THE DREO INERTIAL NAVIGATION LABORATORY: DEVELOPMENT AND TEST CAPABILITIES

by

M. Vinnins

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
REPORT 895

Canada

June 1984
Ottawa
THE DREO INERTIAL NAVIGATION LABORATORY: DEVELOPMENT AND TEST CAPABILITIES

by

M. Vinnins

Electromagnetics Section
Electronics Division

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
REPORT 895

June 1964
Ottawa
ABSTRACT

The DREO Strapdown Inertial Navigation Laboratory is described in detail. Laboratory equipment, much of it custom-designed, is described and specifications are given. Test capabilities are discussed and data acquisition and processing capabilities are detailed.

RÉSUMÉ

Il s'agit d'une description détaillée du laboratoire du CRDO sur le système inertiel non suspendu. On décrit le matériel de laboratoire, qui est en grande partie conçu sur mesure, et en donne les caractéristiques. Il est aussi question des moyens d'essais et de la capacité de collecte et de traitement des données.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT/RESUME</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>v</td>
</tr>
<tr>
<td>1.0 DREO Inertial Navigation Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Laboratory Equipment</td>
<td></td>
</tr>
<tr>
<td>2.1 Motion Table and Associated Electronics</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Clocks and Frequency Sources</td>
<td>8</td>
</tr>
<tr>
<td>2.3 Gyroscope Power Supplies</td>
<td>9</td>
</tr>
<tr>
<td>2.4 Temperature Control and Monitoring</td>
<td>9</td>
</tr>
<tr>
<td>2.5 Monitoring Equipment</td>
<td>10</td>
</tr>
<tr>
<td>2.6 Data Recording Equipment</td>
<td>10</td>
</tr>
<tr>
<td>2.7 Laboratory Support Equipment</td>
<td>12</td>
</tr>
<tr>
<td>3.0 Test Capabilities</td>
<td></td>
</tr>
<tr>
<td>3.1 Types of Tests</td>
<td>12</td>
</tr>
<tr>
<td>3.2 Gyroscope Alignment</td>
<td>13</td>
</tr>
<tr>
<td>4.0 Summary</td>
<td>13</td>
</tr>
<tr>
<td>References</td>
<td>15</td>
</tr>
<tr>
<td>Appendix A. Motion Table Mechanical Specification</td>
<td>17</td>
</tr>
<tr>
<td>Appendix B. Motion Table Electrical Specification</td>
<td>21</td>
</tr>
<tr>
<td>Appendix C. Clock/Multiple Frequency Source</td>
<td>25</td>
</tr>
<tr>
<td>Appendix D. Solid State Sine/Square Wave Wheel Supply</td>
<td>29</td>
</tr>
<tr>
<td>Appendix E. Signal Generator/Microsyn Power Source</td>
<td>33</td>
</tr>
<tr>
<td>Appendix F. Data Acquisition Flowchart</td>
<td>37</td>
</tr>
</tbody>
</table>
The DREO Inertial Navigation Laboratory: Development
And Test Capabilities

1.0 DREO INERTIAL NAVIGATION LABORATORY

The navigation sub-program at DREO was created in 1977 with a mandate to provide technical assistance and advice to DND on all aspects of navigation technology. This has included not only established technologies such as a multitude of radio navigation aids but also satellite position-fixing and strapdown inertial navigation technologies. This latter technology is the basis of the in-house laboratory development at DREO.

The DREO Inertial Navigation Laboratory was developed between 1977 and 1981 as the only complete gyroscope, accelerometer and inertial system test laboratory for the evaluation of strapdown components and systems in Canada. With the aid of a consultant, the laboratory was designed for maximum flexibility; virtually any type of gyroscope can be excited and tested with existing test equipment.

The purpose of such a laboratory is twofold; primarily it provides a test facility for the evaluation of manufacturer's navigation components before procurement of systems but as well it is a flexible, independent facility for experimentation, research and development. More specifically, work within the laboratory has centered upon investigation and characterization of low cost strapdown inertial navigation components and systems. Strapdown technology holds the promise of low cost, long lifetime and ease of maintenance with the mechanical complexity of the traditional gimballed systems being replaced by software computation.

Testing of strapdown gyroscopes is quite different from that of gyroscopes employed on gimballed platforms; a strapdown gyroscope must operate over the entire dynamic range of the vehicle within which it is mounted including not only the possibility of high angular rates but also severe vibration and shock. A photograph of the DREO Gyroscope test station is shown in Figure 1-1. Note that the test platform is a two-axis Goerz motion table which allows both positioning and rate capability about the table axis and positioning capability about the tilt axis.

This report will detail the development, equipment types and specifications, data acquisition capabilities and tests that can be performed in the DREO Inertial Navigation Laboratory.
2.0 LABORATORY EQUIPMENT

Figures 2-1 to 2-4. show the complement of equipment as it is set up in the laboratory. The necessary equipment can be grouped into the following categories:

- Motion table and associated electronics
- Clocks and frequency sources
- Temperature control and monitoring
- Gyroscope power supplies
- Monitoring equipment
- Recording equipment
- Support equipment

Because the laboratory is designed to accommodate a wide variety of gyroscopes and inertial systems, much of the equipment is custom built to permit flexibility. The following sections will describe in detail the limits of performance for the various equipment groups listed. Some equipment specifications are also attached in the Appendices.

