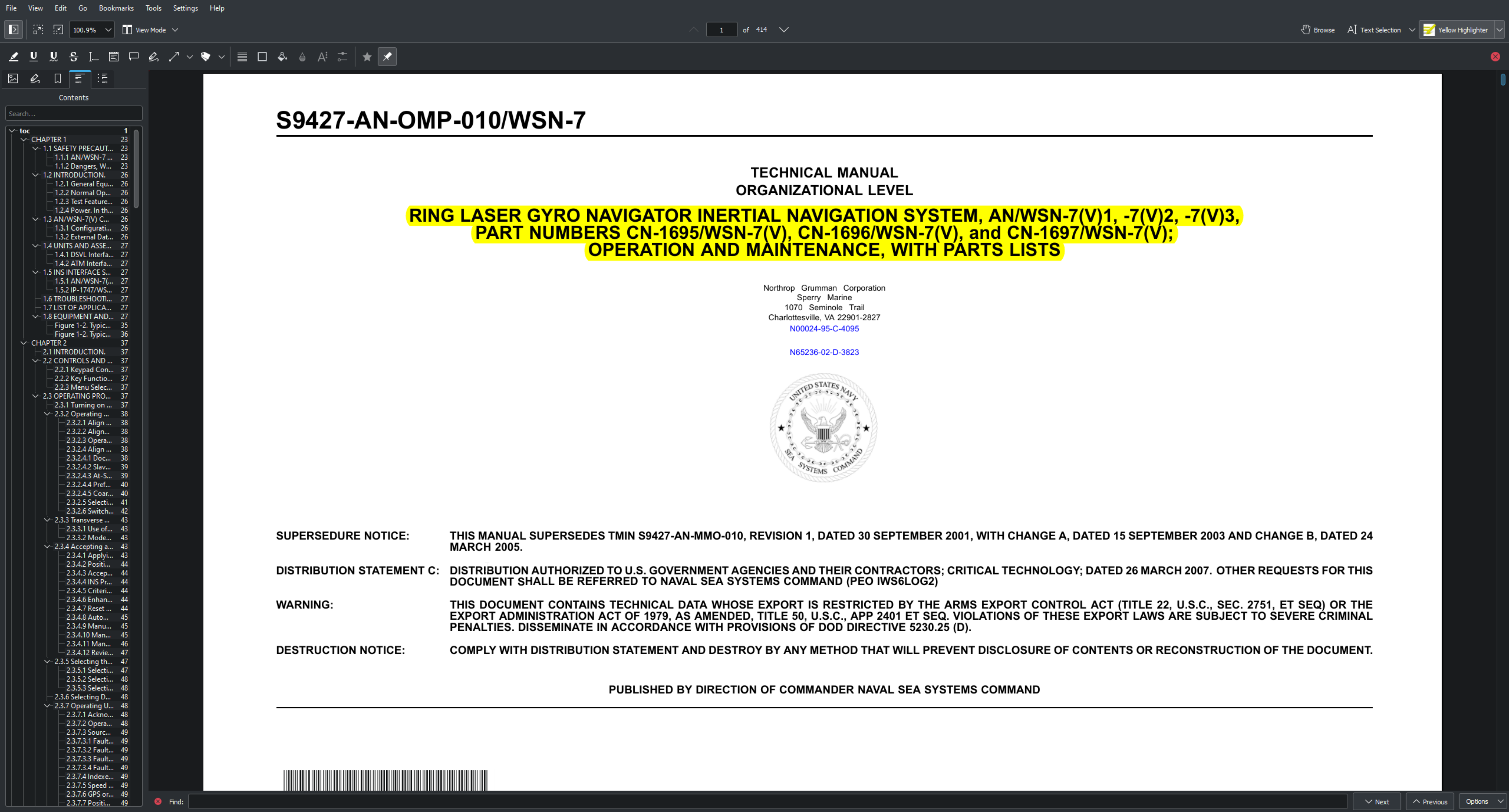


S9427-AN-OMP-010/WSN-7

TECHNICAL MANUAL
ORGANIZATIONAL LEVEL

RING LASER GYRO NAVIGATOR INERTIAL NAVIGATION SYSTEM, AN/WSN-7(V)1, -7(V)2, -7(V)3, PART NUMBERS CN-1695/WSN-7(V), CN-1696/WSN-7(V), and CN-1697/WSN-7(V); OPERATION AND MAINTENANCE, WITH PARTS LISTS

Northrop Grumman Corporation
Sperry Marine
1070 Seminole Trail
Charlottesville, VA 22901-2827
N00024-95-C-4095

N65236-02-D-3823

SUPERSEDURE NOTICE: THIS MANUAL SUPERSEDES TMIN S9427-AN-MMO-010, REVISION 1, DATED 30 SEPTEMBER 2001, WITH CHANGE A, DATED 15 SEPTEMBER 2003 AND CHANGE B, DATED 24 MARCH 2005.

DISTRIBUTION STATEMENT C: DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; CRITICAL TECHNOLOGY; DATED 26 MARCH 2007. OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO NAVAL SEA SYSTEMS COMMAND (PEO IWS6LOG2)

WARNING: THIS DOCUMENT CONTAINS TECHNICAL DATA WHOSE EXPORT IS RESTRICTED BY THE ARMS EXPORT CONTROL ACT (TITLE 22, U.S.C., SEC. 2751, ET SEQ) OR THE EXPORT ADMINISTRATION ACT OF 1979, AS AMENDED, TITLE 50, U.S.C., APP 2401 ET SEQ. VIOLATIONS OF THESE EXPORT LAWS ARE SUBJECT TO SEVERE CRIMINAL PENALTIES. DISSEMINATE IN ACCORDANCE WITH PROVISIONS OF DOD DIRECTIVE 5230.25 (D).

DESTRUCTION NOTICE: COMPLY WITH DISTRIBUTION STATEMENT AND DESTROY BY ANY METHOD THAT WILL PREVENT DISCLOSURE OF CONTENTS OR RECONSTRUCTION OF THE DOCUMENT.

PUBLISHED BY DIRECTION OF COMMANDER NAVAL SEA SYSTEMS COMMAND

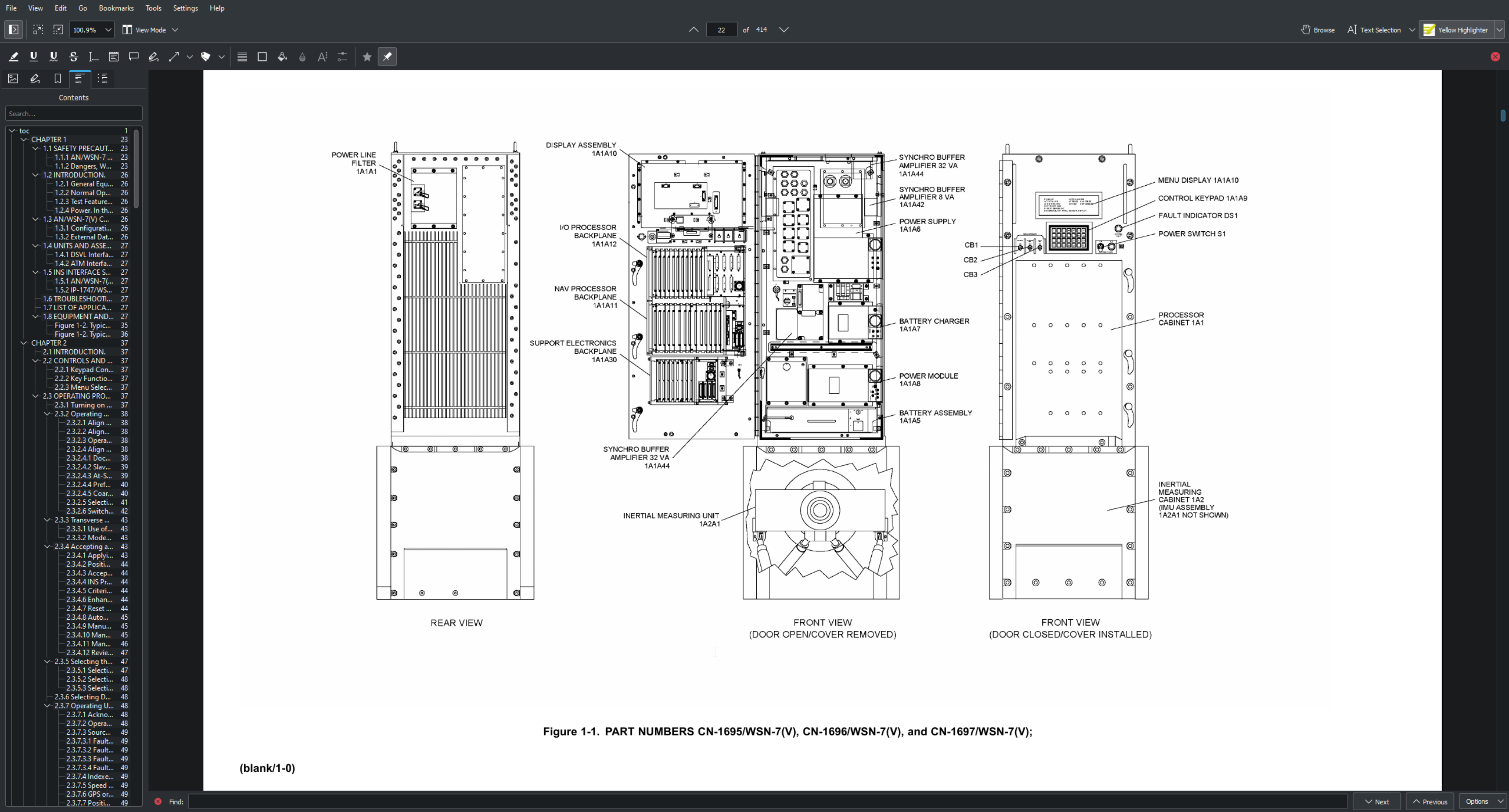
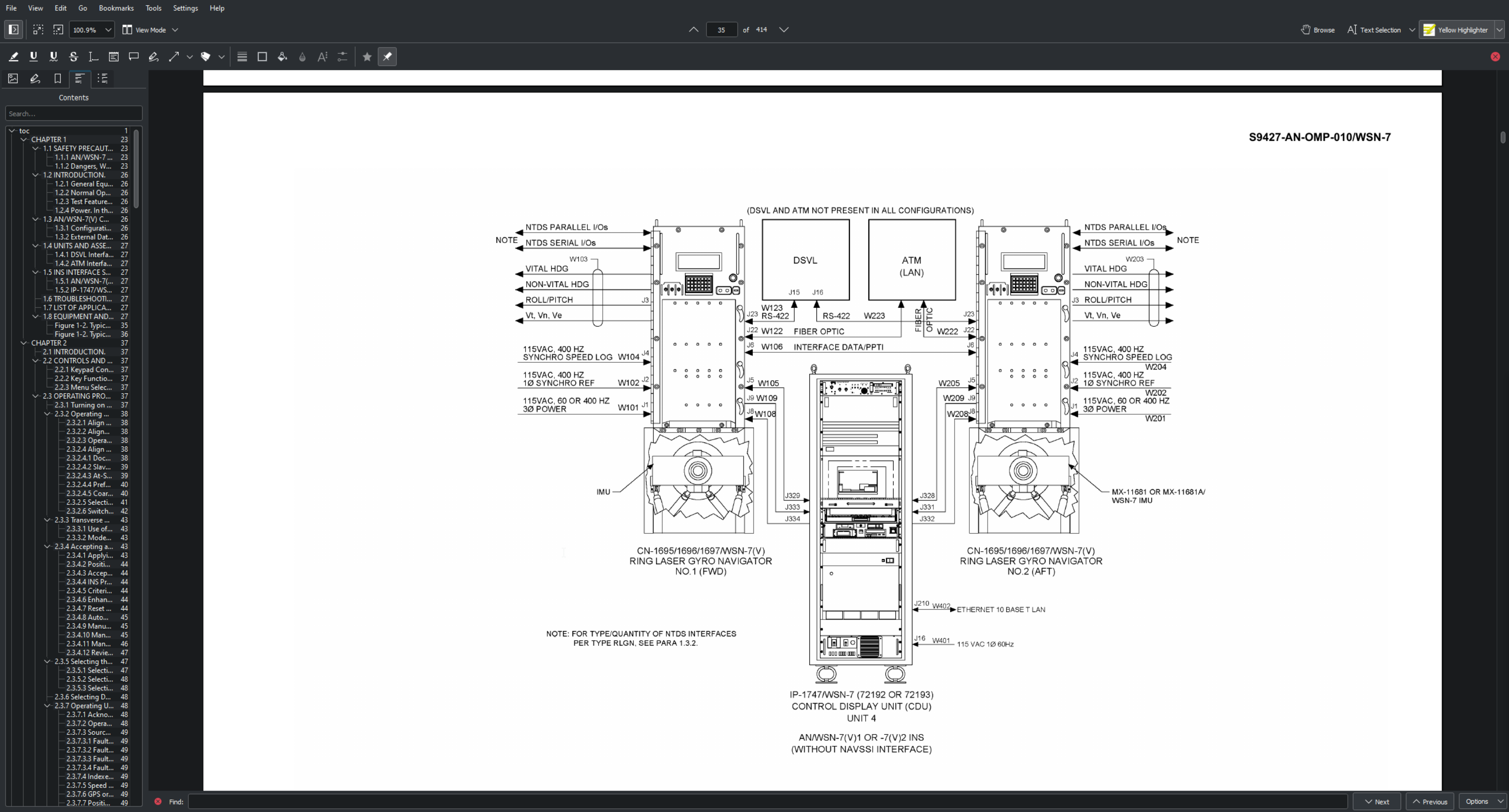


