# UH-60A Airloads Data Acquisition and Processing System

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**National Aeronautics and Space Administration, Ames Research Center, recently completed the joint NASA/Army UH-60A Airloads Program. The objective of this program was to make in-flight the measurements of rotor blade airloads, blade vortex interaction, and blade acoustics. An advanced digital instrumentation system, capable of synchronous acquisition of several hundred high frequency pressure channels was designed and developed to gather the required airloads data. The instrumentation system was designed to operate on the rotor hub of a Blackhawk helicopter acquiring data, in flight, from pressure transducers, strain gauges, and accelerometers embedded in the rotor blade, built under contract by Sikorsky® Aircraft. A parallel effort was initiated to develop a ground telemetry system with the capability to handle the 7.5 megabits per second PCM-encoded telemetry data, generated by the instrumentation system, in real-time. The purpose of this paper is to describe the design and performance of the rotary data acquisition system which was used to digitally acquire high speed rotor blade pressure data. These data were found to achieve the flight test research objectives of the UH-60A Airloads Program.**

## Introduction

The NASA/Army UH-60A Airloads Program was completed in February 1994. The main objective of the Airloads Program was to measure blade airloads, blade-vortex interaction, and blade-acoustics in flight [1]. Over 200 flight conditions were flown and approximately 60 gigabytes of data were collected and archived to a computer database accessible to industry and the scientific community [2]. The data acquisition and processing system used to gather the airload data is described here. The accuracy, resolution, and frequency bandwidth of the pressure and load data are presented. This information is fundamental to the interpretation of the airloads database. The laser tracking system used to measure the space position of the UH-6OA relative to the acoustic microphones for the blade-acoustics measurements will not described here. However, a mobile version of the tracking system has been described elsewhere [3]. The mechanical installation, testing, and calibration of the installed pressure transducers have been described by Robert Gagnon [4].

## Rotating Data Acquisition System

The Rotating Data Acquisition System (RDAS) was designed to function on the rotor hub and rotates with the rotor in flight, as shown in Figure 1. RDAS was composed of an analog and a digital section. The analog section preconditioned and preprocessed the low level analog signals generated by the 242 subminiature pressure transducers, 50 temperature sensors, 25 strain gauges, and 12 accelerometers embedded in the rotor system for the analog to digital conversion processes. The analog section was composed of sample-and-hold amplifiers, programmable gain instrumentation amplifiers, and 6 pole Butterworth low pass antialias filters. In addition, the analog section provided programmable offset and gain, thus allowing the system to depict any pressure regime of interest.

The digital section digitized all of the analog signals simultaneously. Ten Pulse Code Modulation (PCM) encoders were used to convert the analog signals to 10 bit digital data at the main frame rate of 2142.86 Hertz. The end product of the PCM encoding was ten 750 kilobits per second PCM streams. The 10 encoders were synchronized by means of a common clock originated in the UH-60A cabin. Digital information, time, and rotor position information, were encoded via the digital ports of the 10 encoders. Thus every data stream contained the rotor position and the time of digital conversion. Each encoder output a PCM stream at a rate of 750 kilobits per second and the 10 PCM streams were transmitted down the rotor mast and across the slip rings to the cabin of the UH-6OA. In the cabin, the ten PCM streams were multiplexed into a single 7.5 megabits per second PCM stream. The single data stream was then transmitted to ground based telemetry acquisition and processing systems for real-time data monitoring and instrumentation calibration. The 7.5 megabit per second PCM stream was also recorded onboard the UH-60A it across 9 recorder tracks with a data spreader. The 10 individual PCM streams were also recorded for redundancy. Figure 2 shows the functional block diagram of the RDAS.

## Data Processing System

The decommutation, preprocessing, merging, and disk capture of the 7.5 MBS stream was performed by a specially configured telemetry processing system. This system was configured with seven floating point processors and two special device interface controllers. Seven processors were required to preprocess and determine the quality of the acquired data which had an aggregate rate of 2 megabytes per second. One of the special controllers provided the interface between the telemetry processing system and a parallel disk array to handle the 2 megabytes per seconds real time storage requirements. The second interface controller transferred stored daa from the parallel disk array to an industry standard general purpose minicomputer to make it network accessible by a variety of work stations for further analysis, Figure 3.