2.1 MOTION TABLE AND ASSOCIATED ELECTRONICS

The laboratory motion table is a Contraves-Goerz Corporation Model 57CD, two-axis table controlled by a 30H MPACS, (Modular Precision Angular Control System) Level III command system. Detailed mechanical and electrical specifications are contained in Appendices A and B.

The table, shown in Figure 2-2 is optically aligned to the earth's axis using Polaris as a reference. Alignment is to within ±20 arcsec. Mechanically, the table is capable of a position accuracy of ±1.0 arcsec with a resolution of 0.36 arcsec (0.0001°) in both axes. Wobble is less than ±3 arc sec. (All bearings are mechanical, ball type). The azimuth axis is capable of rates between 0.001 and 999.9 deg/sec with a resolution of 0.01% and stable to ±0.1% over 360 degrees. The tilt axis can be used in position mode only with a range of ±185 degrees.

The table top diameter is 14 inches but a larger top may be used if the environmental chamber is removed. Load capacity is 50 pounds, 6 inches from the table top.

Electrically, the table can be used in 6 modes (azimuth axis) and 2 modes in the tilt axis. The drive modes are:
Figure 2-1 Navigation Laboratory Electronics
Figure 2-2 Contraves-Goerz 57CD/30H 2-axis Motion Table
Figure 2-3  Motion Table Control Electronics
Figure 2-4  Table Top Breakouts and Fixturing
- Off Mode
- Position Mode
- Scorsby Mode
- Rate Mode
- Tach Mode
- Gyro Mode

In Off Mode, drift is less than 0.0001 deg/sec. In Tach Rate Mode, the range is 0.001 to 999.9 deg/sec with a resolution of 0.01%. In Position Mode, the range is from 0.0000 to 359.9999 degrees with an accuracy of ± 1.0 arc sec and a resolution of .36 arcsec.

In Digital Rate Mode, the range is 0.0001 to 199.9999 deg/sec with a resolution of 0.0001 deg/sec and an accuracy of 0.001%.

Scorsby Mode is an analog simulate mode which permits remote analog inputs to control table dynamics.

Gyro Servo Mode permits closed loop operation with gyro time constants from 0.1 ms to infinity, gyro gain from 100 mV/mrad to 10,000 mV/mrad and a carrier frequency range of 400 Hz to 10 KHz.

The table is also fitted with a Rate Trip capability which can be operator-adjusted over the entire dynamic range of both axes.

2.2 CLOCKS AND FREQUENCY SOURCES

One of the most important elements in the gyro station is the combination of clocks and frequency sources used to provide the wheel frequency synchronization, pickoff frequency excitation and clocking for data acquisition and test control.

The test station contains a number of frequency sources including:

- Dynamics Research Corp (DRC) Model 4262 Clock/Multiple Frequency Source
- HP 3320B Frequency Synthesizer
- HP 3335A Synthesizer/Level Generator
- Wavetek 184 5 MHz Sweep Generator

The most critical requirement of the main frequency sources is stability. The DRC source has a stability of $1 \times 10^{-9}$ ppm/day and provides, from a single crystal oscillator, synchronization outputs for a
wheel supply, signal generator supplies (2) as well as auxiliary frequencies for counters and data acquisition systems. Specifications for the DRC 4262 source, a custom-built piece of equipment, are contained in Appendix C.

2.3 GYROSCOPE POWER SUPPLIES

Two primary power supplies are generally required to excite a spinning wheel gyro. The wheel or spin supply controls the gyro wheel rotation. A microsyn or signal generator supply excites the gyro pickoffs required to sense gyro angular rotation. The power supplies used in the gyro station are custom built supplies obtained from NH Research Corp. in California.

A Model SF1250W-2 Sine/Square Wave Wheel Supply is the main power supply and is capable of both 2 and 3 phase operation, sine or square wave with output voltage from 12.000 to 96.000VRMS L-N in 3 ranges. Output resolution is 1 mV.

Detailed specifications are contained in Appendix D but several important features bear noting. Provision is made for separate start and run modes; start mode permits from 100% to 150% of run voltage to be applied to the wheel on startup under operator control. The output frequency range is 350 Hz to 5 KHz and the phase stability is \( \pm 0.05^\circ/\text{wk} \).

The signal generator supply is an NH Model SF2599 power source. Output voltage of 1.0 to 80.0 V RMS is available in two ranges. Accuracy is \( \pm 1.0\% \) of setting with \( \pm 0.02\% \) repeatability. The output frequency range is 225 Hz to 50.0 KHz allowing it to be used on virtually all types of signal generators, both inductive and capacitive. Detailed specifications are contained in Appendix E.

It should be noted that both power supplies are synch loss and line power protected preventing overshoot during power supply recovery after failure.

2.4 TEMPERATURE CONTROL AND MONITORING

Thermal control of the instrument under test can be critical, particularly during drift stability and repeatability tests. The gyro test station contains two Dynamics Research Corp. TC-300, 3-channel, proportional temperature controllers. Component temperature can be controlled to better than \( \pm 0.1^\circ\text{F} \). The Block channel permits control
of the component fixture, the component channel controls any component-mounted internal heaters and the third channel can be used for monitoring and recording. Both visual and audible alarms indicate off-temperature conditions. The temperature controller provides over 60 watts of block power and over 15 watts of inertial component heater power.