Figure 1-1. PART NUMBERS CN-1695/WSN-7(V), CN-1696/WSN-7(V), and CN-1697/WSN-7(V);

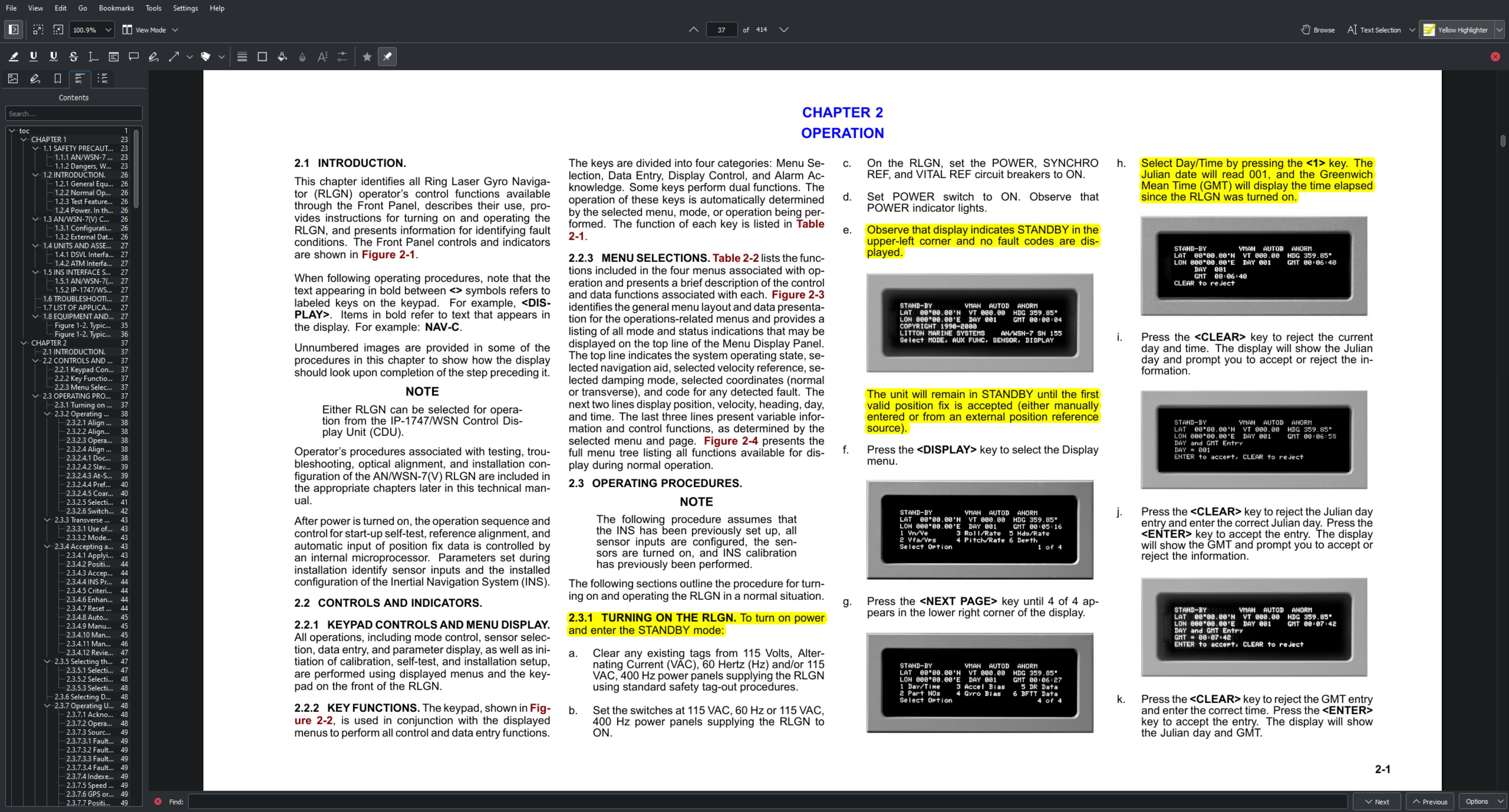


(DSVL AND ATM NOT PRESENT IN ALL CONFIGURATIONS)

NOTE: FOR TYPE/QUANTITY OF NTDS INTERFACES PER TYPE RLGN, SEE PARA 1.3.2.

IP-1747/WSN-7 (72192 OR 72193)
CONTROL DISPLAY UNIT (CDU)
UNIT 4

AN/WSN-7(V)1 OR -7(V)2 INS
(WITHOUT NAVSSI INTERFACE)



CHAPTER 2
OPERATION

2.1 INTRODUCTION.

This chapter identifies all Ring Laser Gyro Navigator (RLGN) operator's control functions available through the Front Panel, describes their use, provides instructions for turning on and operating the RLGN, and presents information for identifying fault conditions. The Front Panel controls and indicators are shown in Figure 2-1.

When following operating procedures, note that the text appearing in bold between **<>** symbols refers to labeled keys on the keypad. For example, **<DISPLAY>**. Items in bold refer to text that appears in the display. For example: **NAV-C**.

Unnumbered images are provided in some of the procedures in this chapter to show how the display should look upon completion of the step preceding it.

NOTE

> Either RLGN can be selected for operation from the IP-1747/WSN Control Display Unit (CDU).

Operator's procedures associated with testing, troubleshooting, optical alignment, and installation configuration of the AN/WSN-7(V) RLGN are included in the appropriate chapters later in this technical manual.

After power is turned on, the operation sequence and control for start-up self-test, reference alignment, and automatic input of position fix data is controlled by an internal microprocessor. Parameters set during installation identify sensor inputs and the installed configuration of the Inertial Navigation System (INS).

2.2 CONTROLS AND INDICATORS.

2.2.1 KEYPAD CONTROLS AND MENU DISPLAY.

All operations, including mode control, sensor selection, data entry, and parameter display, as well as initiation of calibration, self-test, and installation setup, are performed using displayed menus and the keypad on the front of the RLGN.

2.2.2 KEY FUNCTIONS. The keypad, shown in Figure 2-2, is used in conjunction with the displayed menus to perform all control and data entry functions. The keys are divided into four categories: Menu Selection, Data Entry, Display Control, and Alarm Acknowledge. Some keys perform dual functions. The operation of these keys is automatically determined by the selected menu, mode, or operation being performed. The function of each key is listed in Table 2-1.

2.2.3 MENU SELECTIONS. Table 2-2 lists the functions included in the four menus associated with operation and presents a brief description of the control and data functions associated with each. Figure 2-3 identifies the general menu layout and data presentation for the operations-related menus and provides a listing of all mode and status indications that may be displayed on the top line of the Menu Display Panel. The top line indicates the system operating state, selected navigation aid, selected velocity reference, selected damping mode, selected coordinates (normal or transverse), and code for any detected fault. The next two lines display position, velocity, heading, day, and time. The last three lines present variable information and control functions, as determined by the selected menu and page. Figure 2-4 presents the full menu tree listing all functions available for display during normal operation.

2.3 OPERATING PROCEDURES.

NOTE

> The following procedure assumes that the INS has been previously set up, all sensor inputs are configured, the sensors are turned on, and INS calibration has previously been performed.

The following sections outline the procedure for turning on and operating the RLGN in a normal situation.

