Operating Handbook

For

DFC SERIES AUTOPILOTS

TRUTRAK FLIGHT SYSTEMS

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General Introduction

The Trutrak autopilot can be defined as being an orthogonal rate system. This means that gyroscopic rate sensors are installed so as to sense motion about each of the major axes (roll, pitch and yaw). These sensors generate the fast signal responses necessary to create an autopilot with the best possible dynamic performance.

To fly an aircraft well about the axis controlled by the ailerons, velocity of aileron movement must be directly proportional to the rate of roll for small movement. This means that aileron position corrections do not lag behind motion of the craft about the roll axis. Aileron control systems that use a turn coordinator, which senses twice as much azimuth as roll rate, cannot do this. Instead, in turbulence, yaw disturbances cause undesired aileron movement. In some aircraft this effect is so severe that the controls may even move momentarily in the wrong direction.

The challenge at Trutrak is to create, beyond question, systems with the very best dynamic performance available—systems that need not be disengaged in turbulence, but instead provide function when needed most.

The complete Trutrak flight control system combines within a single panel-mounted programmer/computer package which includes all the electronic and sensing elements needed for the roll and pitch functions as well as a rate-gyro-controlled yaw damper.

Basic directional control is provided by digital selection of a GPS track to be flown. This replaces heading selection on the DG, and eliminates drift as well as crosswind correction. In the GPS steering mode of operation, the system responds to digital guidance information so as to fly a complex navigation program.

The vertical portion of the system contains a digital altimeter and associated altitude selector capable of selection in increments as small as fifty feet. Altitude transitions can be made by airspeed, vertical speed, or horizontal distance (VNAV) selection. If and upward vertical speed is selected which is beyond the capability of the aircraft, there will be no stall. Instead, the autopilot will cause the aircraft to climb at a pre-set minimum safe airspeed. This is the only known system to provide this safety feature.

For any set of features all Trutrak computers are identical. Servos likewise are identical in velocity response. Servos do differ according to total torque required. By providing setup functions in the programmer for system activity and torque, one Trutrak programmer-servo combination can fly any aircraft.

As a starting point in understanding how to operate the TruTrak system, the following describes the presentation of data, the operating controls, and the procedures for selecting modes of operation.

POWER UP—AIRCRAFT STATIONARY

SEE INITIALIZING THE AUTOPILOT PAGE 9

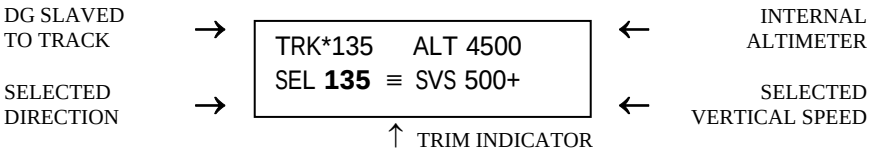
Mode and Data Display

This display normally shows operating modes and associated numerical data. It is also used to display setup mode screens and the setting of associated numerical data. When displaying operating modes, the left side shows lateral data and the right side shows vertical data. (See figure below) The upper left display labeled TRK shows the electronic DG slaved to GPS track. When the GPS track is not available TRK will be replaced by MAG, which means the autopilot now uses an internal source of magnetic information for direction. The lower left display labeled SEL shows the selected direction of flight. The upper right display shows altitude or selected altitude, and the lower right display shows either selected vertical speed or selected airspeed.

The vertical space between the left and right hand display area is used to show pitch trim. This display consists of three horizontal bars spaced vertically as the rungs on a ladder, and are made to move up or down when the aircraft is in need of being trimmed.

In the upper left where direction is shown, a flashing indicator is present between TRK or MAG and the numerals that follow. When there is no GPS position input this will be a flashing period. Once GPS position data becomes valid this will be a flashing asterisk. If GPS flight plan information is being received over the serial channel or if the GPSS option has been added and GPS steering information is being received, a flashing plus sign will indicate the presence of a useable steering (GPSS mode) or waypoint to waypoint (GPS NAV mode) signal.

A cursor in the form of an underline is shown beneath the SEL numerals. This is used to indicate that an underlined number will be set by rotation of the encoder knob.



Controls

Switches labeled **[MODE]** and **[ALT]** when depressed sequentially step through the respective lateral and vertical mode setup screens. When the desired setup screen is displayed, the numerical data to be entered will be underlined. The data is then set by rotating the encoder knob and entered by depressing and then quickly releasing the knob. This will be referred to hereafter as enter.