Digital thermometers are also used to monitor block and component temperature visually or record it digitally during data acquisition.

2.5 MONITORING EQUIPMENT

Gyro station monitoring equipment includes oscilloscopes, phasemeters, wattmeters and custom designed signal breakout panels.

Both the wheel and microsyn signals are continuously displayed on monitoring oscilloscopes. Wheel power consumption on start up and after settling is also recorded to observe bearing wear within the inertial components.

The most important aspect of monitoring involves the signal breakout panels. Since a large number of signal lines are required in most cases, wiring and connection errors are difficult to locate. The solution has been to group all signals to central connection/breakout panels in the station and then route them to the table top slip rings. On the table top, the signals are again exposed through breakout panels allowing several access points for debugging purposes. Typical breakout panels are shown in Figures 2-2 and 2-4.

2.6 DATA RECORDING EQUIPMENT

The laboratory data recording system is based on an LSI-11 microcomputer. This is a 16-bit machine addressing 32K of memory. The operating system is RT-11 version 4.0. The data acquisition system is shown in Figure 2-5.

In an attempt to facilitate data access, all instrumentation in the station is equipped with the IEEE-488 standard bus interface. The LSI-11, through the IEEE-488 bus, controls the Goerz table remotely and reads table states, etc. Data can be recorded on the HP 5150A Thermal Printer, the HP7402 or HP7132A strip chart recorders or digitally on a Kennedy 9832 magnetic tape recorder with a programmable Kennedy 1629 Half Duplex Interface. A very versatile program has been developed which allows the operator to select table states, recording mediums and data during testing. The program is called 'GYRTST' and a flowchart is attached at Appendix F.
Figure 2-5 LSI-II Data Acquisition System
2.7 LABORATORY SUPPORT EQUIPMENT

Additional support equipment in the laboratory includes an HP5345A Electronic Counter, a Fluke 887A/B/AC/DC Differential Voltmeter and two Datron 1071 multi-function, microprocessor controlled DVMs. The Datron is a high accuracy instrument providing a 6 1/2 digit display (7 1/2 digits in 'averaging' mode for 0.05 ppm resolution). These meters are tied to the data acquisition system on the IEEE-488 bus.

In addition, a North Hills Electronics Ltd. DC Current Source (CS-150) is used as an ultra-stable precision current source for servo testing. The unit provides currents from 0 to ± 150 mA to an accuracy of ± 0.01% of full scale and a stability of ± 1 ppm (of F.S.)/100 hours.

Additional power supplies and meters are installed in the station to provide power to auxiliary electronics which may be necessary during certain tests or to assist in monitoring and debugging system operation.

3.0 TEST CAPABILITIES

With the existing equipment, the DREV Inertial Navigation Laboratory is capable of carrying out characterization tests on almost all classes of single- and two-degree-of-freedom spinning mass gyros with the exception of, perhaps, electrostatic gyroscopes. With modifications to several power supplies, ring laser (RLG) and fiber optic gyro could also be tested.

3.1 TYPES OF TESTS

Tests which can be performed in the laboratory include static (drift) tests, constant rate tests, servo mode tests and a wide variety of strapdown (S/D) tests involving a wide range of dynamics.

A list of possible tests includes:

1) **Drift Coefficients**

   - Bias drift, g-sensitive and g^2-sensitive drift, cross-axis coupling (TDF gyro) and compliance terms.
2) **Instrument Integrity Tests**
   - time constant, run-up and run-down time, pickoff offsets, pickoff scale factor, torquer misalignment, torquer scale factor, tuned speed and Figure-of-Merit (for TRG)

3) **Drift Stability and Repeatability Tests**
   - random drift and repeatability of drift coefficients, turn-on repeatability and transient

4) **Thermal Sensitivity Tests**
   - effects of temperature change on drift coefficients and cool-down sensitivity.

5) **Torquer Scale Factor**
   - linearity (0-1000 deg/sec), repeatability, stability, thermal sensitivity.

6) **Rate Transient Effects**
   - scale factor shifts after rate changes

7) **Other Tests**
   - single axis servo and specialty tests

3.2 **GYROSCOPE ALIGNMENT**

Before characterization tests can begin on an instrument, it must be accurately aligned to the motion table. A number of flexible, micrometer-adjustable fixtures have been developed to aid in alignment for both single and two-degree-of-freedom instruments. Details on such fixtures can be found in DREO TN 84-5.

4.0 **SUMMARY**

The DREO Navigation Laboratory has the capability to perform characterization tests on a wide variety of inertial grade gyroscopes including single and two-degree-of-freedom spinning mass instruments as well as ring laser (RLG) and fiber optic gyros.
Future capabilities will include inertial system tests which will require 3-axis positioning capability and expanded data acquisition and recording capability.

