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HELICOPTER IN-FLIGHT VALIDATION SYSTEM

(HELIVALS)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the Helicopter In-Flight Validation System (HELIVALS). The system monitors all six degrees of freedom of the helicopter flight control position to include cyclic, collective and anti-torque pedals; along with airspeed, altitude (both barometric and absolute), and geographic position. These data are recorded digitally on a magnetic tape recorder mounted in the helicopter. The recorded data is then processed and reduced in a ground station.

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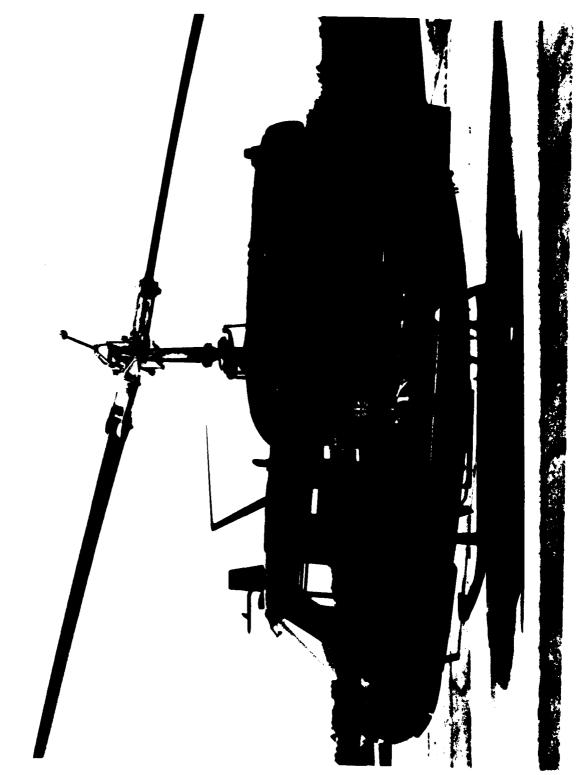
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CONTENTS

JUH1-H Helicopter.

2

HELICOPTER IN-FLIGHT VALIDATION SYSTEM

(HELIVALS)

INTRODUCTION

The helicopter has become an integral resource to the US Army field commander for mobility, surveillance, logistics, medical evacuation and firepower. The utility of this battlefield resource is directly related to the performance of the aviators who pilot the helicopters. This report presents the instrumentation techniques used by the US Army Human Engineering Laboratory (USAHEL) to measure and analyze parameters pertinent to pilot performance.

The Helicopter In-Flight Validation System (HELIVALS) is part of the methodology employed to ascertain pilot performance and various experimental conditions. The methodology consists of paper and pencil analysis followed by laboratory experimentation. The results of these techniques are finally validated in-flight. The HELIVALS provides the experimental resource needed to provide the objective in-flight validation data.

The HELIVALS measures, in real-time, the six degrees of freedom, flight control displacement, pitch, roll, rate-of-turn, aircraft acceleration, aircraft velocity, radar and barometric altitude, airspeed, and geographic position in Universal Transverse Mercator (UTM) coordinates. The data are recorded on magnetic tape. The collected data are then transcribed and analyzed in ground station facilities located at the USAHEL. Growth potential allows for the real-time transmission of data through a telemetry transmitter to a ground station.

DISCUSSION

Airborne System Description

The system permits the simultaneous recording of analog, digital and synchronous sensor data. The analog and synchronous data is converted to digital format while the digital data is recorded as it is generated. The data is then multiplexed and indexed with a time code generator. The digital data is recorded on an instrumentation tape recorder in Pulse Code Modulation (PCM) format. Figure 1 is a block diagram describing the system. A photograph of the data collection system is shown in Figure 2.