2.3.1 TURNING ON THE RLGN. To turn on power and enter the STANDBY mode:

a. Clear any existing tags from 115 Volts, Alternating Current (VAC), 60 Hertz (Hz) and/or 115 VAC, 400 Hz power panels supplying the RLGN using standard safety tag-out procedures.

b. Set the switches at 115 VAC, 60 Hz or 115 VAC, 400 Hz power panels supplying the RLGN to ON.

c. On the RLGN, set the POWER, SYNCHRO REF, and VITAL REF circuit breakers to ON.

d. Set POWER switch to ON. Observe that POWER indicator lights.

e. Observe that display indicates STANDBY in the upper-left corner and no fault codes are displayed.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.85°
LON 000°00.00'E  DAY 001    GMT 00:00:04
COPYRIGHT 1990-2000
LITTON MARINE SYSTEMS    AN/WSN-7 SN 155
Select MODE, AUX FUNC, SENSOR, DISPLAY
```

The unit will remain in STANDBY until the first valid position fix is accepted (either manually entered or from an external position reference source).

f. Press the **<DISPLAY>** key to select the Display menu.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.85°
LON 000°00.00'E  DAY 001    GMT 00:05:16
1 Vn/Ve         3 Roll/Rate  5 Hdg/Rate
2 Vfa/Vps       4 Pitch/Rate 6 Depth
Select Option                     1 of 4
```

g. Press the **<NEXT PAGE>** key until 4 of 4 appears in the lower right corner of the display.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.85°
LON 000°00.00'E  DAY 001    GMT 00:06:27
1 Day/Time      3 Accel Bias    5 DR Data
2 Part NOs      4 Gyro Bias   6 BFTT Data
Select Option                     4 of 4
```

h. Select Day/Time by pressing the **<1>** key. The Julian date will read 001, and the Greenwich Mean Time (GMT) will display the time elapsed since the RLGN was turned on.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.85°
LON 000°00.00'E  DAY 001    GMT 00:06:40
     DAY  001
     GMT  00:06:40
CLEAR to reject
```

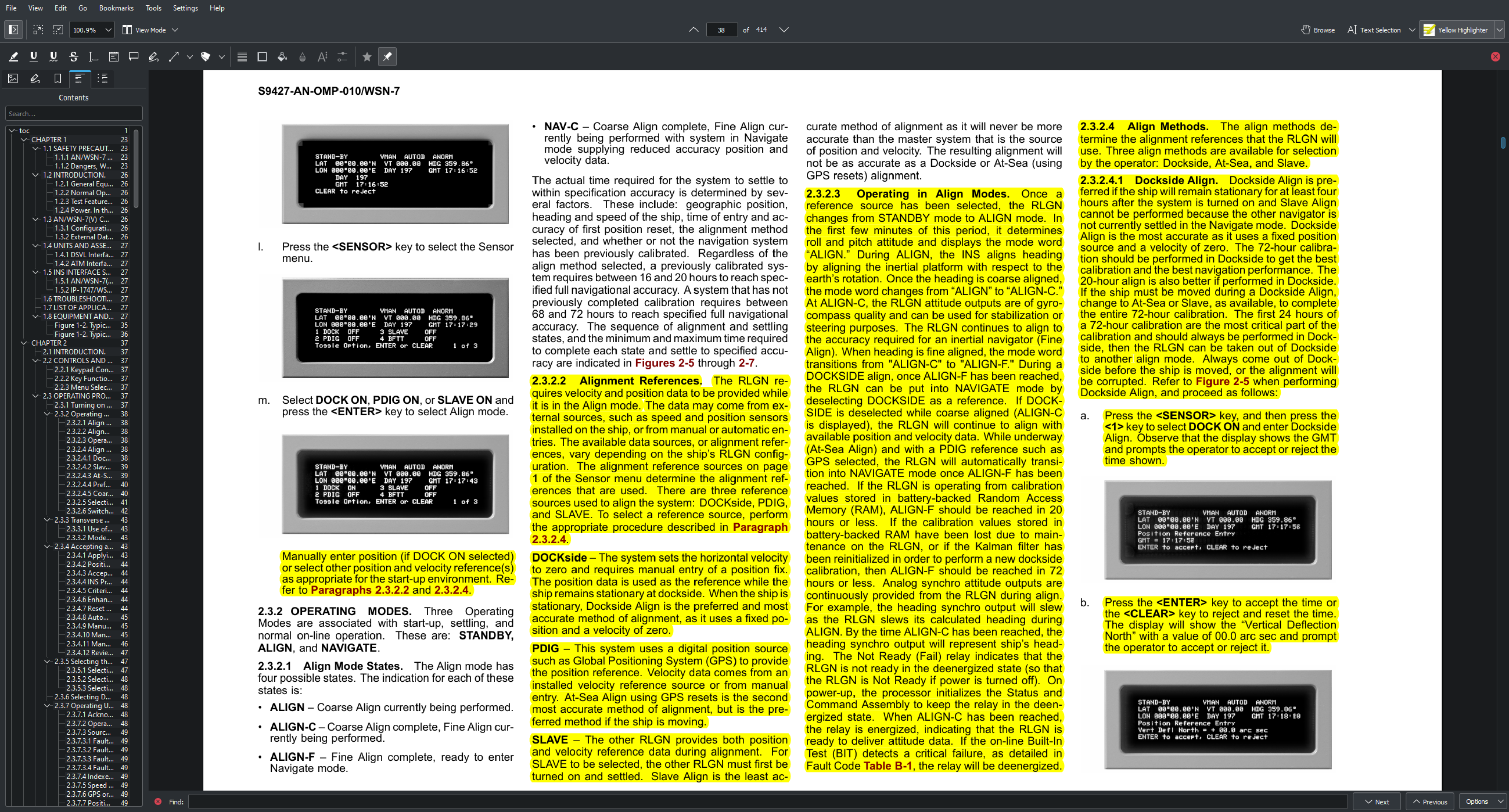
i. Press the **<CLEAR>** key to reject the current day and time. The display will show the Julian day and prompt you to accept or reject the information.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.85°
LON 000°00.00'E  DAY 001    GMT 00:06:55
DAY and GMT Entry
DAY = 001
ENTER to accept, CLEAR to reject
```

j. Press the **<CLEAR>** key to reject the Julian day entry and enter the correct Julian day. Press the **<ENTER>** key to accept the entry. The display will show the GMT and prompt you to accept or reject the information.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.85°
LON 000°00.00'E  DAY 001    GMT 00:07:42
DAY and GMT Entry
GMT = 00:07:42
ENTER to accept, CLEAR to reject
```

k. Press the **<CLEAR>** key to reject the GMT entry and enter the correct time. Press the **<ENTER>** key to accept the entry. The display will show the Julian day and GMT.



```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:16:52
     DAY  197
     GMT  17:16:52
CLEAR to reject
```

l. Press the **<SENSOR>** key to select the Sensor menu.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:17:29
1 DOCK  OFF      3 SLAVE    OFF
2 PDIG  OFF      4 BFTT     OFF
Toggle Option, ENTER or CLEAR     1 of 3
```

m. Select **DOCK ON**, **PDIG ON**, or **SLAVE ON** and press the **<ENTER>** key to select Align mode.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:17:43
1 DOCK  ON       3 SLAVE    OFF
2 PDIG  OFF      4 BFTT     OFF
Toggle Option, ENTER or CLEAR     1 of 3
```

Manually enter position (if DOCK ON selected) or select other position and velocity reference(s) as appropriate for the start-up environment. Refer to Paragraphs 2.3.2.2 and 2.3.2.4.

2.3.2 OPERATING MODES. Three Operating Modes are associated with start-up, settling, and normal on-line operation. These are: **STANDBY, ALIGN**, and **NAVIGATE**.

2.3.2.1 Align Mode States. The Align mode has four possible states. The indication for each of these states is:

- **ALIGN** – Coarse Align currently being performed.
- **ALIGN-C** – Coarse Align complete, Fine Align currently being performed.
- **ALIGN-F** – Fine Align complete, ready to enter Navigate mode.
- **NAV-C** – Coarse Align complete, Fine Align currently being performed with system in Navigate mode supplying reduced accuracy position and velocity data.

The actual time required for the system to settle to within specification accuracy is determined by several factors. These include: geographic position, heading and speed of the ship, time of entry and accuracy of first position reset, the alignment method selected, and whether or not the navigation system has been previously calibrated. Regardless of the align method selected, a previously calibrated system requires between 16 and 20 hours to reach specified full navigational accuracy. A system that has not previously completed calibration requires between 68 and 72 hours to reach specified full navigational accuracy. The sequence of alignment and settling states, and the minimum and maximum time required to complete each state and settle to specified accuracy are indicated in Figures 2-5 through 2-7.

2.3.2.2 Alignment References. The RLGN requires velocity and position data to be provided while it is in the Align mode. The data may come from external sources, such as speed and position sensors installed on the ship, or from manual or automatic entries. The available data sources, or alignment references, vary depending on the ship's RLGN configuration. The alignment reference sources on page 1 of the Sensor menu determine the alignment references that are used. There are three reference sources used to align the system: DOCKside, PDIG, and SLAVE. To select a reference source, perform the appropriate procedure described in Paragraph 2.3.2.4.

DOCKside – The system sets the horizontal velocity to zero and requires manual entry of a position fix. The position data is used as the reference while the ship remains stationary at dockside. When the ship is stationary, Dockside Align is the preferred and most accurate method of alignment, as it uses a fixed position and a velocity of zero.

PDIG – This system uses a digital position source such as Global Positioning System (GPS) to provide the position reference. Velocity data comes from an installed velocity reference source or from manual entry. At-Sea Align using GPS resets is the second most accurate method of alignment, but is the preferred method if the ship is moving.

SLAVE – The other RLGN provides both position and velocity reference data during alignment. For SLAVE to be selected, the other RLGN must first be turned on and settled. Slave Align is the least accurate method of alignment as it will never be more accurate than the master system that is the source of position and velocity. The resulting alignment will not be as accurate as a Dockside or At-Sea (using GPS resets) alignment.

2.3.2.3 Operating in Align Modes. Once a reference source has been selected, the RLGN changes from STANDBY mode to ALIGN mode. In the first few minutes of this period, it determines roll and pitch attitude and displays the mode word "ALIGN." During ALIGN, the INS aligns heading by aligning the inertial platform with respect to the earth's rotation. Once the heading is coarse aligned, the mode word changes from "ALIGN" to "ALIGN-C." At ALIGN-C, the RLGN attitude outputs are of gyrocompass quality and can be used for stabilization or steering purposes. The RLGN continues to align to the accuracy required for an inertial navigator (Fine Align). When heading is fine aligned, the mode word transitions from "ALIGN-C" to "ALIGN-F." During a DOCKSIDE align, once ALIGN-F has been reached, the RLGN can be put into NAVIGATE mode by deselecting DOCKSIDE as a reference. If DOCKSIDE is deselected while coarse aligned (ALIGN-C is displayed), the RLGN will continue to align with available position and velocity data. While underway (At-Sea Align) and with a PDIG reference such as GPS selected, the RLGN will automatically transition into NAVIGATE mode once ALIGN-F has been reached. If the RLGN is operating from calibration values stored in battery-backed Random Access Memory (RAM), ALIGN-F should be reached in 20 hours or less. If the calibration values stored in battery-backed RAM have been lost due to maintenance on the RLGN, or if the Kalman filter has been reinitialized in order to perform a new dockside calibration, then ALIGN-F should be reached in 72 hours or less. Analog synchro attitude outputs are continuously provided from the RLGN during align. For example, the heading synchro output will slew as the RLGN slews its calculated heading during ALIGN. By the time ALIGN-C has been reached, the heading synchro output will represent ship's heading. The Not Ready (Fail) relay indicates that the RLGN is not ready in the deenergized state (so that the RLGN is Not Ready if power is turned off). On power-up, the processor initializes the Status and Command Assembly to keep the relay in the deenergized state. When ALIGN-C has been reached, the relay is energized, indicating that the RLGN is ready to deliver attitude data. If the on-line Built-In Test (BIT) detects a critical failure, as detailed in Fault Code Table B-1, the relay will be deenergized.

2.3.2.4 Align Methods. The align methods determine the alignment references that the RLGN will use. Three align methods are available for selection by the operator: Dockside, At-Sea, and Slave.