Another means of entering numerical data is the sequential pressing of a **[VS]** switch. Each time a **[VS]** switch is pressed, the vertical speed will be changed in increments of 100 feet per minute. Still another means of altering the display presentation is engaging or disengaging the autopilot. This is accomplished by using the **[ON OFF]** switch on the programmer or the switch located on the control wheel or stick. The control stick switch serves a dual purpose. Momentary closure will disengage the autopilot. If the switch is held closed more than two seconds, the autopilot will engage upon release. This means that in addition to disengaging the autopilot, this switch also provides the function referred to as Control Wheel Steering in that the autopilot synchronizes to both direction and vertical speed upon being engaged.

Lateral Modes

Upon being engaged, the autopilot will be in the basic lateral mode, and it will be synchronized to the direction being flown at the time. (See figure on page 3.) Note: The number following SEL (Selected direction) is underlined, meaning that rotation of the encoder will select heading. Rotation of the knob when it is not depressed will cause 5° steps of SEL and when it is depressed the steps will be 1°.

When an external heading source (DG or HSI) is present, depressing **[MODE]** one time will select the EXT DG entry screen. If this is the desired mode, pressing the encoder knob makes it the active lateral mode. When in this mode the heading "bug" within the external DG or HSI will be used to control direction.

```
TRK 135 ALT 4500
EXT  DG SVS 500+
```

The next sequential entry screen will be either GPS NAV or GPSS depending on which, if either, steering signal is available to the autopilot.

In GPS NAV mode the autopilot follows a flight plan programmed into the GPS. The autopilot will however overfly each waypoint prior to turning and intercepting the course line

```
TRK+135   ALT 4500
GPS NAV   SVS 500+
```

In the GPSS mode the autopilot follows lateral steering or bank commands generated by a navigation system (EFIS or GPS).

TRK+135	ALT 4500
GPSS	SVS 500+

The next sequential entry screen is VOR NAV or LOC NAV, depending on which is selected by the navigation receiver. The setup screen for this mode is shown below.

LOC NAV CRS **183**	
INTRCPT ANGLE 30	

The course numerals are underlined. This means that the VOR/LOC course is to be set by rotating the encoder. As the encoder is rotated, knob out equals 5° steps while knob in equals 1° steps. When course has been set press enter. The cursor (underline) has now moved to intercept angle. The default value will be 30°. The intercept angle can be set from 15° to 45° by rotation of the encoder knob. When the desired intercept angle is set, press enter.

LOC NAV CRS 183	
INTRCPT ANGLE **30**	

The selected intercept angle is now converted to an intercept direction according to which side of the course the aircraft is on.

TRK 213	ALT 4500
INT **213**	VS 500↑

Also, intercept direction is underlined which means it can be adjusted. With this feature the system is in a selected direction mode until the on course turn (tracking phase) is initiated. During the intercept phase of the approach, the lower left display will alternate to show CRS for one second out of five. When the aircraft is established on the inbound portion of the approach, the lower left display will indicate the selected course.

TRK 213	ALT 4500
CRS 213	VS 500

If the above is LOC NAV and glide slope is present (ILS), flying below the glide slope in ALT HOLD mode will arm the glide slope coupler. When this occurs, the display will be as shown below

TRK 183	AH 4500
CRS 183	GS ARMED

When the Glide slope is intercepted, the display will be as shown below.

TRK 183	ALT 2200
CRS 183	GS CPLD

When glide slope coupling is terminated, by entering either the ALT HOLD or VS mode, the

lateral mode will switch from LOC NAV to TRK mode. The selected track will be the same as the inbound course.

The next sequential mode is LOC/VOR REV. This refers to flying the localizer or VOR in the reverse direction. Operation of this mode is the same as LOC NAV except that there will be no glideslope coupling.

Magnetic Back-Up Mode

The lateral modes previously described are based on GPS track being present. When GPS is lost, the DG display is slaved to a magnetic heading source contained within the programmer, and TRK is replaced with MAG. This magnetic mode is only a backup and would seldom be needed; however, it does provide a means of selecting and maintaining a drift-free direction of flight. If an external heading source (HSI or DG) is present, the EXT HDG mode remains functional, and if the GPSS signal source is functional, the GPSS mode will also be functional. The remaining modes, VOR and LOC navigation should not be used when GPS track is absent.