3

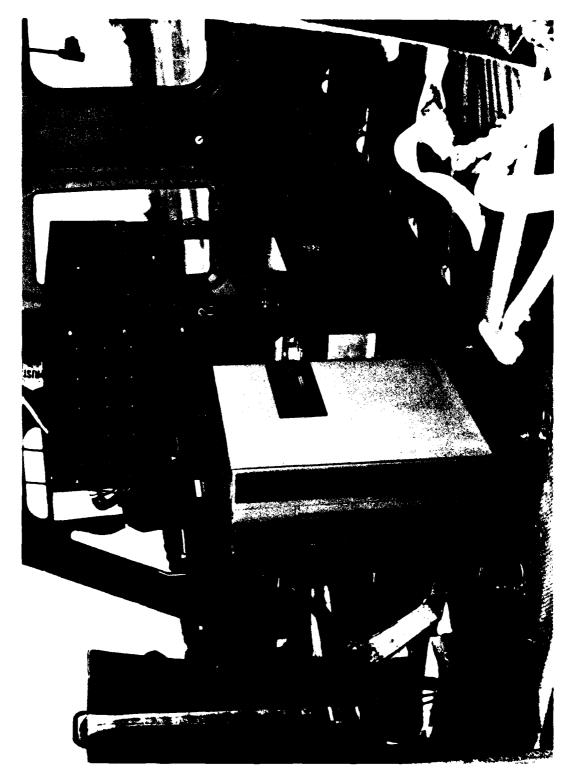Figure 1. In-flight data collection system schematic.

Figure 2. In-flight data collection system.

Sensors

Airspeed

Airspeed is obtained from a differential pressure transducer that is connected to the aircraft's pitot and static lines. The pressure transducer has an output voltage of 0-5 volts which is calibrated with the aircraft's airspeed indicator to provide airspeed values proportional to those seen by the pilot.

Altitude

Two types of altitude are recorded. Absolute, or radar, is the height above the earth's surface. Barometric is the altitude above mean sea level.

Radar Altitude

The radar altimeter provides precise altitude above the terrain. The aircraft is equipped with an AN/APN-209 radar altimeter which is calibrated to read 0 when the aircraft is sitting on the ground and can record to 1500 feet above ground level. Figure 3 shows the pilot's radar altimeter.

Barometric Altitude

The barometric altitude information is processed through an altitude transducer that is connected to the aircraft's static pressure line. The effective resolution is five feet with a recording capability from 0-10,000 feet. The output of this transducer is calibrated to the aircraft's altimeter. Figure 4 shows the pressure transducers for both barometric altitude and airspeed.