At present, all data reduction, plotting and analysis is performed on other site computers but some of this capability will have to be transferred into the laboratory to improve test efficiency.
REFERENCES

A) 'Instruction Manual for a Model 57CD/30H Two-Axes Index Table System', IM-5685', Contraves-Goerz Corporation

B) 'Clock/Multiple Frequency Source Operation Manual, Model 4262', Dynamics Research Corporation

C) 'Model SF 1250W-2 Rev A, Solid State Sine/Square Wave Wheel Supply', NH Research Corporation

D) 'Model SF2599, Signal Generator/Microsyn Power Source', NH Research Incorporated
Appendix A

A.0 Motion Table Mechanical Specification

A.1 GENERAL

<table>
<thead>
<tr>
<th>Specification</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Federal Standard No. 595-25526 Blue</td>
</tr>
<tr>
<td>Height of Table, overall</td>
<td>66.25±1 inches</td>
</tr>
<tr>
<td>Height of Table Top</td>
<td>50 ±0.5 inches</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
</tr>
<tr>
<td>Height of Tilt Axis</td>
<td>43 ±0.5 inches</td>
</tr>
<tr>
<td>Length, overall</td>
<td>45±0.5 inches</td>
</tr>
<tr>
<td>Length of Stand at Base</td>
<td>34±0.5 inches</td>
</tr>
<tr>
<td>Orthogonality of Axes</td>
<td>5 arc seconds, max.</td>
</tr>
<tr>
<td>Leveling Range</td>
<td>1 degree</td>
</tr>
<tr>
<td>Leveling Resolution</td>
<td>2 arc seconds</td>
</tr>
<tr>
<td>Azimuth Adjust Range</td>
<td>±2 degrees</td>
</tr>
<tr>
<td>Shipping Weight</td>
<td>1200 pounds, approximately, including counterbalance weights</td>
</tr>
<tr>
<td>Cables</td>
<td>2 cables for connection to control.</td>
</tr>
</tbody>
</table>
A.2 AZIMUTH AXIS

Wobble ±3 arc seconds, max.
Bearing Type Mechanical, Ball Bearings
Position Resolution 0.36 arc second (0.0001°)
Position Accuracy ±1.0 arc second, RSS, or better

TABLE TOP
Diameter 14 inches
Material Stainless Steel
Flatness 0.001 inch TIR
Load capacity, azimuth axis vertical 250 pounds with environmental chamber attached
Load capacity, moment load as measured from table top surface 50 pounds, 6 inches from table top

DRIVE, TABLE AXIS
Direct coupled 80 ft-lbs
DC torque motor
Continuous Output Torque 80 ft-lbs
Range Infinite

A.3 TILT AXIS

Wobble ±3 arc seconds, max.
Bearing Type Mechanical, Ball Bearings
Position Accuracy ±1.0 arc second, RSS
Load capacity (moment load) as measured from tilt axis Variable up to 70 ft-lbs. (2 adjustable counterweights)
Range ±185 degrees

DRIVE, TILT AXIS
Direct coupled 22 ft-lbs
DC torque motor
Continuous Output Torque 22 ft-lbs
Capacity
### A.4 MPACS CHASSIS (2-AXIS)

<table>
<thead>
<tr>
<th>P/N</th>
<th>Height</th>
<th>Width</th>
<th>Depth</th>
<th>Weight</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>D703295</td>
<td>8.75 inches</td>
<td>Fits standard 19-inch rack</td>
<td>27 inches, overall, including handles</td>
<td>78 pounds</td>
<td>For complete description, operational and maintenance instructions, see separate manual IM-7508. 30H/MPACS, 2-Axis</td>
</tr>
</tbody>
</table>

### A.5 120-60 CGSM

<table>
<thead>
<tr>
<th>P/N</th>
<th>Height</th>
<th>Width</th>
<th>Depth</th>
<th>Weight</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>E702569</td>
<td>7.00 inches</td>
<td>Fits standard 19-inch rack</td>
<td>24 inches</td>
<td>50 pounds</td>
<td>For complete description, operational and maintenance instructions, see separate manual IM-5607A, 120-60-CGSM Switching Power Amplifier which includes a choke assembly with regenerative energy generator.</td>
</tr>
</tbody>
</table>

### A.6 CHOKE ASSEMBLY/R.E.D., 60 AMP

<table>
<thead>
<tr>
<th>P/N</th>
<th>Height</th>
<th>Width</th>
<th>Depth</th>
<th>Weight</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>D702004</td>
<td>7.00 inches</td>
<td>Fits standard 190 inch rack</td>
<td>20 inches</td>
<td>60 pounds</td>
<td>For complete description, operational and maintenance instructions, see separate manual IM-5607A, 120-60-CGSM Switching Power Amplifier</td>
</tr>
</tbody>
</table>

### A.7 SERVO POWER AMPLIFIER (TILT AXIS)

<table>
<thead>
<tr>
<th>P/N</th>
<th>Height</th>
<th>Width</th>
<th>Depth</th>
<th>Weight</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>E703273</td>
<td>7.00 inches</td>
<td>Fits standard 19-inch rack</td>
<td>24 inches</td>
<td>35 pounds</td>
<td>This manual contains complete description, operational, and maintenance instructions.</td>
</tr>
</tbody>
</table>
B.0 Appendix B

Motion Table Electrical Specification

B.1 OPERATING MODES AND SPECIFICATIONS

MODE SUMMARY

<table>
<thead>
<tr>
<th>Drive Modes</th>
<th>A) Off Mode</th>
<th>B) Position Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C) Scorsby Mode</td>
<td>D) Rate Mode</td>
</tr>
<tr>
<td></td>
<td>E) Tach Mode</td>
<td>F) Gyro Mode</td>
</tr>
</tbody>
</table>

A) Off Mode
B) Position Mode
C) Scorsby Mode
D) Rate Mode
E) Tach Mode
F) Gyro Mode

Axis $1$ Only

Provision is incorporated for digital commands in the Digital Control Modes to be driven by a computer input using address/multiplex scheme.

