AN INTEGRATED DATA ACQUISITION SYSTEM FOR PARACHUTE DEVELOPMENT AND QUALIFICATION TESTING

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ABSTRACT

The development and qualification of personnel and cargo aerial delivery parachute systems present unique challenges to the instrumentation and data analysis engineers. Some of the areas that must be addressed include: a) system must be low in cost, b) system often has to be operated on ranges that have limited telemetry or other range instrumentation and support (i.e. commercial skydiving centers), c) system is often rigged and operated by parachute support personnel and test jumpers rather than instrumentation engineers, and d) system must be able to be reconfigured in the field to support a variety of test card requirements during a typical test day, e) data must be available for review and the system be prepared for the next test within a few minutes of parachute recovery, and f) system must withstand ground impact velocities as high as 50 ft/sec (15.24 m/sec) without damage. This paper describes such a system as it is being used for the development and qualification testing of a number of parachute systems for sport skydiving, military personnel, as well as cargo parachute systems. This modular system has been developed as a result of previous experience in other parachute development and qualification projects to address the need for a flexible Data Acquisition System (DAS) system that meets the above requirements. This paper describes some of the tools used to meet these requirements.

Key Words – Parachutes, Parachute Data Acquisition System (PDAS), Integrated Data Acquisition System (IDAS), Programmable, Autonomous, Modular, Integrated, Sensors, GPS Data Analysis.

INTRODUCTION

The development and qualification of parachute systems has become more complex in recent years due to such things as higher canopy performance, the use of high tech materials for strength and weight reduction, shorter design cycle schedules, product safety requirements, as well as the need to have data to address future design requirements and potential litigation in the use of the parachute systems themselves. In the past parachute testing was basically the responsibility of the designer and test jumpers (sometimes one in the same) going to the drop zone and jumping the canopy to evaluate the design requirements. Test results were primarily qualitative; Did the canopy open? How "hard" was the canopy opening? Did anything break? The next improvement in the process was the availability of low cost video camcorders that were able to be taken to the drop-zone. These provided information such parameters as timing, landing velocity, canopy opening and maneuvering characteristics, failure diagnosis, etc. At the other end of the spectrum were military development programs which used the resources of instrumented test ranges with high quality time-space-position information (TSPI) trajectory tracking instrumentation as well as RF telemetry systems onboard the test article for data collection. This paper describes a cost effective solution that fills the gap between the low price, low tech approach and the comprehensive solution available at a National Range facility.

ANALOG DATA SOLUTION FOR A PARACHUTE DT&E EFFORT

A US Government customer which is in the process of evaluating a personnel parachute system for deployment identified a set of basic functional requirements for an instrumentation system to support the ongoing Developmental Test and Evaluation (DT&E) Activities in support of this project. The basic system requirement was that the system be able to measure the parachute dynamics without physically modifying the parachute system or compromising the parachute system's airworthiness and safety. The Air Forces personnel's market surveys indicated, and interface with Industry showed that Commercial Off the Shelf (COTS) technology could support the requirements.

The result of this effort was the identification of an Industry subject matter expert (SME), Mr. Philip Starbuck, to meet the Test Team's requirements. Philip based everything in the integrated system, the IDAS-Mark 4 (IDAS-4), based on the key requirements listed in Table 1.

Table 1 Key System Requirements

REQUREMENT	OBJECTIVE	REMARKS
Position	3D Position and velocity.	WAAS Enabled GPS Receiver
Acceleration	Parachute Opening Shock	Three Axis Enabled Accelerometer
Temperature	Air Temperature During Descent	Fast Response Thermocouple
Strain Forces (Risers)	Riser Forces	Non-Intrusive In Line Webbing Tension Load Cell.
Barometric	Altitude and Descent Rate	Barometric Pressure Sensor

TYPICAL PARAMETERS MEASURED DURING FLIGHT TEST

Time-Space-Position Information (TSPI) –GPS is the primary data source with barometric altimeter used to correlate altitude. (Quantitative)

Acceleration - Tri Axial accelerometers are used to measure the parachute opening acceleration levels. This information is also used to correlate the force data obtained from the riser load cells. (Quantitative)