Control Position

Control position is sensed through linear transducers connected to the push rods of each of the respective controls (cyclic pitch, cyclic roll, collective, anti-torque pedals). The transducers provide $\pm$2-1/2" of travel with 0-5 VDC voltage proportional to the control position. Low pass filters with a 6HZ cutoff are used to eliminate undesirable high frequency artifacts. Three of these transducers are shown in Figure 5.
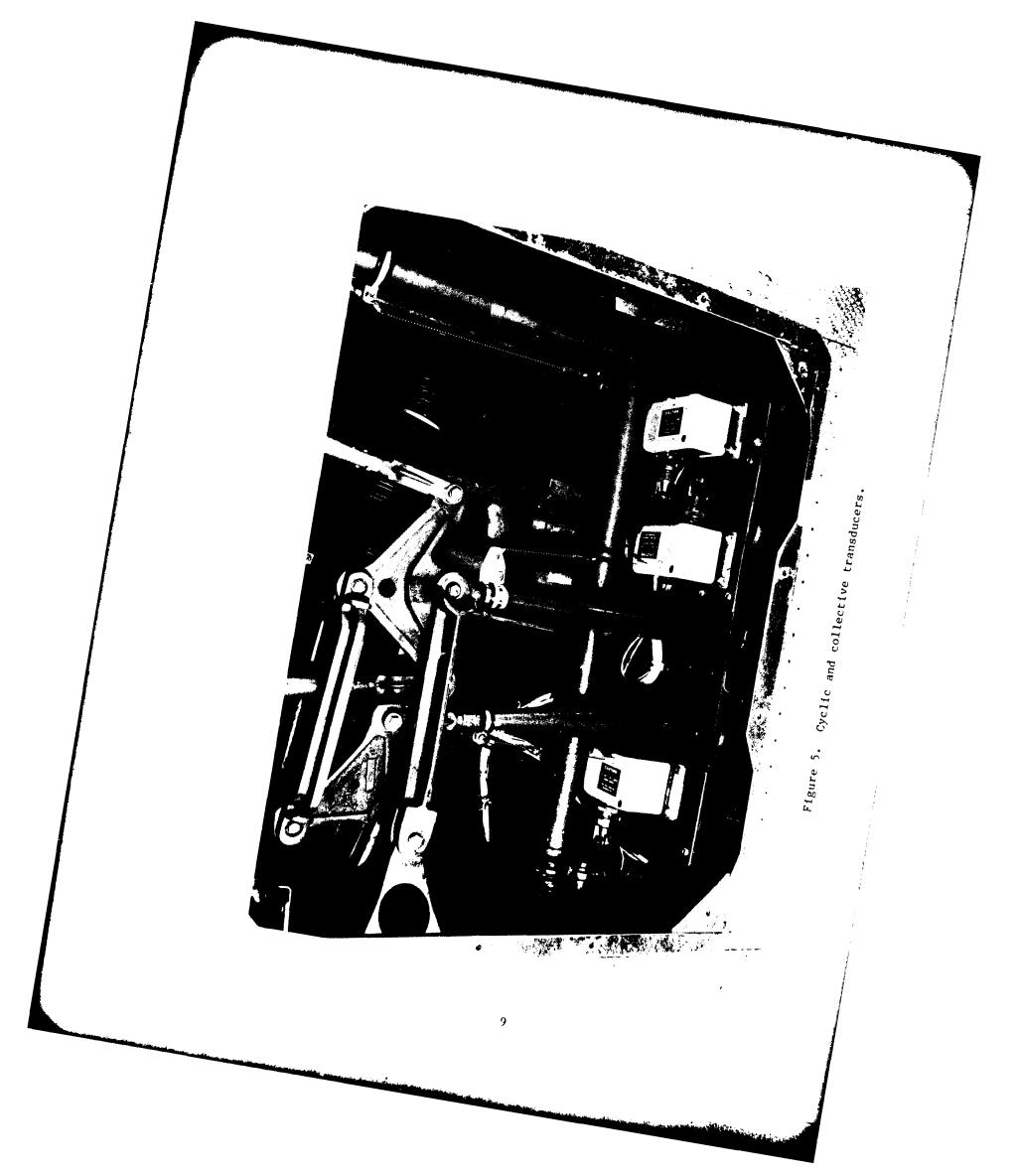

Aircraft Position

The helicopter position is obtained with a Doppler Navigation System. The system installed is the Lightweight Doppler Navigation System (LDNS) or AN/ASN-128. The Doppler System is composed of three Line Replaceable Units

Figure 3. Pilot's radar altimeter.

Figure 4. Barometric altitude and airspeed transducers.

Figure 5. Cyclic and collective transducers.

9

The Doppler System is provided magnetic heading information from the aircraft's AN/ASN-43 magnetic heading reference system. Pitch and roll are provided via the aircraft's MD-1 reference gyro signal. This data is provided in the form of three wire syncro signals plus a 26 VAC, 400-Hz reference signal.

The accuracy of the Doppler Navigation System is highly dependent on the accuracy of the associated heading reference system. The heading reference is the primary source of error in the Doppler Navigation System. Therefore, special emphasis and attention must be given to aligning and calibrating the aircraft's AN/ASN-43 heading reference system.

A specially designed and constructed HEL interface is provided to select any two out of the eleven possible Doppler Navigation data outputs and convert them from serial Binary Coded Decimal (BCD) data to parallel BCD for input to the Airborne Telemetry System. Generally, the logic will be set to provide UTM Easting and Northing data. Figure 6 is a block diagram of the Doppler Navigation/Telemetry interface which will be described in a separate technical report.

