point off the rhumbline track.
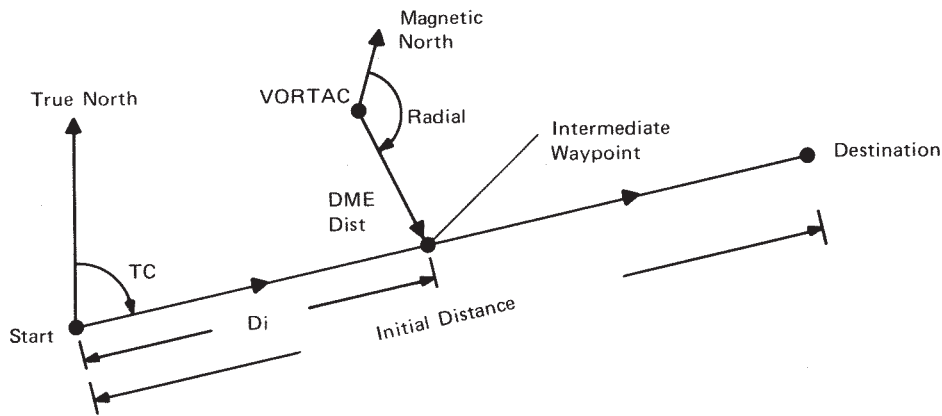
The initial true course and distance are calculated by calling the Rhumbline Navigation program (see AV-10 for equations). Intermediate positions along the rhumbline track are calculated by:

$$L_i = (D_i/60) \cos TC + L_s$$

$$\lambda_i = \lambda_s - \left\{ (180/\pi)[\ln \tan(45 + \frac{L_d}{2}) - \ln \tan (45 + \frac{L_s}{2})] \tan TC \right\}$$

where:

$$D_i = \text{distance along rhumbline track}$$
$$TC = \text{true course}$$
$$L_s, \lambda_s = \text{latitude and longitude of starting position}$$
$$L_d, \lambda_d = \text{latitude and longitude of destination}$$
$$L_i, \lambda_i = \text{latitude and longitude of intermediate point}$$

The DME distance and true radial are computed using the Great Circle Flying program (let L_s, λ_s be the coordinates of the VORTAC and use L_d, λ_d for the intermediate waypoint in the equations for AV-11). The magnetic radial is then computed by adding an input magnetic variation to the true radial.

	Solid State Software	TI ©1977

RNAV FLIGHT PLANNING				AV-22
→TC	→Dist	Leg Dist	Var (+W,−E)	→Rad; DME
WP #	L(+W,−E)	λ(+N,−S)	# From	# To

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 22	
2	Initialize		[SBR] [CLR]	0.0000
	For each waypoint, do Steps 3a, b, and c			
3a	Enter number of waypoint to be entered[1,2]	WP #	[A]	WP #
3b	Enter latitude of waypoint (+N, −S)	L (DD.MMSS)	[B]	L (decimal)
3c	Enter longitude of waypoint (+W, −E)	λ (DDD.MMSS)	[C]	λ (decimal)
4a	Enter starting waypoint number	WP$_s$	[D]	WP$_s$
4b	Enter destination waypoint number	WP$_d$	[E]	WP$_d$
5a[3]	Calculate initial true course		[2nd] [A′]	TC (decimal)
5b	Calculate initial distance		[2nd] [B′]	Dist (n. mi.)
	Do Steps 6-10 for each intermediate waypoint			
6a[5]	Enter number of waypoint from which intermediate waypoint is to be defined	WP #	[D]	WP #
6b	Enter number of intermediate waypoint to be defined	WP #	[E]	WP #
7	Calculate and store coordinates of intermediate waypoint[4]	Leg Dist	[2nd] [C′]	WP$_i$
8[5]	Enter waypoint number of VORTAC to be moved to intermediate waypoint	WP #	[D]	WP #
9[5]	Enter magnetic variation of VORTAC to be moved to intermediate waypoint	Var (+W, −E)	[2nd] [D′]	Var
10a	Compute Radial from VORTAC to intermediate waypoint		[2nd] [E′]	Radial
10b	Compute DME distance from VORTAC to intermediate waypoint		[R/S]	DME Dist