Data Readout Capability

In the above drive modes, the Position Readout System provides the following readout capabilities:

| A) Position Readout | B) Rate Readout | C) 1/Revolution Pulse | D) 1/Degree Pulse | E) Least Significant Bit Pulse | F) LSB Direction |

B.2 DRIVE MODES ELECTRICAL

A. Off Mode

Servoed Stop Mode

Drift ---------- 0.0001 degree/second

B. Tachometer Rate Mode (Axis $1$ Only)

Transducer ------ DC Tachometer
Rate Range ------ 0.001 to 999.9 degrees/second
Resolution ------ 0.01% on each range
Data Format------ 4-digit keyboard entry
Accuracy High Rate 0.1% over 360 degrees
Short Term ------ ±1% over 1 degree, ±0.75% over 10 degrees,
Stability ------ ±0.1% over 360 degrees
Rate Limit ------ An adjustable rate trip limit is provided to torquer cut-off between preselected rates of 1 and 1000 degrees/second.
C. **Position Mode** (Axis #1 and #2)

Transducer ------ 720-pole Inductosyn and resolver  
Data ------ Manual keyboard input or from data bus  
Range ------ 0.0000 to 359.9999 degrees  
Resolution ------ 0.36 arc second  
Accuracy ------ ±1.0 arc second  
Repeatability --- 0.1 arc second  
Traverse ------ 0.1 to 30 degrees per second least path adjustable  

D. **Precision Digital Rate Mode** (Axis #1 Only)

Range (low)------ 0.0001 to 199.9999 deg/sec or ERU  
(Earth Rate Units)  
Data ------ Manual keyboard input or from data bus  
Resolution ------ 0.0001 deg/sec or ERU  
Accuracy ------ 0.001%  

E. **Analog Simulate (Scorsby) Mode**

The analog simulate mode provides for the remote analog inputs. The position input is summed with the low resolution position error and provides a dynamic range of 100°. An auxiliary rate input can also be utilized to provide rate feed-forward inputs.  

F. **Gyro Mode**

Stiffness (Loop-- >6,000 ft-lb/mrad  
Gain)  
Gyro Gain (Range) 100mV/mrad to 10,000 mV/mrad  
Gyro Time ------ 0.1 ms to =  
Constant (Range)  
Bandwidth ------ Variable, limited by gyro constraints  
Compensation to - Breakpoint Frequencies  
Network  
Signal Input Circuit Characteristics (Gyro Output Signal)  
Impedance ------ >10 KΩ differential floated  
Voltage Range --- 0-1V closed loop, 0-5V open loop
Voltage ........... <2 microvolts
Sensitivity*
Carrier Frequency --- 400 Hz to 10 KHz.
Range

Reference Signal Circuit Characteristics (Reference Signal generated by Customer)

Impedance ........... >50 kΩ
Voltage Range ....... 0.5V to 20V RMS
Waveform ............. Sine
Phase-Shift ........... 0 to ±90 degrees or ±45 to +45 degrees
Capability
Tachometer ............. Available, may be switched
Synchronization
Rate Limit ............ 0 degrees per second, 1000 degrees per second

* System equivalent electrical noise will reflect back less than 2 μvolts RMS "in phase" of noise at the gyro output within the servo bandpass. This includes low frequency noise in the DC section of the servo and AC noise centered around the gyro carrier frequency.
Appendix C

Specifications
Model 4262 Clock/Multiple Frequency Source

General Description

The Clock/Multiple Frequency Source is a generator of multiple channel frequencies each digitally derived and in sync from a single crystal oscillator source.

Specifically, the Frequency Source generates four (4) channels of multiply selectable frequencies.

They are:

I. Wheel Frequencies channel — with a front panel rotary switch to select one of the following ten (10) frequencies; 100, 200, 400, 480, 800, 1200, 1600, 2400, 3200 and 4800 Hertz.

The selected output Wheel Frequency is a square wave and amplitude adjustable 0 to 10 volts.

The selected output Wheel Frequency is available at the front panel at a banana plug and BNC test point, labelled Wheel Freq.; and also at the rear panel on two (2) BNC's wired in parallel and labelled Wheel Freq. Sync.

A capability is provided which digitally phase shifts the selected Wheel Frequency 0° to 360°. This is accomplished by a front panel rotary switch which shifts the phase in 120° increments and a 0°/180° phase toggle switch.

The phase shifted Wheel Frequency output is a square wave and amplitude adjustable 0 to 10 Volts.