Pitch and Roll

The pitch and roll positioning information is recorded directly from the altitude information available to the pilot on the MD-1 gyro. The MD-1 is a single gyro with its spin axis stabilized in the vertical position. Two synchros, one on each gimbal of the gyro, have outputs proportional to the pitch and roll angles. Theoretically, there would be no output from the pitch synchro if the nose of the aircraft moved laterally with respect to the earth while at a roll angle of 90 degrees. However, due to the limited maneuverability of the aircraft, this presents no problem. The rotors of the synchros are excited with 110 VAC, 400 Hz from the aircraft's inverters and this is used as the reference for the synchro-digital converters. The three-lead output from the synchros are taken through an adaptor, to be digitized and recorded.

Heading

Heading information is obtained from the auxillary synchro transmitter, B308, in the pilot's ID-998/ASN course indicator. This signal is slaved to J-2 gyro compass by a servo amplifier and motor which drives the pilot's heading dial and the rotor of the synchro. The J-2 gyro is slaved to magnetic north by a flux valve located in the tail of the helicopter.

The three outputs from the synchro stator and the 26 volt, 400 Hz rotor excitation (reference) voltages are fed from an adapter, to the
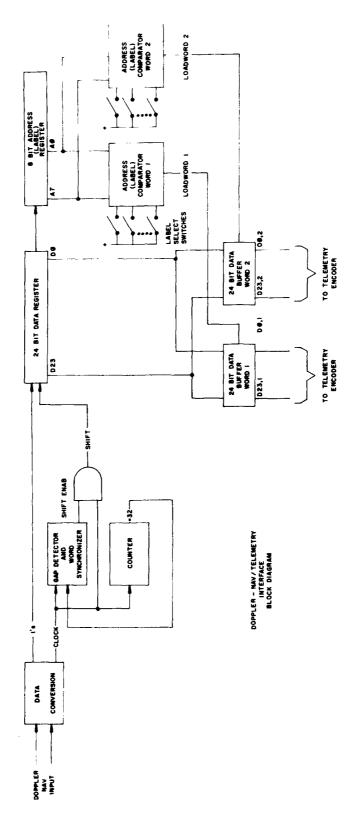
Figure 6. Doppler navigation/telemetry interface.

11

heading synchro/digital converter. An adapter similar to the one used on the MD-1 gyro was used for the ID-998 indicator in order to keep the air-crafts's wiring intact.

Angular Rates

A triaxial rate gyro is used to measure the instantaneous angular velocities corresponding to roll, pitch and yaw. Each rate gyro is a DC-operated gimballess, type with 5,000 ohm potentimeter output with an accuracy of ± 1 percent of full scale at zero degrees/second increasing to ± 2 percent at maximum rate. The threshold is .5 percent of full scale. The gyro spin motors require 28 volts DC ± 10 percent at a running current of 300 ma. and a starting current of 2.5 amps maximum (starting time is approximately 15 seconds). The overall weight is approximately 3.5 pounds.

This velocity transducer is aligned and affixed to a firm structure of the aircraft at a convenient location. The 0-5 volt DC output from the potentiometer goes through a 6 Hz, low pass filter before entering the multiplexer-encoder.

Linear Acceleration

A hermetically-sealed, triaxial accelerometer with 5,000 ohm potentiometer outputs is used to measure linear acceleration. These accelerometers have an accuracy (including linearity and hystereses) of ± 1 percent of full scale at zero G's increasing to ± 2 percent of full scale at maximum load factor. Full scale range is ± 5 G's with a 22 cps natural frequency. They weigh approximately 6 ounces.

Signal Conditioning

All linear transducer signals have low-pass filters with 6 Hz cutoff to eliminate undesirable high frequency artifacts.

GROUND STATION

Ground Station Hardware

A PDP-11/34A Computer hosts the ground-station telemetry hardware which consists of an instrumentation tape recorder/reproducter, a PCM decommutator, a time code translator, a buffered data channel interface, and a priority interrupt module.