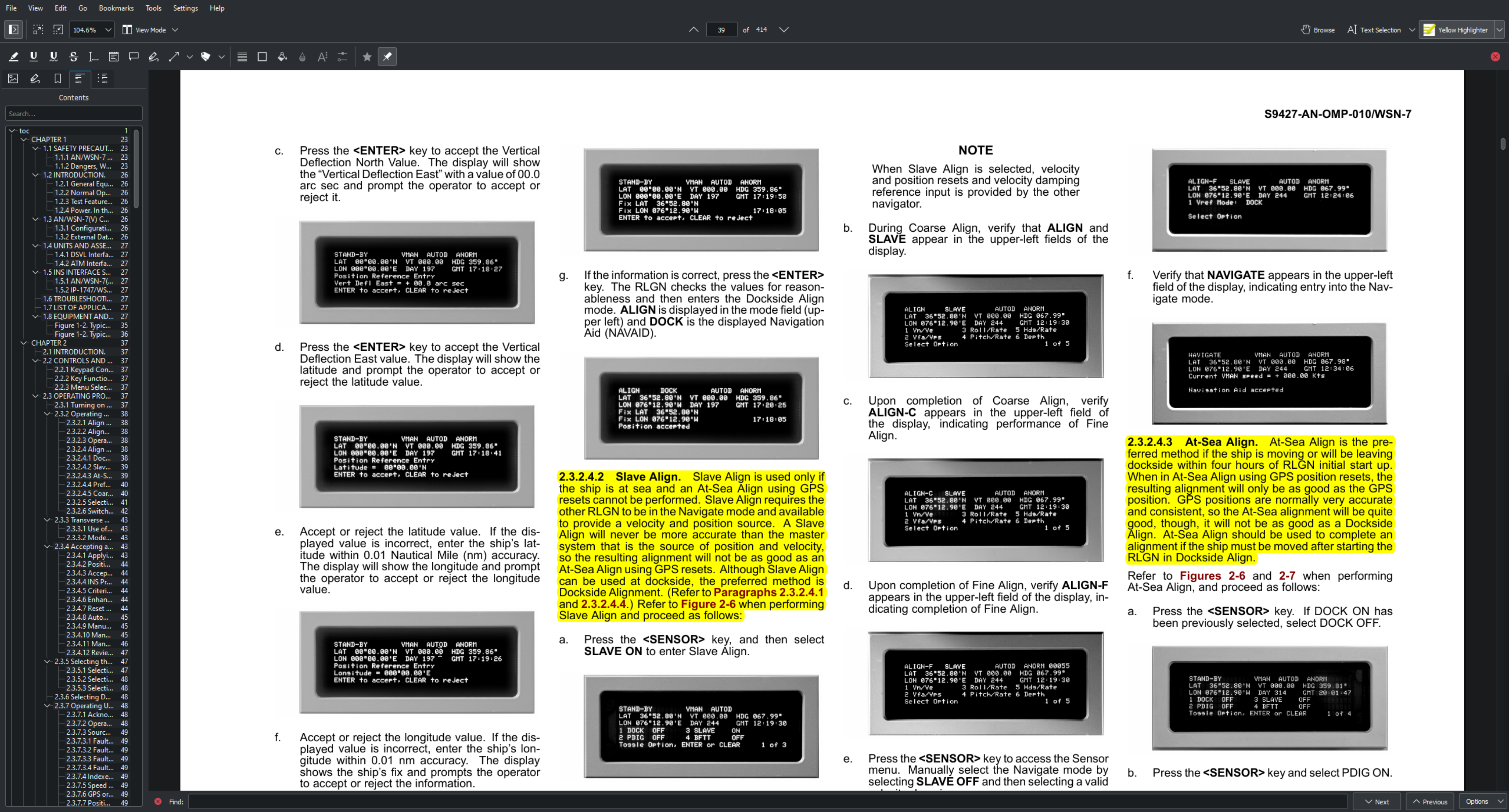
2.3.2.4.1 Dockside Align. Dockside Align is preferred if the ship will remain stationary for at least four hours after the system is turned on and Slave Align cannot be performed because the other navigator is not currently settled in the Navigate mode. Dockside Align is the most accurate as it uses a fixed position source and a velocity of zero. The 72-hour calibration should be performed in Dockside to get the best calibration and the best navigation performance. The 20-hour align is also better if performed in Dockside. If the ship must be moved during a Dockside Align, change to At-Sea or Slave, as available, to complete the entire 72-hour calibration. The first 24 hours of a 72-hour calibration are the most critical part of the calibration and should always be performed in Dockside, then the RLGN can be taken out of Dockside to another align mode. Always come out of Dockside before the ship is moved, or the alignment will be corrupted. Refer to Figure 2-5 when performing Dockside Align, and proceed as follows:

a. Press the **<SENSOR>** key, and then press the **<1>** key to select **DOCK ON** and enter Dockside Align. Observe that the display shows the GMT and prompts the operator to accept or reject the time shown.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:17:56
Position Reference Entry
GMT = 17:17:58
ENTER to accept, CLEAR to reject
```

b. Press the **<ENTER>** key to accept the time or the **<CLEAR>** key to reject and reset the time. The display will show the "Vertical Deflection North" with a value of 00.0 arc sec and prompt the operator to accept or reject it.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:18:00
Position Reference Entry
Vert Defl North = + 00.0 arc sec
ENTER to accept, CLEAR to reject
```



c. Press the **<ENTER>** key to accept the Vertical Deflection North Value. The display will show the "Vertical Deflection East" with a value of 00.0 arc sec and prompt the operator to accept or reject it.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:18:27
Position Reference Entry
Vert Defl East = + 00.0 arc sec
ENTER to accept, CLEAR to reject
```

d. Press the **<ENTER>** key to accept the Vertical Deflection East value. The display will show the latitude and prompt the operator to accept or reject the latitude value.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:18:41
Position Reference Entry
Latitude =  00°00.00'N
ENTER to accept, CLEAR to reject
```

e. Accept or reject the latitude value. If the displayed value is incorrect, enter the ship's latitude within 0.01 Nautical Mile (nm) accuracy. The display will show the longitude and prompt the operator to accept or reject the longitude value.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:19:26
Position Reference Entry
Longitude = 000°00.00'E
ENTER to accept, CLEAR to reject
```

f. Accept or reject the longitude value. If the displayed value is incorrect, enter the ship's longitude within 0.01 nm accuracy. The display shows the ship's fix and prompts the operator to accept or reject the information.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  00°00.00'N  VT 000.00  HDG 359.86°
LON 000°00.00'E  DAY 197    GMT 17:19:58
Fix LAT  36°52.80'N
Fix LON 076°12.90'W               17:18:05
ENTER to accept, CLEAR to reject
```

g. If the information is correct, press the **<ENTER>** key. The RLGN checks the values for reasonableness and then enters the Dockside Align mode. **ALIGN** is displayed in the mode field (upper left) and **DOCK** is the displayed Navigation Aid (NAVAID).

```
ALIGN     DOCK          AUTOD  ANORM
LAT  36°52.80'N  VT 000.00  HDG 359.86°
LON 076°12.90'W  DAY 197    GMT 17:20:25
Fix LAT  36°52.80'N
Fix LON 076°12.90'W               17:18:05
Position accepted
```

2.3.2.4.2 Slave Align. Slave Align is used only if the ship is at sea and an At-Sea Align using GPS resets cannot be performed. Slave Align requires the other RLGN to be in the Navigate mode and available to provide a velocity and position source. A Slave Align will never be more accurate than the master system that is the source of position and velocity, so the resulting alignment will not be as good as an At-Sea Align using GPS resets. Although Slave Align can be used at dockside, the preferred method is Dockside Alignment. (Refer to **Paragraphs 2.3.2.4.1** and **2.3.2.4.4**.) Refer to **Figure 2-6** when performing Slave Align and proceed as follows:

a. Press the **<SENSOR>** key, and then select **SLAVE ON** to enter Slave Align.

```
STAND-BY          VMAN  AUTOD
LAT  36°52.80'N  VT 000.00  HDG 067.99°
LON 076°12.90'E  DAY 244    GMT 12:19:30
1 DOCK  OFF       3 SLAVE    ON
2 PDIG  OFF       4 BFTT     OFF
Toggle Option, ENTER or CLEAR    1 of 3
```

NOTE

When Slave Align is selected, velocity and position resets and velocity damping reference input is provided by the other navigator.

b. During Coarse Align, verify that **ALIGN** and **SLAVE** appear in the upper-left fields of the display.

```
ALIGN     SLAVE         AUTOD  ANORM
LAT  36°52.80'N  VT 000.00  HDG 067.99°
LON 076°12.90'E  DAY 244    GMT 12:19:30
1 Vn/Ve        3 Roll/Rate  5 Hdg/Rate
2 Vfa/Vps      4 Pitch/Rate 6 Depth
Select Option                     1 of 5
```

c. Upon completion of Coarse Align, verify **ALIGN-C** appears in the upper-left field of the display, indicating performance of Fine Align.

```
ALIGN-C   SLAVE         AUTOD  ANORM
LAT  36°52.80'N  VT 000.00  HDG 067.99°
LON 076°12.90'E  DAY 244    GMT 12:19:30
1 Vn/Ve        3 Roll/Rate  5 Hdg/Rate
2 Vfa/Vps      4 Pitch/Rate 6 Depth
Select Option                     1 of 5
```

d. Upon completion of Fine Align, verify **ALIGN-F** appears in the upper-left field of the display, indicating completion of Fine Align.

```
ALIGN-F   SLAVE         AUTOD  ANORM 00055
LAT  36°52.80'N  VT 000.00  HDG 067.99°
LON 076°12.90'E  DAY 244    GMT 12:19:30
1 Vn/Ve        3 Roll/Rate  5 Hdg/Rate
2 Vfa/Vps      4 Pitch/Rate 6 Depth
Select Option                     1 of 5
```

e. Press the **<SENSOR>** key to access the Sensor menu. Manually select the Navigate mode by selecting **SLAVE OFF** and then selecting a valid

```
ALIGN-F   SLAVE         AUTOD  ANORM
LAT  36°52.80'N  VT 000.00  HDG 067.99°
LON 076°12.90'E  DAY 244    GMT 12:24:06
1 Vref Mode:  DOCK

Select Option
```

f. Verify that **NAVIGATE** appears in the upper-left field of the display, indicating entry into the Navigate mode.

```
NAVIGATE          VMAN  AUTOD  ANORM
LAT  36°52.80'N  VT 000.00  HDG 067.98°
LON 076°12.90'E  DAY 244    GMT 12:34:06
Current VMAN speed = + 000.00 Kts

Navigation Aid accepted
```