Free Air Temperature – A small bead diameter (<= 5 mil) thermocouple is placed in the airstream to measure air temperature with a minimum of response time lag. This information is used in the calculation of the air density present during the various phases of flight. The resulting data provides data that is used to determine the dynamic loads that the parachute system is subjected to during various phases of flight. (Quantitative)

Canopy Opening Force and Duration - Are measured by load cells that are installed in the parachute risers to measure riser forces. In this case web tension sensors were used so that the parachute harness would not have to be modified from its tactical configuration for test purposes. This information is also used to correlate the canopy opening acceleration data obtained from the tri axial accelerometer. (Quantitative)

Barometric Altitude – An absolute pressure sensor (PSIA) is used to measure pressure. During data reduction this information is converted to pressure altitude. In addition air density during flight is derived from the barometric altimeter data as well as the real time air temperature at altitude as supplied by the fast response thermocouple sensor. This information is used to determine rates of descent during various phases of flight as well. (Quantitative)

Airspeed – Airspeed, when required, is typically measured onboard the test article using a variety of sensors such as turbine anemometers, hotwire anemometers, pitot or similar. If winds aloft data as described in the following paragraph is available, airspeed may be determined using winds aloft in combination with the TSPI data derived from the test article GPS data. (Quantitative)

Wind speed – Wind speed measurement may use a number of different techniques. In the case of an instrumented range, windsonds or acoustic wind velocity measurement systems may be employed. Some test projects employ dropsonds of various configurations any of which include a small decelerator / parachute and a GPS receiver data logger or RF link to measure the wind velocities vs. altitude. In the case of those systems that measure relative wind speed and direction onboard the test article a variety of sensors such as turbine anemometers, hotwire anemometers, pitot tubes (either hard mounted or gimbaled) or similar. During data reduction, this data combined with the TSPI data from the GPS receiver is used to determine relative wind direction and velocity as well as winds aloft. Another technique involves the test jumpers flying non-maneuvering passes on reciprocal headings under canopy. This data is then reduced using the TSPI data to provide the magnitude and direction of winds aloft at that altitude. (Quantitative)

Video –Video is recorded in flight by cameras located as necessary on the test jumpers rig (i.e. helmet) in order to monitor the parachute canopy during the flight sequence. In addition, one or more additional test jumpers use video camcorders to obtain visual information on the parachute/test jumper in flight. Additional video recorders/cameras are positioned on the ground as necessary to monitor the flight. (Qualitative and Quantitative Timing Data)

Test Jumper – Perhaps the most useful information available is obtained by debriefing the test jumper and the test jumpers supporting the test project after the flight. This qualitative information is useful in correlating the quantitate information as well as providing insight into the performance of the parachute system itself. Often information from this data resource is not properly=captured and over time the information is lost to memory or becomes rumor and hearsay. (Qualitative)

AN INSTRUMENTATION SYSTEM USED IN SUPPORT OF THE PROJECT

Based on the above requirements the IDAS-4 (Integrated Data Acquisition System) as supplied by PSG and Associates was selected by the project.

The IDAS-4 is intended to be used in a variety of flight test programs where the test requirements dictate the need for an as an easily configured autonomous data collection system for recording the dynamic environment present on the test article as well as GPS data. The system has been designed for use in a variety of applications such as flight testing of parachute and unmanned aerial or terrestrial vehicles. The system incorporates up to of eight (8) sensors and/or signal conditioners as well as a commercial GPS receiver. The analog signal(s) are digitized by a 16 bit analog to digital converter and the resulting data is stored along with the GPS data on a Compact Flash memory card.

The typical configuration of the system for parachute flight testing includes up to eight channels of analog data configured as follows: a) Two strain gage signal conditioning modules for use with bridge type load cells for measuring parachute riser loads, b) One Tri Axis accelerometer sensor for measuring parachute opening shock loads, c) One barometric absolute pressure for altitude data, and d) One thermocouple air temperature probe for use in calculating standard atmosphere parameters during descent. In addition the system includes; a) The data logger, b) Commercial GPS Receiver, c) Pull away lanyard to initiate recording, d) Operator controls and indicators, e) Compact Flash memory card, and f) Rechargeable Nickel Metal Hydride (NiMh) battery.