## System Specifications

The gain and offset of the analog section of the RDAS were configured to measure blade pressure from 2 to 18 psi, with a 10 bits of resolution. To determine the performance of RDAS, a pressure calibration was perform on the blade and the result, for pressure channel P560, is shown in Figure 4. Three import results are depicted in Figure 3: (1) the counts varied linearly with pressure, (2) the resolution was 0.019 psi / count, and (3) the maximum standard deviation seen was 0.01 psi or 0.501 count. To find the frequency content of the noise that gave rise to the one half a count fluctuation, the frequency spectrum of the pressure channels were performed. Figure 5 shows the results for P533. The frequency content of is composed of a noise floor of 0.0002 psi (0.01 counts) and two peaks of magnitude 0.002 psi (0.1 count) located at 171 hertz and 921 hertz, respectively. Figure 6 shows the aliasing rejection frequency of the 6 pole Butterworth lowpass filters used in the RDAS. For a 10-bit system with a 1-bit resolution sampling at 21000 Hertz, the frequency regime free of aliasing error is from O to 400 Hertz.

## Conclusions

The RDAS was successfully used on over 200 test maneuvers to acquire more then 60 gigabytes of data from 242 pressure transducers and 36 other sensors measuring acceleration, strain, torque, temperature, and blade motion.

The successful operation of the RDAS demonstrated the feasibility of digital acquisition of high frequency pressure data with the theoretical limit accuracy of 1 bit in 1024 using a 10 bit system. Synchronous acquisition of all data ensured time base accuracy limited only by the granularity of the PCM frame rate. The RDAS time accuracy was 466.67 microseconds.