The data paths are shown in Figure 7. Airborne data in serial PCM format is reproduced from one of the tape recorder channels and passed to the PCM encoder which processes the data stream to provide parallel data
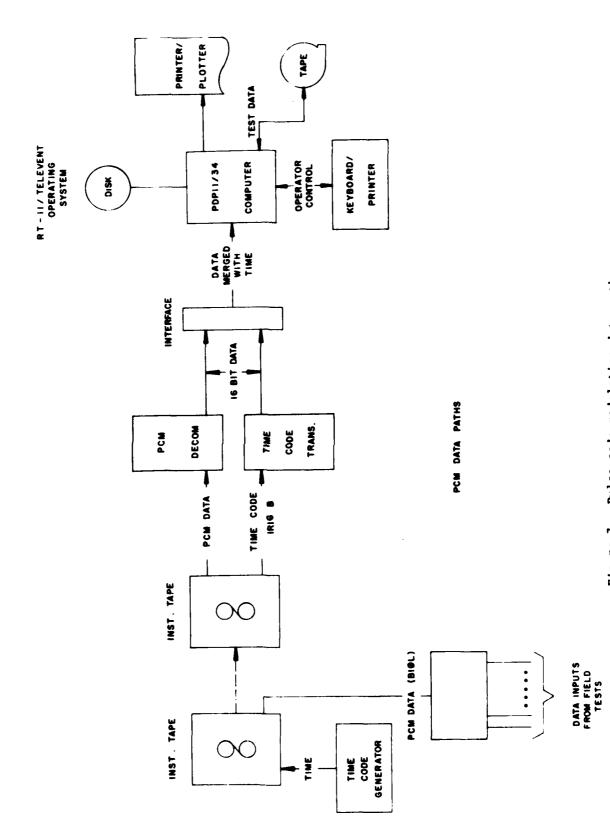
12

Figure 7. Pulse code modulation data paths.

13

words to the buffered data channel interface. Concurrently, Inter-Range Instrumentation Group (IRIG) B-time code from a second tape-recorder channel is passed to a time-code translator which converts the IRIG B code to parallel days, hours, minutes, and seconds and presents this data to the buffered data channel to be merged with the PCM data. Sensor data and time are then additionally processed in the PDP-11/34A Computer. Sensor data may be plotted as it is processed with time indexing and/or stored on digital magnetic tape for later analysis.

Figure 8 depicts the entire ground-station system configuration and shows all the system peripheral and graphic devices available to the user for data reduction, storage, transmission, and analysis. A high-speed communications line to a remote CDC Cyber 173/176 scientific computer system is shown. It provides ready access to an exceptionally powerful tool for data analysis.

Ground-Station Software

The ground-station hardware and the PDP-11/34 computer are integrated and controlled by the ground-station software which consists of the DEC RT-11 operating system and the EMR TELEVENT-11 software. Both software systems are operated under license from the vendor.

TELEVENT is a real-time, event-oriented software system designed for use on PDP-11 computers which provides the operator with the capability to set up, acquire, process, and store data. This is accomplished through the *following functions:*

     a. Prepares the ground-station hardware and computer peripheral devices to accept the incoming data.

     b. Establishes paths for incoming data to the appropriate operating programs.

     c. Acquires data in the form of a PCM stream from 12 digital inputs, 32 analog inputs, and three time words, and stores this data in the PDP memory.

     d. Processes data by converting to engineering units. Data is converted by a user supplied polynomial transformation in the form:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5$$