Yaw Damper

(Option only)

The Yaw Damper can be used whether or not the autopilot is engaged. It automatically comes on when the autopilot is turned on. When the autopilot is off, the display is as shown below. When the autopilot is not engaged the Yaw Damper can be toggled on or off by pressing the **[MODE]** button.

TRK 000	ALT 5000
YD OFF	AP OFF

Vertical Modes

When the autopilot is engaged, it will synchronize to the vertical speed being flown at the time, and thus will be in the basic vertical speed-operating mode (see figure on page 3). While in this basic VS mode, the upper right section of the display shows altitude and the lower right section shows SVS (selected vertical speed). This mode is also entered by depressing a vertical speed button **[VS UP]** or [**VS DN].** If the system is in transition to a selected altitude pressing **[VS]** will switch from AIRSPEED to VS. It will not cancel the selected altitude

Altitude Hold Mode

Press **[ALT]** once to select ALT HOLD entry screen, and then press enter to activate the altitude hold mode. The selected altitude will be to the nearest 100 feet as viewed on

the digital altimeter. For example, pressing enter between 4950 and 5050 will select 5000.

```
CURRENT   ALT 2200
ALTITUDE  HOLD
```

-press enter-

```
TRK 183   AH  2200 SEL
183 ALT   HOLD
```

Altimeter Sync

With the autopilot engaged, the internal altimeter can only be set when the aircraft is level in the ALT HOLD mode. To accomplish this, press **[ALT],** once in order to display the current altimeter reading. Then rotate the encoder to set the internal altimeter to agree with the primary altimeter. When this is done press enter.

When the above altimeter correction has been entered the aircraft will climb or descend to again be at the displayed selected altitude.

When the autopilot is not engaged, pressing **[ALT]** once will bring up the ALTIMITER SYNC screen. Note: Be certain the autopilot screen indicates ALTIMETER SYNC and not SEL ALT as the screens are similar but have entirely different meanings. The procedure is then the same as with the autopilot engaged. When power to the autopilot is turned on the altimeter will show the same altitude as displayed at power shut down, thus if this was done at field elevation, it should show field elevation.

```
CURRENT   ALT 8000
ALTIMETER  SYNC
```

Altitude Select Mode

Pressing **[ALT]** twice will display the SEL ALT set up screen.

```
SEL ALT    4500
SEL AS     165
```

At this screen SEL ALT numerals are underlined so that rotation of the encoder selects the target altitude. When this is done press enter.

If a higher altitude has been selected, the pre-set (best-cruise climb) air speed is now displayed and underlined.

```
SEL ALT    4500
SEL IAS  165 KTS
```

This value can be modified by rotating the encoder knob. When the knob is out each step is 5 Knots and when depressed each step is 1 Knot. When air speed has been set, press enter and the altitude transition will begin. The autopilot will then revert to the normal flight display.

```
TRK 183  SA 4500
SEL 183  SAS 165
```

again be underlined. Both selected altitude and air speed can be modified while in transition. Press and release the

encoder knob once and the underlined cursor moves to selected altitude. Pressing a second time moves it to air speed and a third time returns it to direction, or after 8 seconds it will return automatically to direction. It will be observed that the airspeed will change at a constant pre-set rate from the initial value to the selected value at which point it will cease moving with no overshoot. Finally, because **[VS]** buttons are always active, the climb to a new altitude can be changed from airspeed to VS and the rate adjusted, by pressing the appropriate **[VS]** button the required number of times.

If a lower altitude is selected, the set-up screen will be as shown below in which a default downward vertical speed of 500 Fpm is shown when the selected altitude differs from the present by more than 500 feet.

```
SEL ALT     3000 SEL VS
500-
```

When the new altitude has been selected and entered the downward transition will begin at 500 fpm. Pressing the appropriate **[VS]** button can modify this value.

```
TRK 183  SA 3000 SEL
183 SVS 500-
```

VNAV Mode

Pressing [ALT] three times will display the VNAV screen:

```
SEL ALT     4500
DIST      10  NM
```

At this screen the SEL ALT numerals are under lined so that rotation of the encoder selects the target altitude. When this is done press enter.

```
SEL ALT    10000
DIST      10  NM
```

Once the desired altitude has been entered the DIST numerals are underlined so that rotation of the encoder now will select the distance in which the selected altitude will be reached.