AV-22

NOTES: 1. The number of waypoints that may be entered depends upon the number of data registers available for program use as shown below.
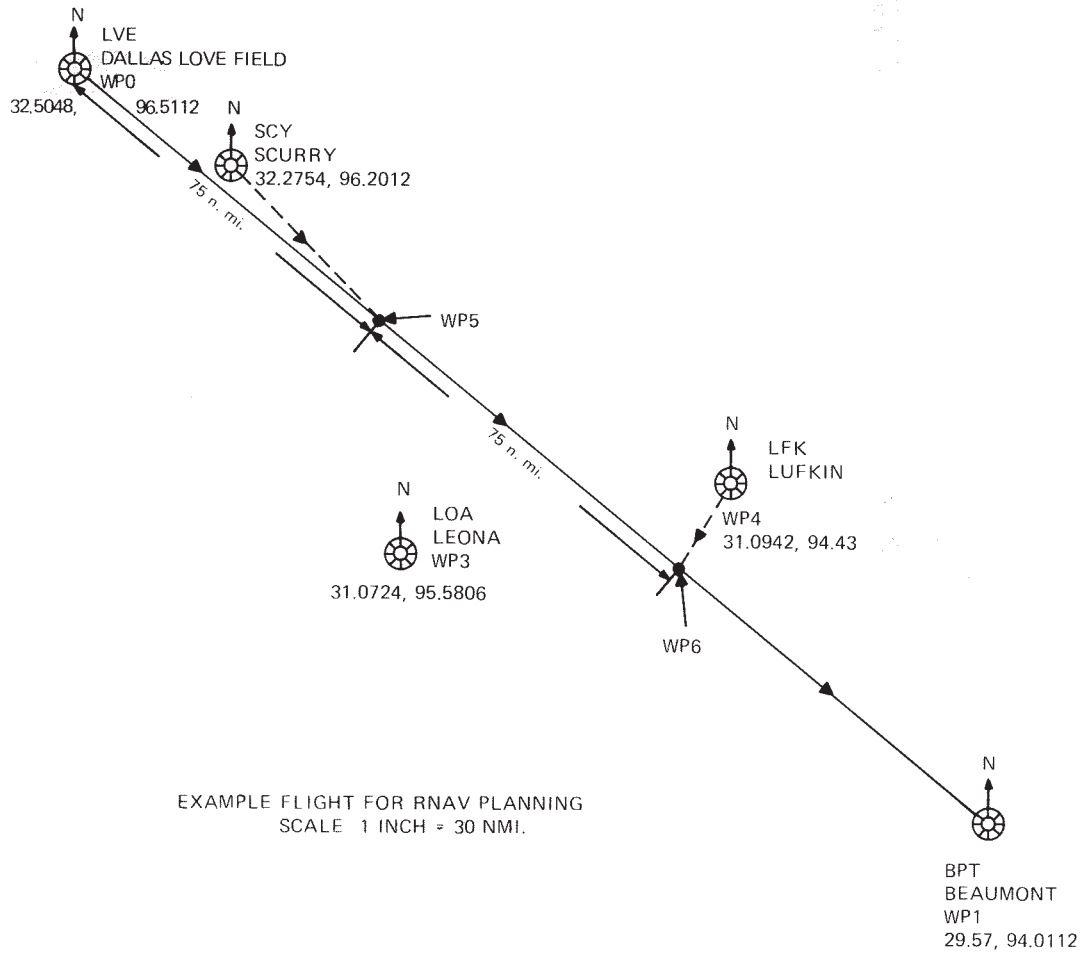
Number of Registers	Maximum Number of Waypoints
20	3
30	8
40	13
50	18
60	23
70*	28
80*	33
90*	38
100*	43

See your Owner's Manual for complete instructions on partitioning your calculator's storage area.

2. Once you have entered this data you may record it on a magnetic card. If you have already recorded the data simply read the card to load the data registers. For 8 or fewer waypoints you need only record bank 4 of your calculator's storage area. For more than 8 points record banks 3 and 4; for more than 23, record 2, 3, and 4; and for more than 38 points, record all four banks. See your Owner's Manual for complete instructions on reading and recording magnetic cards (TI Programmable 59 only).

3. This step establishes an initial rhumbline course for setting up intermediate waypoints.

4. The coordinates are stored as indicated in Register Contents. The output is simply a reminder of the waypoint number. If you need to know these coordinates simply recall the appropriate data registers and press [INV] [2nd] [D.MS] to convert the latitude and longitude to the form DD.MMSSs.