     e. Plot selected channels of data in stripchart form on the printer/plotter. Up to 10 preselected channels can be plotted in real-time simultaneously with data acquisition, conversion, and storage. Figure 9 is an example of several channels of data from a flight test which have been plotted.
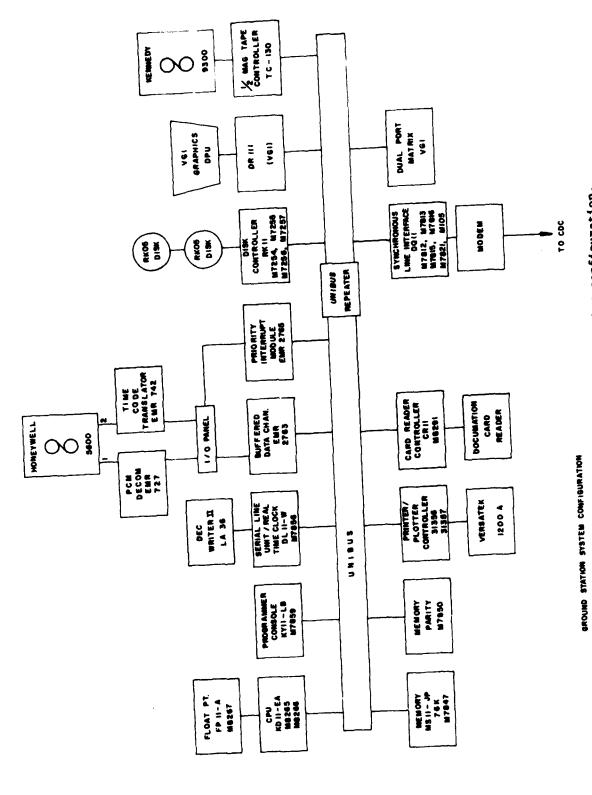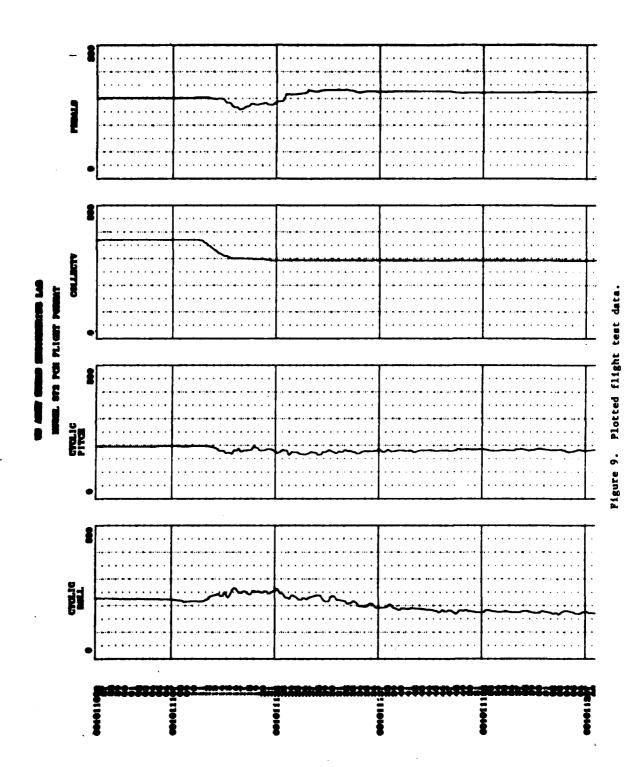
14

GROUND STATION SYSTEM CONFIGURATION

Figure 8. Ground station system configuration.

15

Figure 9. Plotted flight test data.

16

f. Formats and stores data on nine-track magnetic tape in ASCII characters.

g. Provides the operator with the capability to connect/disconnect interrupts to appropriate software programs.

Once the data has been received, processed, and stored on magnetic tape, the RT-11 operating system can be utilized to process the data through analysis programs. Using FORTRAN under RT-11, USAHEL can develop analysis programs for specific applications. In addition, if more complex data analysis is required, the data can be transmitted to a remote CDC Cyber 173/176 scientific computer system.

SUMMARY

The HELIVALS provides the USAHEL with a dynamic operational measurement tool to gather and validate in-flight performance measurements of Army aircrew members. Such a research system provides the capability to obtain and validate data that often times is theoretical in nature. The HELIVALS allows the researcher to reach the final plateau in quantifying both aircraft performance maneuvers and pilot performance in a highly valid and versatile research tool. Such a system can only enhance the quality of the research product.

A summary table of the data collected is presented in the Appendix.