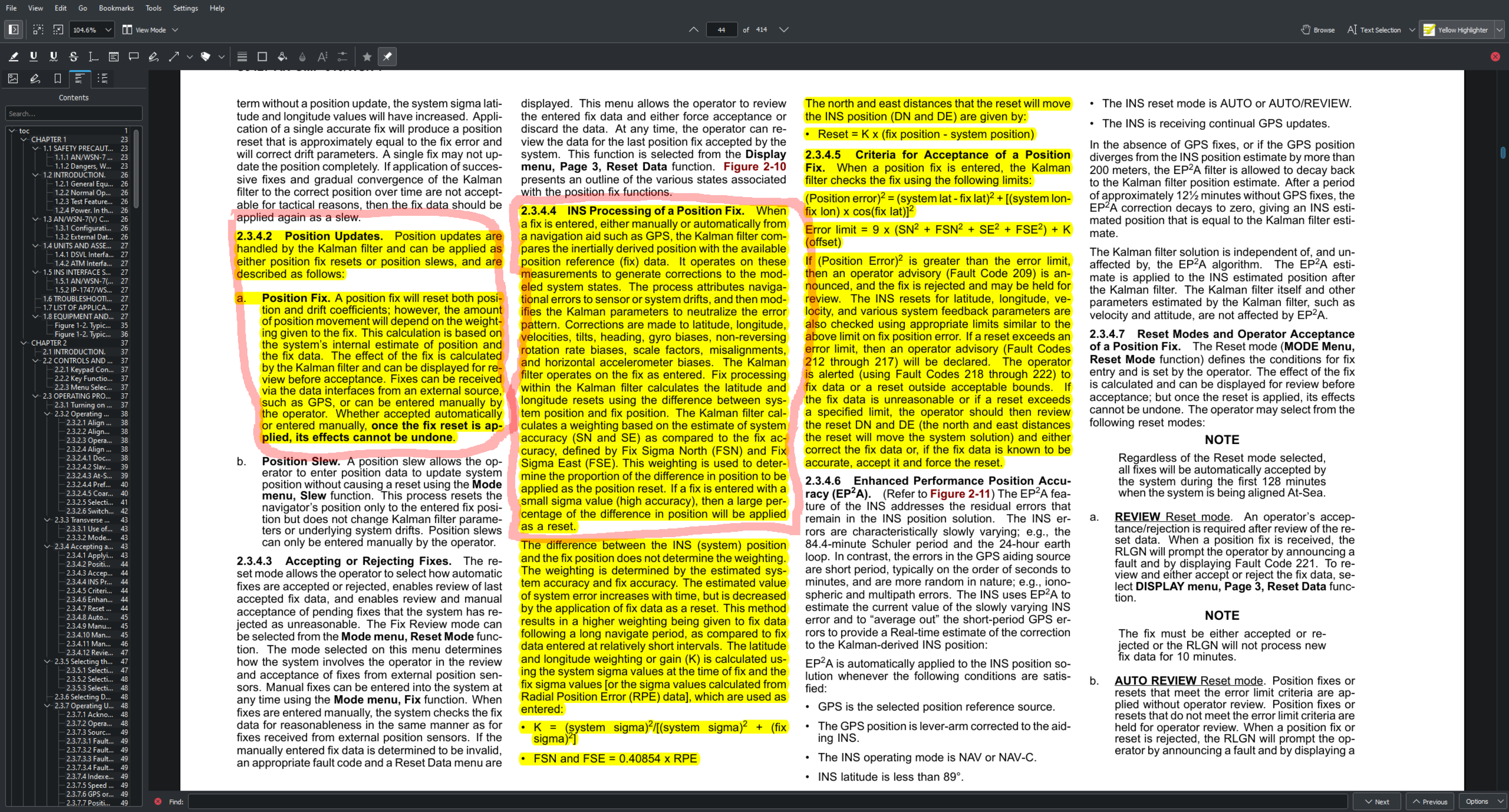
2.3.2.4.3 At-Sea Align. At-Sea Align is the preferred method if the ship is moving or will be leaving dockside within four hours of RLGN initial start up. When in At-Sea Align using GPS position resets, the resulting alignment will only be as good as the GPS position. GPS positions are normally very accurate and consistent, so the At-Sea alignment will be quite good, though, it will not be as good as a Dockside Align. At-Sea Align should be used to complete an alignment if the ship must be moved after starting the RLGN in Dockside Align.

Refer to **Figures 2-6** and **2-7** when performing At-Sea Align, and proceed as follows:

a. Press the **<SENSOR>** key. If DOCK ON has been previously selected, select DOCK OFF.

```
STAND-BY          VMAN  AUTOD  ANORM
LAT  36°52.80'N  VT 000.00  HDG 359.81°
LON 076°12.90'W  DAY 314    GMT 20:01:47
1 DOCK  OFF       3 SLAVE    OFF
2 PDIG  OFF       4 BFTT     OFF
Toggle Option, ENTER or CLEAR    1 of 4
```

b. Press the **<SENSOR>** key and select PDIG ON.



term without a position update, the system sigma latitude and longitude values will have increased. Application of a single accurate fix will produce a position reset that is approximately equal to the fix error and will correct drift parameters. A single fix may not update the position completely. If application of successive fixes and gradual correction of the Kalman filter to the correct position over time are not acceptable for tactical reasons, then the fix data should be applied again as a slew.

2.3.4.2 Position Updates. Position updates are handled by the Kalman filter and can be applied as either position fix resets or position slews, and are described as follows:

a. **Position Fix.** A position fix will reset both position and drift coefficients; however, the amount of position movement will depend on the weighting given to the fix. This calculation is based on the system's internal estimate of position and the fix data. The effect of the fix is calculated by the Kalman filter and can be displayed for review before acceptance. Fixes can be received via the data interfaces from an external source, such as GPS, or can be entered manually by the operator. Whether accepted automatically or entered manually, **once the fix reset is applied, its effects cannot be undone**.

b. **Position Slew.** A position slew allows the operator to enter position data to update system position without causing a reset using the **Mode menu, Slew** function. This process resets the navigator's position only to the entered fix position but does not change Kalman filter parameters or underlying system drifts. Position slews can only be entered manually by the operator.

2.3.4.3 Accepting or Rejecting Fixes. The reset mode allows the operator to select how automatic fixes are accepted or rejected, enables review of last accepted fix data, and enables review and manual acceptance of pending fixes that the system has rejected as unreasonable. The Fix Review mode can be selected from the **Mode menu, Reset Mode** function. The mode selected on this menu determines how the system involves the operator in the review and acceptance of fixes from external position sensors. Manual fixes can be entered into the system at any time using the **Mode menu, Fix** function. When fixes are entered manually, the system checks the fix data for reasonableness in the same manner as for fixes received from external position sensors. If the manually entered fix data is determined to be invalid, an appropriate fault code and a Reset Data menu are displayed. This menu allows the operator to review the entered fix data and either force acceptance or discard the data. At any time, the operator can review the data for the last position fix accepted by the system. This function is selected from the **Display menu, Page 3, Reset Data** function. Figure 2-10 presents an outline of the various states associated with the position fix functions.

2.3.4.4 INS Processing of a Position Fix. When a fix is entered, either manually or automatically from a navigation aid such as GPS, the Kalman filter compares the inertially derived position with the available position reference (fix) data. It operates on these measurements to generate corrections to the modeled system states. The process attributes navigational errors to sensor or system drifts, and then modifies the Kalman parameters to neutralize the error pattern. Corrections are made to latitude, longitude, velocities, tilts, heading, gyro biases, non-reversing rotation rate biases, scale factors, misalignments, and horizontal accelerometer biases. The Kalman filter operates on the fix as entered. Fix processing within the Kalman filter calculates the latitude and longitude resets using the difference between system position and fix position. The Kalman filter calculates a weighting based on the estimate of system accuracy (SN and SE) as compared to the fix accuracy, defined by Fix Sigma North (FSN) and Fix Sigma East (FSE). This weighting is used to determine the proportion of the difference in position to be applied as the position reset. If a fix is entered with a small sigma value (high accuracy), then a large percentage of the difference in position will be applied as a reset.

The difference between the INS (system) position and the fix position does not determine the weighting. The weighting is determined by the estimated system accuracy and fix accuracy. The estimated value of system error increases with time, but is decreased by the application of fix data as a reset. This method results in a higher weighting being given to fix data following a long navigate period, as compared to fix data entered at relatively short intervals. The latitude and longitude weighting or gain (K) is calculated using the system sigma values at the time of fix and the fix sigma values [or the sigma values calculated from Radial Position Error (RPE) data], which are used as entered:

- $K = (\text{system sigma})^2/[(\text{system sigma})^2 + (\text{fix sigma})^2]$
- FSN and FSE = 0.40854 x RPE

The north and east distances that the reset will move the INS position (DN and DE) are given by:

- Reset = K x (fix position - system position)

2.3.4.5 Criteria for Acceptance of a Position Fix. When a position fix is entered, the Kalman filter checks the fix using the following limits:

$(\text{Position error})^2 = (\text{system lat} - \text{fix lat})^2 + [(\text{system lon-fix lon}) \times \cos(\text{fix lat})]^2$

$\text{Error limit} = 9 \times (SN^2 + FSN^2 + SE^2 + FSE^2) + K\ (\text{offset})$

If $(\text{Position Error})^2$ is greater than the error limit, then an operator advisory (Fault Code 209) is announced, and the fix is rejected and may be held for review. The INS resets for latitude, longitude, velocity, and various system feedback parameters are also checked using appropriate limits similar to the above limit on fix position error. If a reset exceeds an error limit, then an operator advisory (Fault Codes 212 through 217) will be declared. The operator is alerted (using Fault Codes 218 through 222) to fix data or a reset outside acceptable bounds. If the fix data is unreasonable or if a reset exceeds a specified limit, the operator should then review the reset DN and DE (the north and east distances the reset will move the system solution) and either correct the fix data or, if the fix data is known to be accurate, accept it and force the reset.

2.3.4.6 Enhanced Performance Position Accuracy (EP^2A). (Refer to Figure 2-11) The EP^2A feature of the INS addresses the residual errors that remain in the INS position solution. The INS errors are characteristically slowly varying; e.g., the 84.4-minute Schuler period and the 24-hour earth loop. In contrast, the errors in the GPS aiding source are short period, typically on the order of seconds to minutes, and are more random in nature; e.g., ionospheric and multipath errors. The INS uses EP^2A to estimate the current value of the slowly varying INS error and to "average out" the short-period GPS errors to provide a Real-time estimate of the correction to the Kalman-derived INS position:

EP^2A is automatically applied to the INS position solution whenever the following conditions are satisfied:

- GPS is the selected position reference source.
- The GPS position is lever-arm corrected to the aiding INS.
- The INS operating mode is NAV or NAV-C.
- INS latitude is less than 89°.
- The INS reset mode is AUTO or AUTO/REVIEW.
- The INS is receiving continual GPS updates.

In the absence of GPS fixes, or if the GPS position diverges from the INS position estimate by more than 200 meters, the EP^2A filter is allowed to decay back to the Kalman filter position estimate. After a period of approximately 12½ minutes without GPS fixes, the EP^2A correction decays to zero, giving an INS estimated position that is equal to the Kalman filter estimate.

The Kalman filter solution is independent of, and unaffected by, the EP^2A algorithm. The EP^2A estimate is applied to the INS estimated position after the Kalman filter. The Kalman filter itself and other parameters estimated by the Kalman filter, such as velocity and attitude, are not affected by EP^2A.