The phase shifted Wheel Frequency output is available at the front panel at a banana plug and BNC test point, labelled Wheel Freq. Phase; and also at the rear panel on two (2) BNC's wired in parallel and labelled Wheel Freq. Phase Sync.

II. Microsyn Frequencies Channel — This channel functions the same as channel #1 except that Thirteen (13) selectable frequencies are provided 1600, 2400, 3200, 4800, 6400, 7200, 9600, 12800, 14400, 19200, 38400, and 51200 Hertz.

III. Suspension/Precision AC Frequencies Channel — This channel functions the same as channel #1 except that eleven (11) selectable frequencies are provided 800, 1000, 1200, 1600, 2400, 3200, 4800, 6400, 7200, 9600, and 12800 Hertz.
IV. Auxiliary Frequencies Channel - This channel functions the same as channel #1 except that seventeen (17) selectable frequencies are provided; 100, 200, 400, 800, 1600, 3200, 4800, 7200, 9600, 12800, 14400, 19200, 25600, 28800, 38400, and 51200 Hertz.

A wheel run down time output is also provided. The selected output frequency of the Wheel Frequency is divided by 4 and filtered to a sine wave. This Wheel Run Down time output is also amplitude adjustable 0-10 Volts P-P. It is available on the front panel at the banana plug and BNC test points labelled wheel RDT. The crystal oscillator 1,916,000 Hertz 10 appears at the front panel BNC labelled crystal +10. Also, a one (1) Hertz pulse 2.0u sec, 0 to 10V amplitude appears at a front panel BNC and also a rear panel BNC, labelled 1.0 sec timing pulse.

All outputs may be short circuited and will recover when short is removed. All output amplitudes are adjustable from 0-10 volts via front panel screw driver adjustable potentiometer.

Operating Instructions

The Clock/Multiple Frequency Source requires only 115 Volt 60 Hertz power. A power connector and 3 AMP fuse are located on the rear panel and an on/off switch and AC power light are located on the front panel.

The unit contains two Lambda Power Supplies. They are Model LND-X-152 with over voltage protection to generate plus and minus 15 volts D.C.; and Model LNS-X-5-0V, also with over voltage protection to generate plus 5 Volts D.C.

The D.C. power enters the Augat circuit board thru plug El. The crystal oscillator is a Ventron Laboratories, Inc. unit that requires 5 Volt DC for its oven and crystal oscillator. It is model CO-2175A-5 9.216 MHZ.

The specifications for the crystal oscillator are.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>9,216,000 Hertz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>1 x 10^-9 ppm/day</td>
</tr>
<tr>
<td>Short term Stability less than</td>
<td>1 x 10^-10 ppm/sec</td>
</tr>
<tr>
<td>Temp. Stability</td>
<td>0^0/+50^0 C +1 x 10^-8</td>
</tr>
<tr>
<td>Freq. Offset vs:</td>
<td></td>
</tr>
<tr>
<td>Supply ± 5%</td>
<td>+2 x 10^-8</td>
</tr>
<tr>
<td>Load ± 10%</td>
<td>± 5 x 10^-9</td>
</tr>
</tbody>
</table>

5 Volt D.C. power is supplied to the oven and crystal oscillator thru plug El.

With power applied the crystal frequency can be checked at front panel test point labelled Crystal + 10. It is a 921, 600 HZ TTL square wave output.
The 1.0 Sec timing pulse can be checked at its front panel and rear panel banana jack and BNC connectors. It is a 1 Hz less than 2 usec pulse adjustable by its front panel potentiometer from 0 to 10 Volts.

The other four channel frequency and their related phase shifted frequency can be observed at their respective front panel and rear panel and BNC test points. The respective rotary switches can be manipulated to check for the proper frequency and phase. Also the respective amplitude adjustment potentiometer located on the front panel may be adjusted to give the desired amplitude square wave frequency output.

The wheel RDT sine wave signal may also be observed at its front panel banana plug and BNC test point. Its amplitude may be adjusted to ±10V by its adjustment potentiometer. See layouts for locations and drawings for typical output circuits.
Appendix D

SPECIFICATIONS

MODEL SF 1250W-2 REV A

SOLID STATE SINE/SQUARE WAVE WHEEL SUPPLY

Output Configuration: 4 Wire transformer isolated and floating with 4 wire remote sense.

Phasing (switch selected):
2 (Sine/Square): $90^\circ$ (OB lags A)
3 (Sine): $120^\circ$ Wye

Output Voltage:
Start Mode: Adjustable from 100% to 150% of the set run voltage via a separate front panel mounted 10-turn potentiometer.

Run Mode: 12,000 to 96,000V RMS L-N, in three switch selected ranges. Adjustable via a front panel mounted five decade thumb wheel switch

Resolution: 1 mV min.

Slow Rise Control: Output voltage is front panel adjustable from 0 to 150V via a ten-turn control. This control may be used as a de-mag function

Start-Run Switch: Front panel mounted

Start-Run Decay: Wide range of timing is available by selecting an external capacitor which is mounted on binding posts and adjusting a ten-turn potentiometer, both of which are located on rear of instrument.