APPENDIX

ANALOG AND DIGITAL SIGNALS

Signal Name	Transducer Input Range	Transducer Output Range	Type Transducer	Transducer Manufacturer and Model Number	Filter	Excitation Voltage	Channel Assignment[d]	Data Requirement
Lat. Cyclic	0-5"	0-5 VDC	Position/ Displacement	Colesco Model # PT101-RX-5A-100E	6 Hz	5 VDC	–	Time history of displace-ment.
Long. Cyclic	0-5"	0-5 VDC	Position/ Displacement	Colesco Model # PT101-RX-5A-100E	6 Hz	5 VDC	–	Time history of displace-ment.
Anti-Torque Pedal	0-5"	0-5 VDC	Position/ Displacement	Colesco Model # PT101-RX-5A-100E	6 Hz	5 VDC	–	Time history of displace-ment.
Collective	0-10"	0-5 VDC	Position/ Displacement	Colesco Model # PT101-RX-10A-100G	6 Hz	5 VDC	–	Time history of displace-ment.
Velocity – X	±5°/sec	0-5 VDC	Rate[b]	Humphrey- 3 Axis Gyro - Rate R002-2356-1	6 Hz	5 V/28 V	–	Time history of X-rate.
Velocity – Y	±5°/sec	0-5 VDC	Rate[b]	Humphrey- 3 Axis Gyro - Rate R002-2356-1	6 Hz	5 V/28 V	–	Time history of Y-rate.
Velocity – Z	±5°/sec	0-5 VDC	Rate[b]	Humphrey- 3 Axis Gyro - Rate R002-2356-1	6 Hz	5 V/28 V	–	Time history of Z-rate.
Acceleration – X	±5 eg	0-5 VDC	Accel[c]	Humphrey- 3 Axis Accel - LA 700-0301-1	6 Hz	5 V	–	Time history of X-Accel-eration.
Acceleration – Y	±5 eg	0-5 VDC	Accel[c]	Humphrey- 3 Axis Accel - LA 700-0301-1	6 Hz	5 V	–	Time history of Y-Accel-eration.
Acceleration – Z	±5 eg	0-5 VDC	Accel[c]	Humphrey- 3 Axis Accel - LA 700-0301-1	6 Hz	5 V	–	Time history of Z-Accel-eration.
Altitude – Baro	0-10000 ft	0-10 V	Altitude (Press xducer)	CIC Model # 8000	6 Hz	±15 VDC	–	Time history of altitude.
Airspeed	30-200 knots	1.5 V - 10 V Clamp at 5 V	Airspeed	CIC Model # 8100	6 Hz	±15 VDC	–	Time history of airspeed.
Engine RPM	0-6600 RPM	0-5 V	[a]	–	–	–	–	Time history of engine RPM.
Altitude – RADAR	0-1500 ft	0V - 11.1 V .0V = zero feet 11.1V = 1500 feet (0V means loss of track condition. Clamp output at +5 V [620.6 feet])	[a]	AN/APN-209	–	±15 VDC[e]	–	Time history of RADAR altitude.

[a] Requires inverter with 0.6 V offset. ±15 V excitation required for offset and inverter circuit.
[b] Rate transducer integrated in single unit.
[c] Acceleration transducers integrated in single unit.
[d] To be determined by USAAEFA.
[e] Signal conditioning to be provided by USAAEFA.

20

DIGITAL SIGNALS

Signal Name	Digital Type	Digital Code Output to PCM Encoder	Digital Range	Digital Converter Manufacturer and Model Number	Channel Assignment[b]	Remarks
Roll	10-bit parallel	BIN	1023	[a]	1	Syncro MD-1 Gyro.
Pitch	10-bit parallel	BIN	1023	[a]	2	Syncro MD-1 Gyro.
Heading	10-bit parallel	BIN	1023	[a]	3	Syncro ID-998.
Switch 1/ Switch 2	Parallel 4-bits per switch	BCD	0-99	BCD thumbwheel switches	4	Subject code.
Position - Northing	Parallel	BCD	0-99.99	USAHEL serial-to-parallel converter	5,6	Northing Doppler.
Position - Easting	Parallel	BCD	0-99.99	USAHEL serial-to-parallel converter	7,8	Easting Doppler.
Switch 3/ Switch 4	Parallel	BCD/BCD	0-99	BCD thumbwheel switches	9	Month (2 digits).
Switch 5/ Switch 6	Parallel	BCD/BCD	0-99	BCD thumbwheel switches	10	Day (2 digits).
Switch 7/ Switch 8	Parallel	BCD/BCD	0-9/0-9	BCD thumbwheel switches	11	Year/course code.
Switch 9/ Switch 10	Parallel	BCD/BCD	0-9/0-9	BCD thumbwheel switches	12	Test code (2 digits).