5. This step may be omitted if the last value entered on this key was the same as the value you currently desire to enter.

*Indicates TI Programmable 59 only.

Example: You are planning a flight from Dallas Love Field to Beaumont/Port Arthur Jefferson County Airport. Your RNAV gives you heading information to fly directly to or from "pseudo VORTAC's" moved a specified distance on a specified radial from the given VORTAC station. Looking at your chart you decide you would like 2 such intermediate waypoints along your rhumbline course which are 75 and 150 miles from Dallas Love Field.

N
LVE
DALLAS LOVE FIELD
WP0
32.5048,   96.5112

N
SCY
SCURRY
32.2754, 96.2012

75 n. mi.

WP5

75 n. mi.

N
LFK
LUFKIN

N
LOA
LEONA
WP3
31.0724, 95.5806

WP4
31.0942, 94.43

WP6

EXAMPLE FLIGHT FOR RNAV PLANNING
SCALE 1 INCH = 30 NMI.

N
BPT
BEAUMONT
WP1
29.57, 94.0112

The first intermediate point is to be established from Scurry VOR (SCY) and the second from Lufkin (LFK). What is the rhumbline true course and distance for the overall flight? What are the radials and DME distances of the intermediate waypoints from the appropriate VOR's assuming the magnetic variation is 8°E for Scurry and Lufkin.

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 22 [SBR] [CLR]	0.0000	Initialize
0	[A]	0.0000	Load FIX #0
32.5048	[B]	32.8467	L_0
96.5112	[C]	96.8533	λ_0
1	[A]	1.0000	Load FIX #1
29.57	[B]	29.9500	L_1
94.0112	[C]	94.0200	λ_1
2	[A]	2.0000	Load FIX #2
32.2754	[B]	32.4650	L_2
96.2012	[C]	96.3367	λ_2
3	[A]	3.0000	Load FIX #3
31.0724	[B]	31.1233	L_3
95.5806	[C]	95.9683	λ_3
4	[A]	4.0000	Load FIX #4
31.0942	[B]	31.1617	L_4
94.43	[C]	94.7167	λ_4
(Now that your data is entered establish the initial rhumbline course.)			
0	[D]	0.0000	Starting WP #
1	[E]	1.0000	Destination WP #
	[2nd] [A']	140.1466	Initial TC
	[2nd] [B']	226.3944	Initial Dist
(Establish waypoint #5 75 miles from Dallas Love Field.)			
0*	[D]	0.0000	From WP #
5	[E]	5.0000	New WP #
75	[2nd] [C']	5.0000	Dist
2	[D]	2.0000	Move WP #2 (SCY)
8	[+/−] [2nd] [D']	−8.0000	Var of above WP
	[2nd] [E']	139.5805	Rad to #5
	[R/S]	41.0264	Dist to #5
(Establish waypoint #6 75 miles from waypoint #5.)			
5	[D]	5.0000	From WP #
6	[E]	6.0000	New WP #
75	[2nd] [C']	6.0000	Dist
4	[D]	4.0000	Move WP #4 (LFK)
8*	[+/−] [2nd] [D']	−8.0000	Var of above WP
	[2nd] [E']	214.4745	Rad to #6
	[R/S]	19.0333	Dist to #6

Register Contents

R_{00}	Pointer	R_{05}	Var	R_{10}	Used	R_{15} λ_0	R_{20} and above
R_{01}	From L	R_{06}	TC	R_{11}	Used	R_{16} L_1	are used similar
R_{02}	From λ	R_{07}	$\lambda_{FM} - \lambda_{TO}$	R_{12}	TC (Rhumbline)	R_{17} λ_1	to $R_{14} - R_{19}$
R_{03}	To L	R_{08}	Dist/60	R_{13}		R_{18} L_2	
R_{04}	To λ	R_{09}	tot Dist	R_{14}	L_0	R_{19} λ_2	

* Note that this step is not actually needed since the last entry made on this key was the same as the current entry.

TIME ZONE CONVERSIONS

Given the date and time in any particular time zone, this program will determine the date and time in the same or in another zone at a specified time earlier or later.