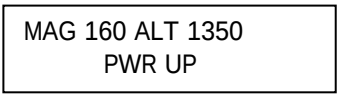
Stopping the Transition to a Selected Altitude

Once the aircraft is in climb or descent to a selected altitude, the process can only be stopped by entering the ALT HOLD mode. This is accomplished by arriving at the selected altitude or by selecting the ALT HOLD mode as per the procedure previously outlined.

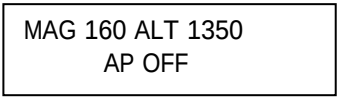
Additional Operating Instructions

Initializing the Autopilot

The autopilot master switch should be in the off position when the engine is started. Aircraft electrical systems can generate voltage transients during an engine start, and like other avionics systems, the autopilot should not be subjected unnecessarily to these conditions. After start up, turn on the autopilot master switch and **hold the aircraft stationary** as the internal gyros are initialized. This takes approximately ten seconds during which time the display will show the words PWR UP in the lower right.



When initializing is complete PWR UP will change to AP OFF.



GPS Acquisition

Between the word MAG and the three digit numeric display, a flashing period MAG•155 will appear each time the GPS sends a message to the autopilot (once per second). This indicates the GPS is working but has not yet obtained a position fix. As long as the period is shown, the heading display cannot transition to the TRK mode. When the GPS does obtain a fix, the period will be replaced by an asterisk MAG*155. This means that when a certain velocity is attained MAG will be replaced by TRK. This happens at approximately 10 Knots groundspeed as detected by GPS and will even occur at rapid taxi speeds.

Altitude Select With AP Off

If a target or assigned altitude is known prior to take-off, this altitude can be set while on the ground. As with the AP on, pressing **[ALT]** twice will display the ALT SEL setup screen. The procedure is to select the desired altitude and then press enter.

The display will show the selected altitude even though the autopilot is still off. This will serve as a reminder that the autopilot will climb to the selected altitude when engaged.

Gyro Set

When the initializing has been done correctly, the gyros should already be centered at the time of take off. If **confirmation of this is desired, with the aircraft stationary on the runway,** pressing and holding the encoder knob will put the gyros in the fast centering mode. The knob should be depressed for approximately 10 seconds during

which time the words GYRO SET will be displayed.

MAG*180 ALT 1350
GYRO SET

Engaging the Autopilot

Since the autopilot synchronizes to VS, the VS at the time of engaging should be a value that can be sustained. Otherwise airspeed will diminish as the aircraft attempts to sustain VS. As airspeed then diminishes to the pre-set minimum it will hold this value and thus prevent a stall.

When aircraft vertical speed is less than approximately 350 feet per minute, the autopilot will initially select zero vertical speed. The **[VS UP]** and **[VS DN]** keys can be used to change the initial value if desired.

Setting Pitch Trim

The pitch servo contains a torque sensor that sends a signal to the computer when the up or down force greater than a threshold value is required to fly a selected flight condition. When this signal indicates an out-of-trim condition that persists in one direction for more than a few seconds, the three moving horizontal bars will come into view and move according to the direction in which trim is required. The pilot is then required to operate the trim control (electric or manual) so as to bring the system to neutral trim. With mechanical trim this is easily done, but with electric systems it may be necessary to develop a technique. If the trim is slow enough, the pilot has plenty of time to react when the bars disappear before the trim condition is reversed. With a fast trim it will be necessary to tap or pulse the trim button so that it will be slow enough to turn it off before going too far. When a reversal takes place, a slight tap in the reverse direction may be required to get the bars to stay off. Finally, when the bars have been made to disappear and there has been no speed change, the bars can be ignored if they reappear if it is known the aircraft is close to being in trim.

Power Loss

If there is a momentary loss of electrical power, the autopilot will disengage. When this happens it is necessary to do a GYRO SET before re-engaging the autopilot. To accomplish this, the aircraft must be held very straight during which time the encoder knob is pressed to do GYRO SET. After this, engage the autopilot and note the extent to which TRK differs from SEL. If this is more than 15° repeat the gyro set procedure. The difference between TRK and SEL will be reduced at the rate of 8° per minute by the automatic gyro centering system within.