[a]To be provided by EMR.
[b]Channels can be reassigned as required.

21

Signal Name	Transducer Input Range	Transducer Output Range	Type Transducer	Transducer Manufacturer and Model Number	Filter	Excitation Voltage	Channel Assignment[d]	Data Requirement
Lat. Cyclic	0-5"	0-5 VDC	Position/ Displacement	Celesco Model # PT101-RX-5A- 100E	6 Hz	5 VDC	–	Time history of displace- ment.
Long. Cyclic	0-5"	0-5 VDC	Position/ Displacement	Celesco Model # PT101-RX-5A- 100E	6 Hz	5 VDC	–	Time history of displace- ment.
Anti-Torque Pedal	0-5"	0-5 VDC	Position/ Displacement	Celesco Model # PT101-RX-5A- 100E	6 Hz	5 VDC	–	Time history of displace- ment.
Collective	0-10"	0-5 VDC	Position/ Displacement	Celesco Model # PT101-RX-10A- 100G	6 Hz	5 VDC	–	Time history of displace- ment.
Velocity - X	$\pm 5°$/sec	0-5 VDC	Rate[b]	Humphrey- 3 Axis Gyro - Rate RG02-2356-1	6 Hz	5 V/28 V	–	Time history of X-rate.
Velocity - Y	$\pm 5°$/sec	0-5 VDC	Rate[b]	Humphrey- 3 Axis Gyro - Rate RG02-2356-1	6 Hz	5 V/28 V	–	Time history of Y-rate.
Velocity - Z	$\pm 5°$/sec	0-5 VDC	Rate[b]	Humphrey- 3 Axis Gyro - Rate RG02-2356-1	6 Hz	5 V/28 V	–	Time history of Z-rate.
Acceleration - X	± 5 og	0-5 VDC	Accel[c]	Humphrey- 3 Axis Accel - LA 700- 0301-1	6 Hz	5 V	–	Time history of X-Accel- eration.
Acceleration - Y	± 5 og	0-5 VDC	Accel[c]	Humphrey- 3 Axis Accel - LA 700- 0301-1	6 Hz	5 V	–	Time history of Y-Accel- eration.
Acceleration - Z	± 5 og	0-5 VDC	Accel[c]	Humphrey- 3 Axis Accel - LA 700- 0301-1	6 Hz	5 V	–	Time history of Z-Accel- eration.
Altitude - Baro	0-10000 ft	0-10 V	Altitude (Press xducer)	CIC Model # 8000	6 Hz	± 15 VDC	–	Time history of altitude.
Airspeed	30-200 knots	1.5 V - 10 V Clamp at 5 V	Airspeed	CIC Model # 8100	6 Hz	± 15 VDC	–	Time history of airspeed.
Engine RPM	0-6600 RPM	0-5 V	•	–	–	–	–	Time history of engine RPM.
Altitude - RADAR	0-1500 ft	0V - 11.1 V .6V = zero feet 11.1V = 1500 feet (OV means loss of track condition. Clamp output at +5 V [628.6 feet])	•	AN/APN-209	–	± 15 VDC[a]	–	Time history of RADAR altitude.

[a]Requires inverter with 0.6 V offset. ± 15 V excitation required for offset and inverter circuit.
[b]Rate transducer integrated in single unit.
[c]Acceleration transducers integrated in single unit.
[d]To be determined by EMR.
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