2.3.4.7 Reset Modes and Operator Acceptance of a Position Fix. The Reset mode (**MODE Menu, Reset Mode** function) defines the conditions for fix entry and is set by the operator. The effect of the fix is calculated and can be displayed for review before acceptance; but once the reset is applied, its effects cannot be undone. The operator may select from the following reset modes:

NOTE

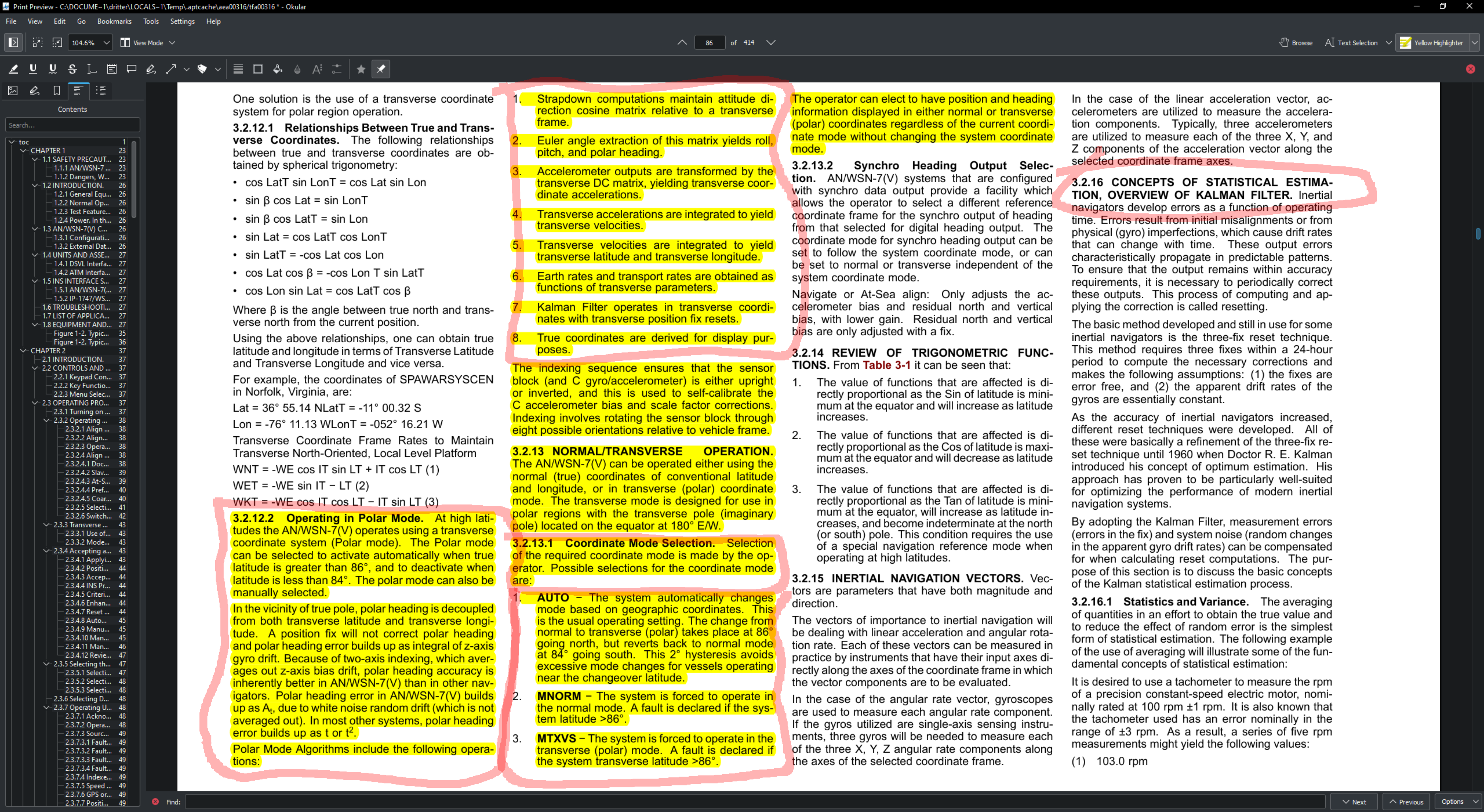
Regardless of the Reset mode selected, all fixes will be automatically accepted by the system during the first 128 minutes when the system is being aligned At-Sea.

a. **<u>REVIEW</u>** <u>Reset mode</u>. An operator's acceptance/rejection is required after review of the reset data. When a position fix is received, the RLGN will prompt the operator by announcing a fault and by displaying Fault Code 221. To review and either accept or reject the fix data, select **DISPLAY menu, Page 3, Reset Data** function.

NOTE

The fix must be either accepted or rejected or the RLGN will not process new fix data for 10 minutes.

b. **<u>AUTO REVIEW</u>** <u>Reset mode</u>. Position fixes or resets that meet the error limit criteria are applied without operator review. Position fixes or resets that do not meet the error limit criteria are held for operator review. When a position fix or reset is rejected, the RLGN will prompt the operator by announcing a fault and by displaying a



One solution is the use of a transverse coordinate system for polar region operation.

3.2.12.1 Relationships Between True and Transverse Coordinates. The following relationships between true and transverse coordinates are obtained by spherical trigonometry:

- cos LatT sin LonT = cos Lat sin Lon
- sin β cos Lat = sin LonT
- sin β cos LatT = sin Lon
- sin Lat = cos LatT cos LonT
- sin LatT = -cos Lat cos Lon
- cos Lat cos β = -cos Lon T sin LatT
- cos Lon sin Lat = cos LatT cos β

Where β is the angle between true north and transverse north from the current position.

Using the above relationships, one can obtain true latitude and longitude in terms of Transverse Latitude and Transverse Longitude and vice versa.

For example, the coordinates of SPAWARSYSCEN in Norfolk, Virginia, are:

Lat = 36° 55.14 NLatT = -11° 00.32 S

Lon = -76° 11.13 WLonT = -052° 16.21 W

Transverse Coordinate Frame Rates to Maintain Transverse North-Oriented, Local Level Platform

WNT = -WE cos IT sin LT + IT cos LT (1)

WET = -WE sin IT − LT (2)

WKT = -WE cos IT cos LT − IT sin LT (3)

3.2.12.2 Operating in Polar Mode. At high latitudes the AN/WSN-7(V) operates using a transverse coordinate system (Polar mode). The Polar mode can be selected to activate automatically when true latitude is greater than 86°, and to deactivate when latitude is less than 84°. The polar mode can also be manually selected.

In the vicinity of true pole, polar heading is decoupled from both transverse latitude and transverse longitude. A position fix will not correct polar heading and polar heading error builds up as integral of z-axis gyro drift. Because of two-axis indexing, which averages out z-axis bias drift, polar heading accuracy is inherently better in AN/WSN-7(V) than in other navigators. Polar heading error in AN/WSN-7(V) builds up as A_t, due to white noise random drift (which is not averaged out). In most other systems, polar heading error builds up as t or t^2.

Polar Mode Algorithms include the following operations:

1. Strapdown computations maintain attitude direction cosine matrix relative to a transverse frame.
2. Euler angle extraction of this matrix yields roll, pitch, and polar heading.
3. Accelerometer outputs are transformed by the transverse DC matrix, yielding transverse coordinate accelerations.
4. Transverse accelerations are integrated to yield transverse velocities.
5. Transverse velocities are integrated to yield transverse latitude and transverse longitude.
6. Earth rates and transport rates are obtained as functions of transverse parameters.
7. Kalman Filter operates in transverse coordinates with transverse position fix resets.
8. True coordinates are derived for display purposes.

The indexing sequence ensures that the sensor block (and C gyro/accelerometer) is either upright or inverted, and this is used to self-calibrate the C accelerometer bias and scale factor corrections. Indexing involves rotating the sensor block through eight possible orientations relative to vehicle frame.

3.2.13 NORMAL/TRANSVERSE OPERATION. The AN/WSN-7(V) can be operated either using the normal (true) coordinates of conventional latitude and longitude, or in transverse (polar) coordinate mode. The transverse mode is designed for use in polar regions with the transverse pole (imaginary pole) located on the equator at 180° E/W.

3.2.13.1 Coordinate Mode Selection. Selection of the required coordinate mode is made by the operator. Possible selections for the coordinate mode are:

1. **AUTO** – The system automatically changes mode based on geographic coordinates. This is the usual operating setting. The change from normal to transverse (polar) takes place at 86° going north, but reverts back to normal mode at 84° going south. This 2° hysteresis avoids excessive mode changes for vessels operating near the changeover latitude.
2. **MNORM** – The system is forced to operate in the normal mode. A fault is declared if the system latitude >86°.
3. **MTXVS** – The system is forced to operate in the transverse (polar) mode. A fault is declared if the system transverse latitude >86°.

The operator can elect to have position and heading information displayed in either normal or transverse (polar) coordinates regardless of the current coordinate mode without changing the system coordinate mode.

3.2.13.2 Synchro Heading Output Selection. AN/WSN-7(V) systems that are configured with synchro data output provide a facility which allows the operator to select a different reference coordinate frame for the synchro output of heading from that selected for digital heading output. The coordinate mode for synchro heading output can be set to follow the system coordinate mode, or can be set to normal or transverse independent of the system coordinate mode.

Navigate or At-Sea align: Only adjusts the accelerometer bias and residual north and vertical bias, with lower gain. Residual north and vertical bias are only adjusted with a fix.

3.2.14 REVIEW OF TRIGONOMETRIC FUNCTIONS. From Table 3-1 it can be seen that:

1. The value of functions that are affected is directly proportional as the Sin of latitude is minimum at the equator and will increase as latitude increases.
2. The value of functions that are affected is directly proportional as the Cos of latitude is maximum at the equator and will decrease as latitude increases.
3. The value of functions that are affected is directly proportional as the Tan of latitude is minimum at the equator, will increase as latitude increases, and become indeterminate at the north (or south) pole. This condition requires the use of a special navigation reference mode when operating at high latitudes.

3.2.15 INERTIAL NAVIGATION VECTORS. Vectors are parameters that have both magnitude and direction.

The vectors of importance to inertial navigation will be dealing with linear acceleration and angular rotation rate. Each of these vectors can be measured in practice by instruments that have their input axes directly along the axes of the coordinate frame in which the vector components are to be evaluated.

In the case of the angular rate vector, gyroscopes are used to measure each angular rate component. If the gyros utilized are single-axis sensing instruments, three gyros will be needed to measure each of the three X, Y, Z angular rate components along the axes of the selected coordinate frame.

In the case of the linear acceleration vector, accelerometers are utilized to measure the acceleration components. Typically, three accelerometers are utilized to measure each of the three X, Y, and Z components of the acceleration vector along the selected coordinate frame axes.

3.2.16 CONCEPTS OF STATISTICAL ESTIMATION, OVERVIEW OF KALMAN FILTER. Inertial navigators develop errors as a function of operating time. Errors result from initial misalignments or from physical (gyro) imperfections, which cause drift rates that can change with time. These output errors characteristically propagate in predictable patterns. To ensure that the output remains within accuracy requirements, it is necessary to periodically correct these outputs. This process of computing and applying the correction is called resetting.

The basic method developed and still in use for some inertial navigators is the three-fix reset technique. This method requires three fixes within a 24-hour period to compute the necessary corrections and makes the following assumptions: (1) the fixes are error free, and (2) the apparent drift rates of the gyros are essentially constant.