Waveform:
A) Sine Wave:
   Distortion: .1% max THD

B) Square Wave:
   Rise & Fall Time: 15 sec max., 10% - 90%
   Overshoot & Ringing: 5% max
   Tilt: 2% max

NOTE: Run Mode Only
MODEL 1250W-2 REV A (Cont'd)

Output Current:

2 - - 3 Wire 90°

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Output Current per phase. Start or Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.000 - 24.000</td>
<td>2 amps</td>
</tr>
<tr>
<td>24.000 - 48.000</td>
<td>1 amp</td>
</tr>
<tr>
<td>48.000 - 96.000</td>
<td>500 ma</td>
</tr>
</tbody>
</table>

3 - - 4 Wire 120° Wye

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Output Current per Phase. Start or Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.000 - 24.000</td>
<td>1.33 amps</td>
</tr>
<tr>
<td>24.000 - 48.000</td>
<td>667 ma</td>
</tr>
<tr>
<td>48.000 - 96.000</td>
<td>333 ma</td>
</tr>
</tbody>
</table>

Phase Stability. ± 0.05°wk at max voltage

Output Frequency Range: 350Hz to 5 KHz

Frequency Time: The automatic timing circuitry will require 15 seconds maximum to lock on any signal in the given frequency range.

External Input Requirements:

Input Voltage: 5 - 30V RMS or TTL

Input Impedance: 10K single ended

Frequency:

Sine Wave Mode: Same frequency as derived output

Square Wave Mode: 2 operation: 4 x the desired output frequency

Load:

Sine Wave Mode: 0.7 lead to 0 lag

Square Wave Mode: 0.7 lead to unity
Amplitude Stability:*  
Vs load: (Sine Wave Mode)  \( \pm 0.005\% \), NL-FS with remote sensing  
(Square Wave Mode)  \( \pm 0.05\% \), NL-FL with remote sensing  
Vs line:  \( \pm 0.001\% \) for 115V \( \pm 10\) V line  
Vs time:  \( \pm 0.0025\%/\text{week} \) under constant conditions  
Vs temp:  \( \pm 0.002\%/\text{C} \) average from 150C to 400C  
Vs input signal:  \( \pm 0.001\% \) for specified input  

* Measurements made with an average sensing voltmeter in the run mode. Specifications are in percent of the full range voltage as measured L-N.

Ambient Temperature:  
00C to 500C

Overload Protection:  
Output may be short circuited indefinitely, recovery is automatic when short is removed.

Front Panel Test Points:  
Voltage and current for both phases. Current is measured via a current transformer with a correlation of 1 amp = 1 volt.

On-Standby Switch:  
Output voltage can be turned off without turning off primary power.

On-Calibrate Switch:  
Front panel mounted control disconnects output from the rear terminal block and places instrument in internal sense mode. This control may be used for gyro back EMF checks.

Line Power/Sync Loss Protections:  
Loss of line power or input sync will not cause overshoot during recovery.

Monitors:  
Voltage and Current meters with front panel mounted phase switch.

High Temperature Interlock:  
A 28VDC relay is provided to allow power to outputs. Loss of this interlock signal puts supply into standby mode. This interlock may be overridden through a rear panel mounted switch.

Electrical Construction:  
All silicon solid state.
MODEL SF 125OW-2 REV A (Cont'd)

Physical: 15 3/4" high, std 19" RETMA panel
Line Power: 115V ±10V, 50/60 Hz
Color: Off-White, Fed. Code 595-16622
APPENDIX E
SPECIFICATIONS
MODEL SF2599
SIGNAL GENERATOR/MICROSYN POWER SOURCE

Output Configuration: Single phase, two wire, floating with two wire remote sense

Range I: 1.0-15.99 VRMS in 10MV increments
Range II 10.0-80.0VRMS in 0.1V increments

Voltage Programming: Front panel mounted, manually set via four thumbwheel switches, and a range switch.

Accuracy: ±1.0% of setting

Repeatability: ±0.02% of maximum voltage

Output Waveform: Sine Wave

Output Power:
Range I: 1.0-15.99VRMS, 10VA (1A max current)
Range II: 10.0-80.0 VRMS, 5VA

Load Power Frequency: 0.7 lead to 0 lag

Output Frequency: 225Hz - 50.0 KHz (usable to 56 KHz)

External Signal Input Requirements:
Voltage: 3-30 V PK-PK, Sine or symmetrical square wave
Frequency: ± 0.25% of operating frequency
Impedance: 10K nominal
Distortion: Less than 0.2% THD 225Hz = 20 KHz
Less than 1.0% THD, 20 KHz = 50 KHz
MODEL SF 2599 (Cont'd)

Amplitude Stability:* +0.005% NL-FL with remote sense
   Vs. line: +0.001% for +10V line, 110VAC
   Vs. time: +0.005%/wk after warmup
   Vs. temp: +0.002%/°C over 15-40°C range
   Vs. sync: ±0.001% for any variation within
   specified limits

* Measurements made with an average sensing voltmeter and are in
  percent of maximum voltage.

Overload Protection: Outputs may be short circuited
   indefinitely, recovery is automatic
   when short is removed.

Current Test Points: Front panel mounted, transformer
   isolated, 1A 1V. Also current
   meter

Voltage Test Points: Front panel mounted, test points
   are connected directly across
   output

On/Standby: Front panel switch that turns off
   the output voltage without turning
   off primary power

Sync Presence Detector: Detects sync voltage and turns on
   supply. If sync is not present,
   supply will remain in standby mode

Line Power Loss Protection: Loss and recovery of line power will
   not cause overshoot of greater than
   1%.