The standard time zone system is theoretically based on the division of the world into 24 zones, each 15° longitude in width (first done to simplify railroad scheduling). In practice, the division does not follow this scheme exactly, but more often follows national boundaries or other convenient divisions. Therefore, the pilot should consult applicable maps for schematic representation. The best tabular references are the *Air Almanac,* 1976 (pp. A20-A23) and the *Nautical Almanac,* 1976 (pp. 262-265). The times shown in these publications is divided into 3 groups: List 2 are those places using GMT (zone 0); List 1 are those places east of Greenwich, and times shown should be entered as negative zone numbers; List 3 is west of Greenwich, and should be entered as positive (see below).

Each zone is assigned a zone number corresponding to time fast or slow on GMT. The zone (GMT) containing 0° longitude is assigned zone number 0. The zone number increases in the westerly direction, reaching +12 on the eastern side of the International Dateline; and decreases in the easterly direction, reaching −12 on the western side of the Dateline. (Note that zone 12 is plus or minus depending on the side of the Dateline.) Note also that a place where the standard time is not an even hour from GMT can also be considered a zone. For instance, the Chatham Islands, east of Greenwich, keep a time 12:45 minutes fast on GMT. The zone number should be entered as −12.75.

Crossing the International Dateline in a westerly direction results in a date and time exactly 1 day later; crossing in an easterly direction results in a date and time exactly 1 day earlier.

Some often-used zones have names:

Eastern time	= zone 5	Hawaiian time	= zone 10
Central time	= zone 6	Greenwich mean time	= zone 0
Mountain time	= zone 7	Mid-European time	= zone −1
Pacific time	= zone 8	East-European time	= zone −2

The time is computed from:

$$t' = t + (zone - zone') + \Delta t \qquad (0 \leqslant time < 24)$$

where

t = time in first zone $\qquad$ t' = time in second zone

zone = first zone number $\qquad$ zone' = second zone number

Δt = time increment (+ if later, − if earlier)

Time is entered as HH.MMSS
Date is entered as MM.DD (MM = month, DD = day)

Limitations: Δt must be within ±648 hours (27 days). Program assumes 28 days in February. User must correct zone number or result for daylight savings time.

	Solid State Software		TI ©1977	
	TIME ZONE CONVERSIONS			AV-23
				→date'
zone	date	t	Δt	→t'

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 23	
2	Initialize		[SBR] [CLR]	0.
3	Enter time first zone number[1]	Zone	[A]	0.
4	Enter date[1],[2]	Date (MM.DD)	[B]	0.
5	Enter time[2]	t (HH.MMSS)	[C]	0.
6	Enter time increment[1],[2]	Δt (HH.MMSS)	[D]	0.
7	(Optional) Display new time and date (same zone)		[E] [2nd] [E']	t (HH.MMSS) Date (MM.DD)
8	Enter new zone number[1]	Zone'	[A]	0.
9	Display time[1] and date (new zone)		[E] [2nd] [E']	t' (HH.MMSS) date' (MM.DD)
10	To convert results of Step 9 to a new time and/or zone, go to Step 6. For a new case, go to Step 3.			

NOTES: 1. See **Limitations** in test above.

2. t, Δt, and date must be entered as follows:
   t, Δt — HH.MMSS on 24-hour clock
   date — MM.DD (M-month, D-day)

3. Interpret 24:00:00 as 0:00:00 and add one day to date.

Example 1: You plan a business flight from Tucson (zone 7) to New York (zone 5) at 22:10 on December 31 which will take 5 hours, 22 minutes. What date and time will you arrive in New York?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 23 [SBR] [CLR]	0.*	Initialize
7	[A]	0.	Zone no.
12.31	[B]	0.	Date
22.1	[C]	0.	t
5.22	[D]	0.	Δt
5	[A]	0.	Zone'
	[E]	5.3200	t' (arrival)
	[2nd] [E']	1.01	date' (Jan 1)

*Initialization requires about 10 seconds.

Example 2: You wish to fly from Honolulu, Hawaii (zone 10) to New Dehli, India (zone —5.5). With stopovers, the flight will take 35 hours, 27 minutes. You will leave at 08:40 on September 19. What date and time will you arrive in New Dehli?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 23 [SBR] [CLR]	0.	Initialize
10	[A]	0.	Zone no.
9.19	[B]	0.	Date
8.4	[C]	0.	t
35.27	[D]	0	Δt
5.5	[+/−] [A]	0.	Zone'
	[E]	11.3700	t' (arrival)
	[2nd] [E']	9.21	Date' (arrival)

Your connection in New Dehli has been delayed 6 days, and will meet you at the airport on 9/27 at 15:00. If the length of the flight is the same, when must you leave Honolulu to make your appointment?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 23 [SBR] [CLR]	0.	Initialize
5.5	[+/−] [A]	0.	Zone
9.27	[B]	0.	Date
15	[C]	0.	t
35.27	[+/−] [D]	0.	Δt
10	[A]	0.	Zone'
	[E]	12.0300	t' (depart)
	[2nd] [E']	9.25	Date'

Example 3: At 21:15 in Chicago (zone 6) on November 23, what time and date is it in Greenwich, England?