DFC Series Setup Procedure

Lateral Setup

The lateral setup consists of setting activity, torque, serial baud rate, and magnetometer calibration and various configuration parameters. To enter the setup mode, press and hold the **[MODE]** button for two or more seconds, until the first setup screen appears. This screen shows current values for the activity and torque of the aileron servo, with an underline under the present setting of activity. A typical screen might show:

```
LAT ACTIVITY 8
LAT TORQUE 200
```

The underlined number is set by rotating the encoder knob. Turn this knob to set the activity level to the desired value for the particular aircraft. Any value between 0 and 12 may be chosen. In this example, the value of 1 will be selected. Activity should be set so as to not be excessive in turbulence and yet sufficient to fly without hunting in still air. (Any lost motion or play between the servo and the control surface can cause hunting in still air).

Once activity is set to the desired value, press and quickly release the knob to confirm and enter the selected value into storage. The underline (cursor) will now move to the torque setting:

```
LAT ACTIVITY 1
LAT TORQUE 200
```

In a manner similar to activity, use the encoder knob to select the desired value of roll servo torque. This value should be between 75 and 250. A default value is set at the factory but may need to be modified to suit a particular aircraft. The value chosen should be sufficient to fly the aircraft, but not so much that it is difficult to override the autopilot if necessary.

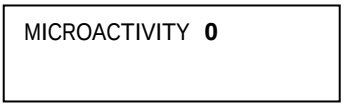
Having selected the desired torque level, again press and quickly release the encoder knob to confirm and enter the selected torque value into storage. The unit will now show the next screen:

```
BAUD RATE 4800
```

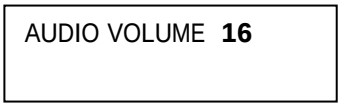
The value shown represents the speed of the primary RS-232 interface to the external GPS unit. By default at the factory it is set to 9600 baud, as that is the most commonly used value. However, it may be set to any of 600, 1200, 2400, 4800, or 9600 baud. Consult the manual for the GPS unit and follow its setup instructions to determine

its setting and set the baud rate of the autopilot to the same value. The autopilot will recognize NMEA-0183 protocol, Garmin protocol, or Apollo GX50/GX60 protocol (moving map output).

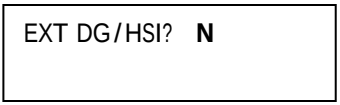
Once the desired baud rate has been selected, again press and quickly release the encoder knob to confirm and enter the selected baud rate into storage. The unit will now show the next screen:



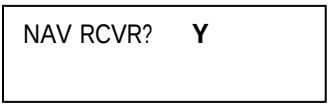
This setting is to be left at zero unless advised by the factory. Press the encoder know and the unit will now show the next screen:



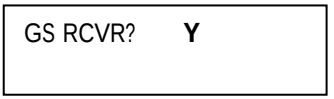
While this screen is displayed, the autopilot will send an audio tone to the audio system. Adjust the value between 0 and 16 for the desired volume, then press the knob to go to the next screen:



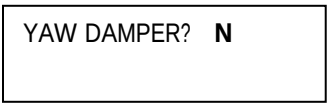
Use the encoder to select either Y (yes) or N (no) depending on whether an external DG or HSI is connected to the system. Press the knob to go to the next screen:



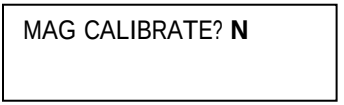
Again, select either Y or N depending on whether a source of CDI deflection is connected to the autopilot. If the question is answered Y, the NAV and LOC/NAV REV modes will be available. Press the knob to go to the next screen:



Again, select Y or N depending on whether a source of glideslope deflection is connected to the autopilot. If the question is answered Y, glideslope coupling will be available (ILS) when LOC mode is in use and a valid deflection appears on the input terminal. Press enter to go to the next screen.



Answer Y or N to indicate whether or not a Yaw Damper is present. Press the knob to go to the next screen:



This setup allows the internal magnetometer in the unit to be compensated for any

internal magnetic disturbances within the aircraft, and should be performed once the autopilot is installed in the panel of the aircraft. It may need to be repeated if the autopilot is moved within the panel, or if new equipment is installed nearby. In order to skip this step, press and quickly release the encoder knob while **N** is selected.

If a calibration is desired, it may be done in either of two ways: (1) With the autopilot disengaged, either in the air or on the ground, the operator will turn the aircraft through a full circle according to instructions, or (2) With the autopilot engaged, in flight, the autopilot directs the aircraft in the necessary flight path.

In either method of calibration, the aircraft is turned, first to North, then East, then South, and finally West. At each step, the heading is flown for approximately 20 seconds while the autopilot gathers and averages the data from the magnetometer.