Line Power: 115V ± 10V 50/60Hz

Electrical Construction: All silicon solid state

Operating Temperature: 0 - 50°C

Physical: 8-3/4" high, std 19" RETMA rack
   mount panel

*Addendum to Specification: SF 2599 as of 10/1/79

Addendum - Output frequency changed from 100 Hz -55KHz to 225 Hz-57.
   6KHz per phone conversation W/M. Vinnins 12/12/79.

Addendum: March 28, 1980 - Specs revised per P. Swartz and
   M Vinnins
OPERATING INSTRUCTIONS

2.0 CONTROLS

2.0.1 Power Switch: Turns instrument on and off. A power indicator light is included on the front panel.

2.0.2 Fuse: This is the primary power fuse and should be replaced with a 2 1/2 amp slow blow fuse.

2.0.3 ONSTBY Switch: Turns off the output without turning off the main supply. An indicator light is provided which indicates unit is in ON condition.

2.0.4 Sine Voltage Adjust: This is a rear panel control. Refer to Section 5 Calibration.

2.0.5 Sync Presence Indicator: Indicates the presence of a sync signal to the instrument. When the sync signal is absent the instrument reverts to the "STBY" mode and the "ON" indicator lamp is extinguished.

2.0.6 Voltage Programming Switches: Voltage programming is accomplished by 3 1/2 digit switches (BCD) located on front panel.

2.0.7 Range Switch: Selects Range I or II of voltage range program. Range I selects 1.0 - 15.99 VRMS and Range II selects 10.0-80.0 VRMS.

2.1 INSTALLATION

2.1.1 Mounting: The instrument may be mounted in a standard RETMA 19 inch rack panel or may be used as a bench instrument.

2.1.2 Line Power: The instrument requires 105 to 125V, 60 Hz

2.1.3 Grounding the Power Output: The power output of the instrument is completely isolated from chassis ground. Wherever possible, it is recommended that the output Lo be strapped to ground at some point in the system.

2.1.4 Output Connections: The output is available at an MS Connector located on the rear panel of the instrument. As with any remote sensed power supply, the remote sense connections are essential for proper operation of the instrument.

2.1.5 Input Signal: A BNC connector is provided on the rear panel for the external input signal.
APPENDIX F

DATA ACQUISITION FLOWCHART
'GYRTST' Data Acquisition Program
The DREO Strapdown Inertial Navigation Laboratory is described in detail. Laboratory equipment, much of it custom-designed, is described and specifications are given. Test capabilities are discussed and data acquisition and processing capabilities are detailed.
### Key Words

- Inertial Navigation
- Motion simulator
- Strapdown

### Instructions

1. **Originating Activity:** Enter the name and address of the organization issuing the document.

2a. **Document Security Classification:** Enter the overall security classification of the document including special warning terms whenever applicable.

2b. **Group:** Enter security reclassification group number. The three groups are defined in Appendix M of the ORB Security Regulations.

3. **Document Title:** Enter the complete document title in all capital letters. Titles in all cases should be unclassified. If a sufficiently descriptive title cannot be selected without classification, show title classification with the usual one-capital-letter abbreviation in parentheses immediately following the title.

4. **Descriptive Notes:** Enter the category of document, e.g. technical report, technical note or technical letter. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.

5. **Author(s):** Enter the name(s) of author(s) as shown on or in the document. Enter last name, first name, middle initial. If military, show rank. The name of the principal author is an absolute minimum requirement.

6. **Document Date:** Enter the date (month, year) of establishment approval for publication of the document.

7a. **Total Number of Pages:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **Number of References:** Enter the total number of references cited in the document.

8a. **Project or Grant Number:** If appropriate, enter the applicable research and development project or grant number under which the document was written.

8b. **Contract Number:** If appropriate, enter the applicable number under which the document was written.

9a. **Originator’s Document Number(s):** Enter the official document number by which the document will be identified and controlled by the originating activity. This number must be unique to this document.

9b. **Other Document Number(s):** If the document has been assigned any other document numbers (either by the originator or by the sponsor), also enter this number(s).

10. **Distribution Statement:** Enter any limitations on further dissemination of the document, other than those imposed by security classification, using standard statements such as:
   - (1) “Qualified requesters may obtain copies of this document from their defense documentation center.”
   - (2) “Announcement and dissemination of this document is not authorized without prior approval from originating activity.”

11. **Supplementary Notes:** Use for additional explanatory notes.

12. **Sponsoring Activity:** Enter the name of the departmental project office or laboratory sponsoring the research and development. Include address.

13. **Abstract:** Enter an abstract giving a brief and factual summary of the document, even though it may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall end with an indication of the security classification of the information in the paragraph unless the document itself is unclassified. The abstract shall be represented as (TS), (S), (C), (R), or (U).

The length of the abstract should be limited to 20 single-spaced standard typewritten lines, 7½ inches long.

14. **Key Words:** Key words are technically meaningful terms or short phrases that characterize a document and could be helpful in cataloging the document. Key words should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context.