ENTER	PRESS	DISPLAY	COMMENT
	[2nd] [Pgm] 23 [SBR] [CLR]	0.	Initialize
6	[A]	0.	Zone
11.23	[B]	0.	Date
21.15	[C]	0.	t
(0)*	[D]	0.	Δt
(0)*	[A]	0.	Zone'
	[E]	3.1500	t'
	[2nd] [E']	11.24	Date'

*Already in display.

Register Contents

R_{00}	Used	R_{05}	31	R_{10}	31	R_{15}	Used
R_{01}	31	R_{06}	30	R_{11}	30	R_{16}	Used
R_{02}	28	R_{07}	31	R_{12}	31	R_{17}	
R_{03}	31	R_{08}	31	R_{13}	Used	R_{18}	
R_{04}	30	R_{09}	30	R_{14}	Used	R_{19}	

APPENDIX A: PROGRAM REFERENCE DATA

Program Number	Title	No. of Steps	Data Reg. Used	Flags Used	SBR Levels	Paren. Levels	Calls Pgm.	Special Functions Used	x ≥ t	ABS Address	Fix Decimal	CLR	=	EE*	Program Number
01	Diagnostic	106	1-6, 11		1	4	10	N/A	CP	X	9				01
02	Flight Plan with Wind	494	0, 3, 5-18		1	4		D.MS, P/R	X	X	4		X		02
03	Flight Plan and Verification	225	0, 6-17	0-3	2	4		D.MS, P/R	X	X	4	X	X		03
04	Long Range Flight Plan	555	0-29+		1	4			X	X	4	X	X		04
05	Atm, Speed, Temp, and Altitude	216	10-13		2	4		D.MS	X		2		X		05
06	Freezing Level; Lowest Usable Flight Level	89	10, 11		0	0			CP	X	0	X	X	X	06
07	Wind Components and Average Vector	187	0, 5-7, 9-15	2	2	2		P/R	X	X	2		X		07
08	Wind Triangle	219	0, 5-11, 14, 15, 17-19		3	4		D.MS, P/R	CP	X	2		X		08
09	Dead Reckoning	214	0-5, 10, 14-18		2	4		D.MS, P/R	X	X	4	X	X		09
10	Rhumbline Navigation	225	0-11		1	4		D.MS, P/R	X	X	2	X	X		10
11	Great Circle Flying	211	1-4, 6-8		1	4		D.MS	CP	X	4		X		11
12	Line of Sight Dist & Alt; DME Speed	189	0, 10-19	0	1	1			X	X	0		X		12
13	Position and Nav by One VOR	231	0, 3-11, 13-15, 17		2	4		D.MS, P/R	X	X	4		X		13
14	DME Area Nav	188	0-5, 8-29+	1	2	4		D.MS, P/R	CP	X	4		X		14
15	Area Nav Load Module	83	0-3, 12-19+		1	1	16	P/R	X		9		X		15
16	VOR Area Nav	211	0-29+	1	2	4	14	D.MS	CP	X	4		X		16
17	Course Correction	107	10-13		1	3			CP	X	2		X		17
18	Rate of Climb; Turn Performance	177	8, 10-14		1	2		D.MS	CP	X	4	X	X		18
19	General Weight and Balance	101	10-13	0	1	1				X	2	X	X		19
20	Customized Weight and Balance	156	0-19		0	1			CP	X	2	X	X		20
21	Pilot Unit Conversions	205	15, 16	0, 1	1	2		D.MS, P/R	X	X					21
22	RNAV Flight Plan	199	0-12, 14-29+		2	4	10, 11			X	4		X		22
23	Time Zone Conversions	207	0-16		1	4		D.MS	CP	X	4		X	X	23
	Pointers & Counters	205											X		

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