All configuration parameters are stored on the CF card using any of the commonly available test editing tools. The system does not require special "dashboard" software for configuration or data downloading. Data reduction and analysis is straightforward and is typically performed using commonly available data analysis tools, such as, Hydesoft Computing DPLOT® (http://www.dplot.com/), National Instruments LabVIEW® (http://www.ni.com/labview/), Mathworks MATLAB® (http://www.mathworks.com/products/matlab/), Microsoft Excel® (http://office.microsoft.com/en-us/excel/), Parametric Technology Corporation (PTC) Mathcad® (http://www.ptc.com/products/mathcad/), or similar.
GPS data is typically reduces using a combination of software tools. These include (but are not limited to) Microsoft Excel® (http://office.microsoft.com/en-us/excel/) for data reduction, analysis, and plotting, GPSBable (http://www.gpsbabel.org/) for data format conversion, Google Earth (http://earth.google.com/) for graphic display, as well as other software tools appropriate to the reduction and analysis process.

SOME OTHER RERESENTATIVE INSTRUMENTATION SOLUTIONS

The following is a list of some of the other instrumentation solutions found in use in the parachute industry. It is by no means comprehensive and is only intended to provide a representation of solutions currently in use.

Industrologic – (http://www.industrologic.com/) PDAS, is a ruggedized, self-contained analog or serial data logger originally designed for military parachute air drop testing. The PDAS has been widely used for a number of years in the parachute industry in support of test programs. Another product, the PDAS Lite, is a smaller lower price version of the PDAS. The PDAS can alternately be configured as a serial data logger for applications that require a serial data logger such as GPS data recording. As these units provide either eight (8) analog voltage inputs or one (1) RS-232 serial data input, it is necessary for the user to configure the sensors and signal conditioners necessary for the particular application. Industrologic also has a number of sensor and signal conditioner subsystems related to parachute testing in their product portfolio as well.

Eagle Tree – (http://www.eagletreesystems.com/) Seagull/Seagull PRO are a low sample rate (up to 40 Hz.) data logger system that is typically used by the radio control modeler community. Because of the products heritage it leverages the large consume base to provide a low price solution a large support base. It has a number of features that may be of use in parachute testing. These include the ability to record sensor data onboard as well as downlink the data via a 900MHz spread spectrum RF transmitter. The user is required to adapt the system from its primarily RC configuration to the needs of the parachute test instrumentation configuration requirements.

Gulf Coast Data Concepts – (http://www.gcdataconcepts.com/) Gulf Coast Data Concepts (GCDC) has developed and manufacturers an interesting line of single purpose triaxial accelerometers and barometric pressure sensor data loggers that incorporate a USB interface and user interface. These devices provide the user with a low price means to measure acceleration or altitude.

GPS Flight - (http://gpsflight.com/) Supplies a number of GPS telemetry systems with optional barometric altimeter sensors. Their principle produce is the ST900e which incorporates a GPS receiver, RF communications link, and optionally barometric pressure and temperature sensors. The ST900e supports many different radio configurations from 5mW Zigbee radios to 1000mW 900 Mhz Spread spectrum radios. The most typical configuration is the 100mw license-free 900mhz band from 902 to 928Mhz. The unit provides excellent range by sending compressed binary data using the SWARM protocol. SWARM compresses data 8x so that it can be sent faster and over longer distances than non-optimized protocols like NMEA. GPS Flight also supplies software which supports the real-time display and data logging of can collect data from hundreds of simultaneous ST900e units at once.

Flytec (http://www.flytec.com/) – Flytec manufactures a line of handheld instruments primarily intended for the hang gliding, ultra light aircraft, and balloonist users. These units have been used in the parachute and skydiving community for a number of years to help quantify the performance of parachute systems. In addition, Flytec supplies a number of anemometer systems that are useful for obtaining surface wind data.

CONCLUSIONS

The introduction of the IDAS-4 into the test programs support resources provides a flexible toolset to support a variety of parachute test programs. The ability to reconfigure the system by the user through the selection and installation of a number of interchangeable sensors and signal conditioners as well as reconfigure the sample rates and number of channels being used, provides a great deal of performance and flexibility to the test program.

The IDAS-4 system and its variants are gaining increase acceptance in the test community in parachute testing as well as surface vehicles, and other airborne systems.

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