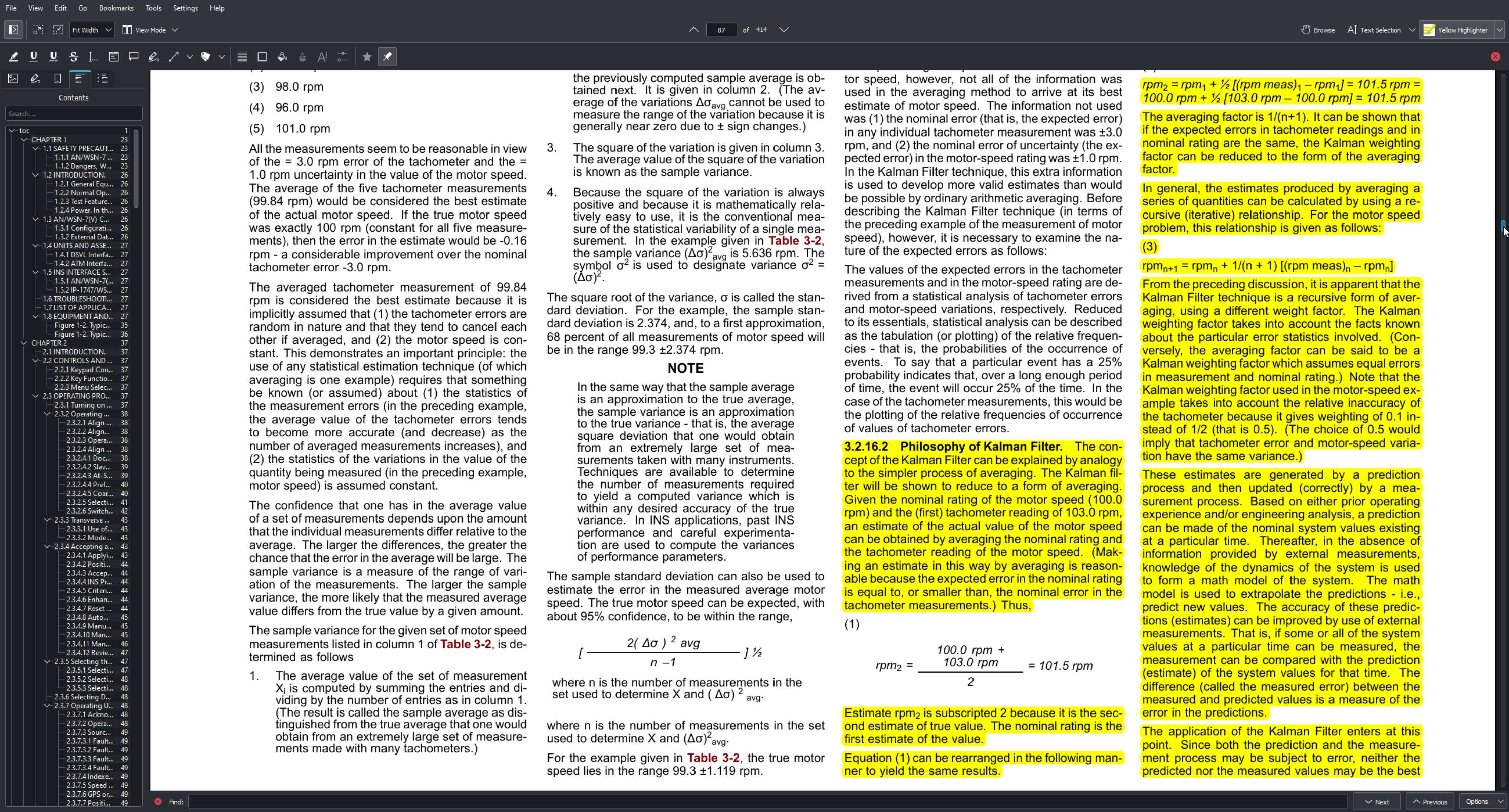
As the accuracy of inertial navigators increased, different reset techniques were developed. All of these were basically a refinement of the three-fix reset technique until 1960 when Doctor R. E. Kalman introduced his concept of optimum estimation. His approach has proven to be particularly well-suited for optimizing the performance of modern inertial navigation systems.

By adopting the Kalman Filter, measurement errors (errors in the fix) and system noise (random changes in the apparent gyro drift rates) can be compensated for when calculating reset computations. The purpose of this section is to discuss the basic concepts of the Kalman statistical estimation process.

3.2.16.1 Statistics and Variance. The averaging of quantities in an effort to obtain the true value and to reduce the effect of random error is the simplest form of statistical estimation. The following example of the use of averaging will illustrate some of the fundamental concepts of statistical estimation:

It is desired to use a tachometer to measure the rpm of a precision constant-speed electric motor, nominally rated at 100 rpm ±1 rpm. It is also known that the tachometer used has an error nominally in the range of ±3 rpm. As a result, a series of five rpm measurements might yield the following values:

(1) 103.0 rpm



(3) 98.0 rpm

(4) 96.0 rpm

(5) 101.0 rpm

All the measurements seem to be reasonable in view of the = 3.0 rpm error of the tachometer and the = 1.0 rpm uncertainty in the value of the motor speed. The average of the five tachometer measurements (99.84 rpm) would be considered the best estimate of the actual motor speed. If the true motor speed was exactly 100 rpm (constant for all five measurements), then the error in the estimate would be -0.16 rpm - a considerable improvement over the nominal tachometer error -3.0 rpm.

The averaged tachometer measurement of 99.84 rpm is considered the best estimate because it is implicitly assumed that (1) the tachometer errors are random in nature and that they tend to cancel each other if averaged, and (2) the motor speed is constant. This demonstrates an important principle: the use of any statistical estimation technique (of which averaging is one example) requires that something be known (or assumed) about (1) the statistics of the measurement errors (in the preceding example, the average value of the tachometer errors tends to become more accurate (and decrease) as the number of averaged measurements increases), and (2) the statistics of the variations in the value of the quantity being measured (in the preceding example, motor speed) is assumed constant.

The confidence that one has in the average value of a set of measurements depends upon the amount that the individual measurements differ relative to the average. The larger the differences, the greater the chance that the error in the average will be large. The sample variance is a measure of the range of variation of the measurements. The larger the sample variance, the more likely that the measured average value differs from the true value by a given amount.

The sample variance for the given set of motor speed measurements listed in column 1 of Table 3-2, is determined as follows

1. The average value of the set of measurement X_i is computed by summing the entries and dividing by the number of entries as in column 1. (The result is called the sample average as distinguished from the true average that one would obtain from an extremely large set of measurements made with many tachometers.)

the previously computed sample average is obtained next. It is given in column 2. (The average of the variations $\Delta\sigma_{avg}$ cannot be used to measure the range of the variation because it is generally near zero due to ± sign changes.)

3. The square of the variation is given in column 3. The average value of the square of the variation is known as the sample variance.

4. Because the square of the variation is always positive and because it is mathematically relatively easy to use, it is the conventional measure of the statistical variability of a single measurement. In the example given in Table 3-2, the sample variance $(\Delta\sigma)^2_{avg}$ is 5.636 rpm. The symbol σ^2 is used to designate variance $\sigma^2 = (\Delta\sigma)^2$.

The square root of the variance, σ is called the standard deviation. For the example, the sample standard deviation is 2.374, and, to a first approximation, 68 percent of all measurements of motor speed will be in the range 99.3 ±2.374 rpm.

NOTE

In the same way that the sample average is an approximation to the true average, the sample variance is an approximation to the true variance - that is, the average square deviation that one would obtain from an extremely large set of measurements taken with many instruments. Techniques are available to determine the number of measurements required to yield a computed variance which is within any desired accuracy of the true variance. In INS applications, past INS performance and careful experimentation are used to compute the variances of performance parameters.

The sample standard deviation can also be used to estimate the error in the measured average motor speed. The true motor speed can be expected, with about 95% confidence, to be within the range,

$$\left[\frac{2(\Delta\sigma)^2 avg}{n-1} \right]^{½}$$

where n is the number of measurements in the set used to determine X and $(\Delta\sigma)^2{}_{avg}$.

where n is the number of measurements in the set used to determine X and $(\Delta\sigma)^2_{avg}$.

For the example given in Table 3-2, the true motor speed lies in the range 99.3 ±1.119 rpm.

tor speed, however, not all of the information was used in the averaging method to arrive at its best estimate of motor speed. The information not used was (1) the nominal error (that is, the expected error) in any individual tachometer measurement was ±3.0 rpm, and (2) the nominal error of uncertainty (the expected error) in the motor-speed rating was ±1.0 rpm. In the Kalman Filter technique, this extra information is used to develop more valid estimates than would be possible by ordinary arithmetic averaging. Before describing the Kalman Filter technique (in terms of the preceding example of the measurement of motor speed), however, it is necessary to examine the nature of the expected errors as follows:

The values of the expected errors in the tachometer measurements and in the motor-speed rating are derived from a statistical analysis of tachometer errors and motor-speed variations, respectively. Reduced to its essentials, statistical analysis can be described as the tabulation (or plotting) of the relative frequencies - that is, the probabilities of the occurrence of events. To say that a particular event has a 25% probability indicates that, over a long enough period of time, the event will occur 25% of the time. In the case of the tachometer measurements, this would be the plotting of the relative frequencies of occurrence of values of tachometer errors.

3.2.16.2 Philosophy of Kalman Filter. The concept of the Kalman Filter can be explained by analogy to the simpler process of averaging. The Kalman filter will be shown to reduce to a form of averaging. Given the nominal rating of the motor speed (100.0 rpm) and the (first) tachometer reading of 103.0 rpm, an estimate of the actual value of the motor speed can be obtained by averaging the nominal rating and the tachometer reading of the motor speed. (Making an estimate in this way by averaging is reasonable because the expected error in the nominal rating is equal to, or smaller than, the nominal error in the tachometer measurements.) Thus,

(1)

$$rpm_2 = \frac{100.0\ rpm + 103.0\ rpm}{2} = 101.5\ rpm$$

Estimate rpm_2 is subscripted 2 because it is the second estimate of true value. The nominal rating is the first estimate of the value.

Equation (1) can be rearranged in the following manner to yield the same results.

$$rpm_2 = rpm_1 + ½\,[(rpm\ meas)_1 - rpm_1] = 101.5\ rpm = 100.0\ rpm + ½\,[103.0\ rpm - 100.0\ rpm] = 101.5\ rpm$$

The averaging factor is 1/(n+1). It can be shown that if the expected errors in tachometer readings and in nominal rating are the same, the Kalman weighting factor can be reduced to the form of the averaging factor.