The magnetometer is initially calibrated at the factory for operation in an environment free of magnetic disturbances, and should be functional, though not accurate, when mounted in the aircraft. The first calibration of the magnetometer in the actual aircraft is probably best done on the ground, on a level pavement surface, as there are fewer variables involved than would be the case in flight. Assuming that it is desired to perform this calibration, do the following steps:

(1) Rotate the encoder knob to select **Y** in the setup screen.
(2) Press and quickly release the encoder knob to begin the setup sequence. The screen will now show:

```
CALIBRATING
  TURN NORTH
```

Turn the aircraft to a heading of North using a reliable reference, either a compass or magnetically slaved DG or HSI. Once this is done, press and quickly release the encoder knob to confirm that the heading is steady. The screen will now show:

```
CALIBRATING
    HOLD NORTH
```

After a period of approximately 20 seconds, the screen will show:

```
CALIBRATING
  TURN EAST
```

Again, turn the aircraft to a heading of 090 magnetic and then press and quickly release the encoder knob. In the same manner as before, the screen will say HOLD for twenty seconds. This process is continued through South and West. Once the westerly data

has been averaged for twenty seconds, the process is complete and the screen will show:

```
CALIBRATION DONE
  PRESS ENTER
```

At this time, press and quickly release the encoder knob to confirm the calibration and enter the resulting data into permanent memory.

If the "YAW DAMPER?" question was answered "Y" and the "MAG CALIBRATE?" question was answered "N" the next screen in the setup sequence will allow adjustment controls for the yaw damper:

```
YD LEVELING __0
YD ACTIVITY  6
```

The value for leveling is adjustable from -8 to 8 and is used as necessary to have the yaw damper keep the aircraft slip/skid indicator (ball) centered when the yaw damper is engaged and the autopilot is flying the aircraft straight and level. When adjusting this value, allow a few seconds for the yaw damper to respond to each new value setting. Press and release the encoder know once the correct setting has been determined.

```
 YD LEVELING  0
YD ACTIVITY __7
```

Use the encoder knob to determine the correct amount of yaw damper response in conditions of light to moderate turbulence. Having found a satisfactory value for flight in turbulence, press and release the encoder knob to enter the value into storage.

This concludes the DFC-250 lateral setup mode.

Pitch Setup

The pitch (vertical) setup consists of setting activity and torque in a manner similar to that done for the aileron servo in the lateral setup. To enter the vertical setup mode, press and hold the **[ALT]** button for two or more seconds, until the first setup screen appears. This screen shows current values for the activity and torque of the aileron servo with an underline under the present setting of activity. A typical screen might show

```
VRT ACTIVITY 8
VRT TORQUE  200
```

Turn the encoder knob to set the activity level to the desired value for the particular aircraft. Any value between 0 and 12 may be chosen. In this example, the value of 4 will be selected.

Once activity is set to the desired value, press and quickly release the knob to confirm and enter the selected value into storage. The underline (cursor)

will now move to the torque setting:

```
VRT ACTIVITY  4
VRT TORQUE  200
```

In a manner similar to activity, use the encoder knob to select the desired value of pitch servo torque. This value should be between 75 and 250. A default value is set at the factory but may need to be modified to suit a particular aircraft. The value chosen should be sufficient to fly the aircraft, but not so much that it is difficult to override the autopilot if necessary.

Having selected the desired torque level, again press and quickly release the encoder knob to confirm and enter the selected torque value into storage. The next screen will show:

```
MIN AIRSPD  95KT
NORM CLIMB 120KT
```

Use the encoder knob to select the minimum airspeed at which the autopilot will fly the aircraft. This speed should be a safe margin above a stall. Press the knob to enter the minimum airspeed into storage, and the cursor will move to the second line, as shown below.

Select, using the encoder knob, the default value most commonly used for a climb to a selected altitude. Press the encoder knob to enter this value into storage.

```
MIN AIRSPD 120KT
NORM CLIMB 170KT
```

The next screen in the pitch setup sequence allows adjustment to compensate for the lag (delay) in the aircraft's static system.

```
STATIC LAG 0
```

Select the lowest value over the range 0 to 2 which results in the elimination of "hunting" in the altitude hold mode. This adjustment should be done in still air at cruise airspeed. Press the encoder knob to enter this value into storage.

This concludes the DFC-series autopilot pitch setup procedure.

TruTrak Flight Systems, Inc.

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