In general, the estimates produced by averaging a series of quantities can be calculated by using a recursive (iterative) relationship. For the motor speed problem, this relationship is given as follows:

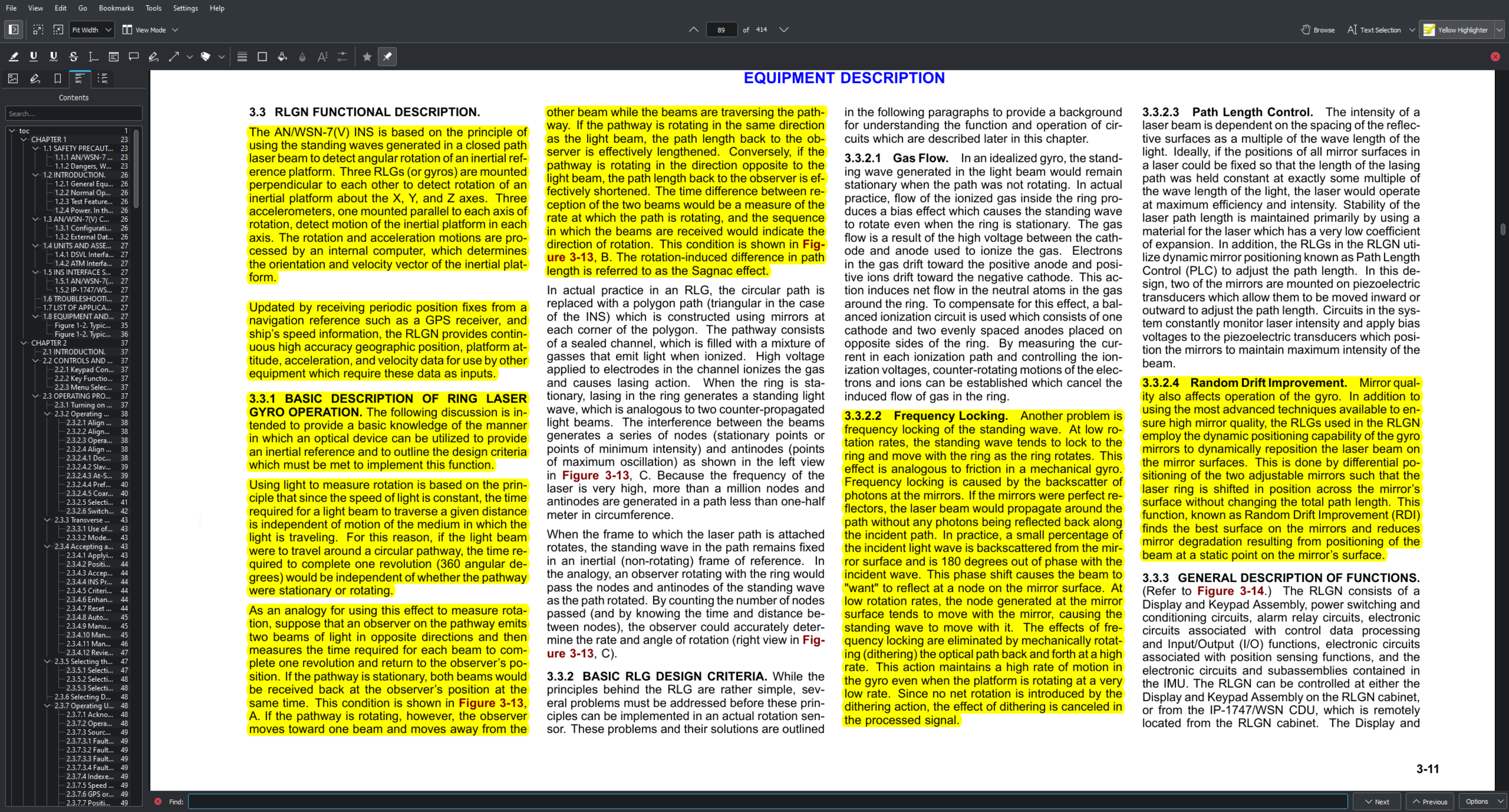
(3)

$$rpm_{n+1} = rpm_n + 1/(n+1)\,[(rpm\ meas)_n - rpm_n]$$

From the preceding discussion, it is apparent that the Kalman Filter technique is a recursive form of averaging, using a different weight factor. The Kalman weighting factor takes into account the facts known about the particular error statistics involved. (Conversely, the averaging factor can be said to be a Kalman weighting factor which assumes equal errors in measurement and nominal rating.) Note that the Kalman weighting factor used in the motor-speed example takes into account the relative inaccuracy of the tachometer because it gives weighting of 0.1 instead of 1/2 (that is 0.5). (The choice of 0.5 would imply that tachometer error and motor-speed variation have the same variance.)

These estimates are generated by a prediction process and then updated (correctly) by a measurement process. Based on either prior operating experience and/or engineering analysis, a prediction can be made of the nominal system values existing at a particular time. Thereafter, in the absence of information provided by external measurements, knowledge of the dynamics of the system is used to form a math model of the system. The math model is used to extrapolate the predictions - i.e., predict new values. The accuracy of these predictions (estimates) can be improved by use of external measurements. That is, if some or all of the system values at a particular time can be measured, the measurement can be compared with the prediction (estimate) of the system values for that time. The difference (called the measured error) between the measured and predicted values is a measure of the error in the predictions.

The application of the Kalman Filter enters at this point. Since both the prediction and the measurement process may be subject to error, neither the predicted nor the measured values may be the best



3.3 RLGN FUNCTIONAL DESCRIPTION.

The AN/WSN-7(V) INS is based on the principle of using the standing waves generated in a closed path laser beam to detect angular rotation of an inertial reference platform. Three RLGs (or gyros) are mounted perpendicular to each other to detect rotation for an inertial platform about the X, Y, and Z axes. Three accelerometers, one mounted parallel to each axis of rotation, detect motion of the inertial platform in each axis. The rotation and acceleration motions are processed by an internal computer, which determines the orientation and velocity vector of the inertial platform.

Updated by receiving periodic position fixes from a navigation reference such as a GPS receiver, and ship's speed information, the RLGN provides continuous high accuracy geographic position, platform attitude, acceleration, and velocity data for use by other equipment which require these data as inputs.

3.3.1 BASIC DESCRIPTION OF RING LASER GYRO OPERATION. The following discussion is intended to provide a basic knowledge of the manner in which an optical device can be utilized to provide an inertial reference and to outline the design criteria which must be met to implement this function.

Using light to measure rotation is based on the principle that since the speed of light is constant, the time required for a light beam to traverse a given distance is independent of motion of the medium in which the light is traveling. For this reason, if the light beam were to travel around a circular pathway, the time required to complete one revolution (360 angular degrees) would be independent of whether the pathway were stationary or rotating.

As an analogy for using this effect to measure rotation, suppose that an observer on the pathway emits two beams of light in opposite directions and then measures the time required for each beam to complete one revolution and return to the observer's position. If the pathway is stationary, both beams would be received back at the observer's position at the same time. This condition is shown in Figure 3-13, A. If the pathway is rotating, however, the observer moves toward one beam and moves away from the other beam while the beams are traversing the pathway. If the pathway is rotating in the same direction as the light beam, the path length back to the observer is effectively lengthened. Conversely, if the pathway is rotating in the direction opposite to the light beam, the path length back to the observer is effectively shortened. The time difference between reception of the two beams would be a measure of the rate at which the path is rotating, and the sequence in which the beams are received would indicate the direction of rotation. This condition is shown in Figure 3-13, B. The rotation-induced difference in path length is referred to as the Sagnac effect.

In actual practice in an RLG, the circular path is replaced with a polygon path (triangular in the case of the INS) which is constructed using mirrors at each corner of the polygon. The pathway consists of a sealed channel, which is filled with a mixture of gasses that emit light when ionized. High voltage applied to electrodes in the channel ionizes the gas and causes lasing action. When the ring is stationary, lasing in the ring generates a standing light wave, which is analogous to two counter-propagated light beams. The interference between the beams generates a series of nodes (stationary points or points of minimum intensity) and antinodes (points of maximum oscillation) as shown in the left view in Figure 3-13, C. Because the frequency of the laser is very high, more than a million nodes and antinodes are generated in a path less than one-half meter in circumference.

When the frame to which the laser path is attached rotates, the standing wave in the path remains fixed in an inertial (non-rotating) frame of reference. In the analogy, an observer rotating with the ring would pass the nodes and antinodes of the standing wave as the path rotated. By counting the number of nodes passed (and by knowing the time and distance between nodes), the observer could accurately determine the rate and angle of rotation (right view in Figure 3-13, C).

3.3.2 BASIC RLG DESIGN CRITERIA. While the principles behind the RLG are rather simple, several problems must be addressed before these principles can be implemented in an actual rotation sensor. These problems and their solutions are outlined in the following paragraphs to provide a background for understanding the function and operation of circuits which are described later in this chapter.

3.3.2.1 Gas Flow. In an idealized gyro, the standing wave generated in the light beam would remain stationary when the path was not rotating. In actual practice, flow of the ionized gas inside the ring produces a bias effect which causes the standing wave to rotate even when the ring is stationary. The gas flow is a result of the high voltage between the cathode and anode used to ionize the gas. Electrons in the gas drift toward the positive anode and positive ions drift toward the negative cathode. This action induces net flow in the neutral atoms in the gas around the ring. To compensate for this effect, a balanced ionization circuit is used which consists of one cathode and two evenly spaced anodes placed on opposite sides of the ring. By measuring the current in each ionization path and controlling the ionization voltages, counter-rotating motions of the electrons and ions can be established which cancel the induced flow of gas in the ring.

3.3.2.2 Frequency Locking. Another problem is frequency locking of the standing wave. At low rotation rates, the standing wave tends to lock to the ring and move with the ring as the ring rotates. This effect is analogous to friction in a mechanical gyro. Frequency locking is caused by the backscatter of photons at the mirrors. If the mirrors were perfect reflectors, the laser beam would propagate around the path without any photons being reflected back along the incident path. In practice, a small percentage of the incident light wave is backscattered from the mirror surface and is 180 degrees out of phase with the incident wave. This phase shift causes the beam to "want" to reflect at a node on the mirror surface. At low rotation rates, the node generated at the mirror surface tends to move with the mirror, causing the standing wave to move with it. The effects of frequency locking are eliminated by mechanically rotating (dithering) the optical path back and forth at a high rate. This action maintains a high rate of motion in the gyro even when the platform is rotating at a very low rate. Since no net rotation is introduced by the dithering action, the effect of dithering is canceled in the processed signal.

3.3.2.3 Path Length Control. The intensity of a laser beam is dependent on the spacing of the reflective surfaces as a multiple of the wave length of the light. Ideally, if the positions of all mirror surfaces in a laser could be fixed so that the length of the lasing path was held constant at exactly some multiple of the wave length of the light, the laser would operate at maximum efficiency and intensity. Stability of the laser path length is maintained primarily by using a material for the laser which has a very low coefficient of expansion. In addition, the RLGs in the RLGN utilize dynamic mirror positioning known as Path Length Control (PLC) to adjust the path length. In this design, two of the mirrors are mounted on piezoelectric transducers which allow them to be moved inward or outward to adjust the path length. Circuits in the system constantly monitor laser intensity and apply bias voltages to the piezoelectric transducers which position the mirrors to maintain maximum intensity of the beam.

3.3.2.4 Random Drift Improvement. Mirror quality also affects operation of the gyro. In addition to using the most advanced techniques available to ensure high mirror quality, the RLGs used in the RLGN employ the dynamic positioning capability of the gyro mirrors to dynamically reposition the laser beam on the mirror surfaces. This is done by differential positioning of the two adjustable mirrors such that the laser ring is shifted in position across the mirror's surface without changing the total path length. This function, known as Random Drift Improvement (RDI) finds the best surface on the mirrors and reduces mirror degradation resulting from positioning of the beam at a static point on the mirror's surface.

3.3.3 GENERAL DESCRIPTION OF FUNCTIONS. (Refer to Figure 3-14.) The RLGN consists of a Display and Keypad Assembly, power switching and conditioning circuits, alarm relay circuits, electronic circuits associated with control data processing and Input/Output (I/O) functions, electronic circuits associated with position sensing functions, and the electronic circuits and subassemblies contained in the IMU. The RLGN can be controlled at either the Display and Keypad Assembly on the RLGN cabinet, or from the IP-1747/WSN CDU, which is remotely located from the RLGN cabinet. The Display and