## Acknowledgments

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## References

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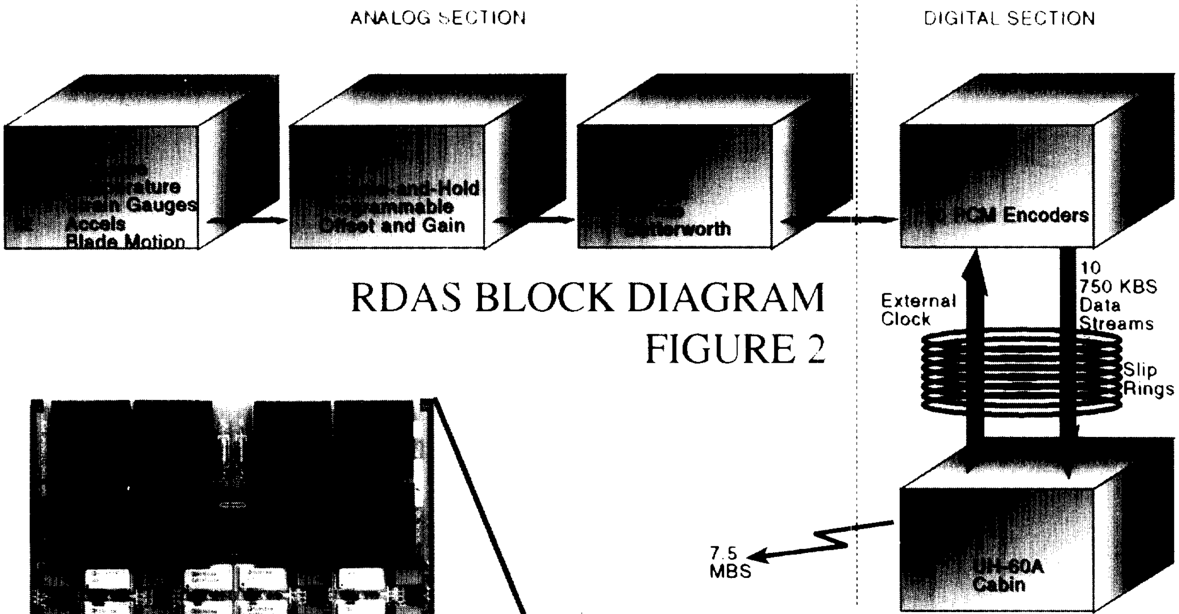
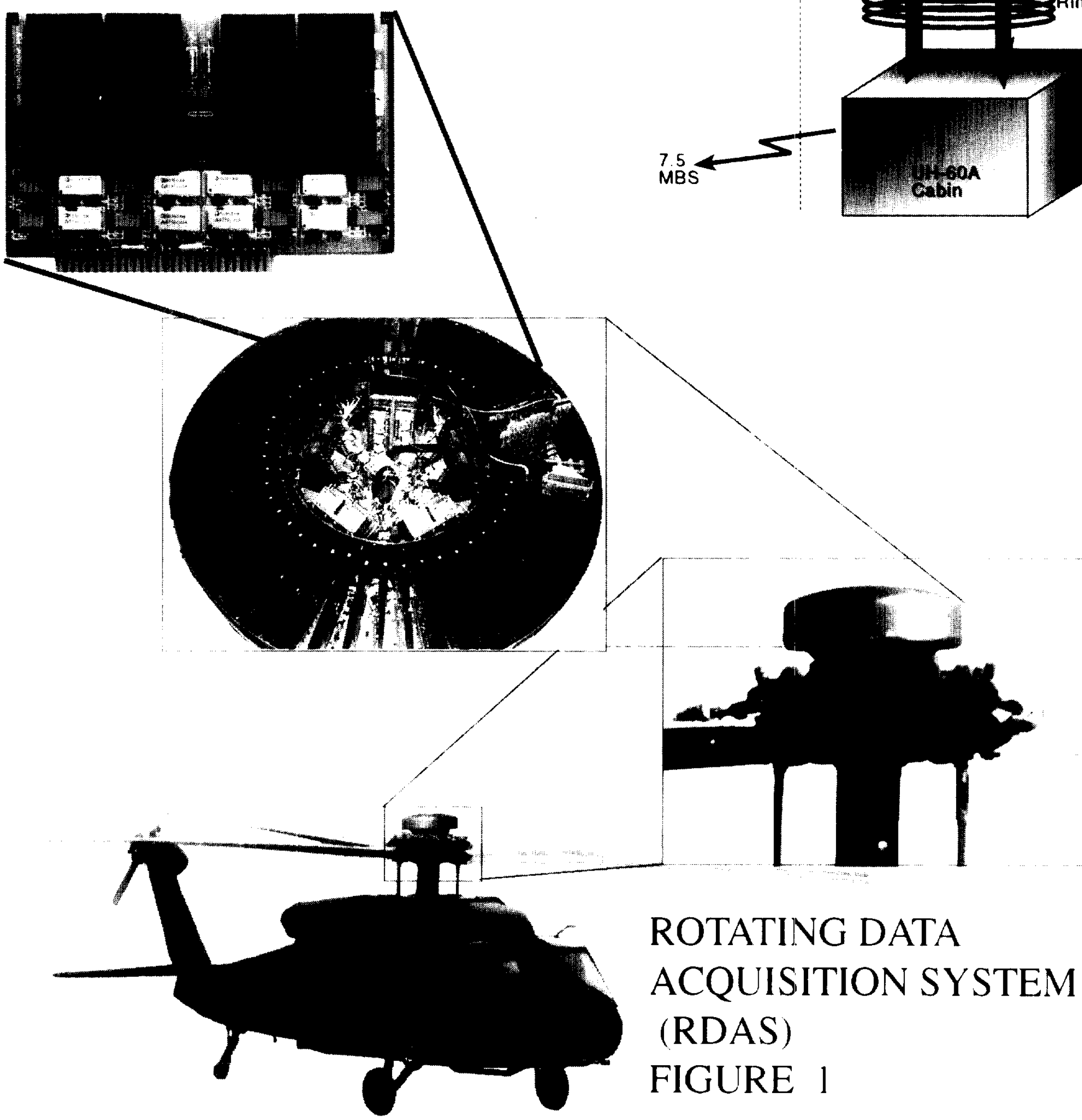
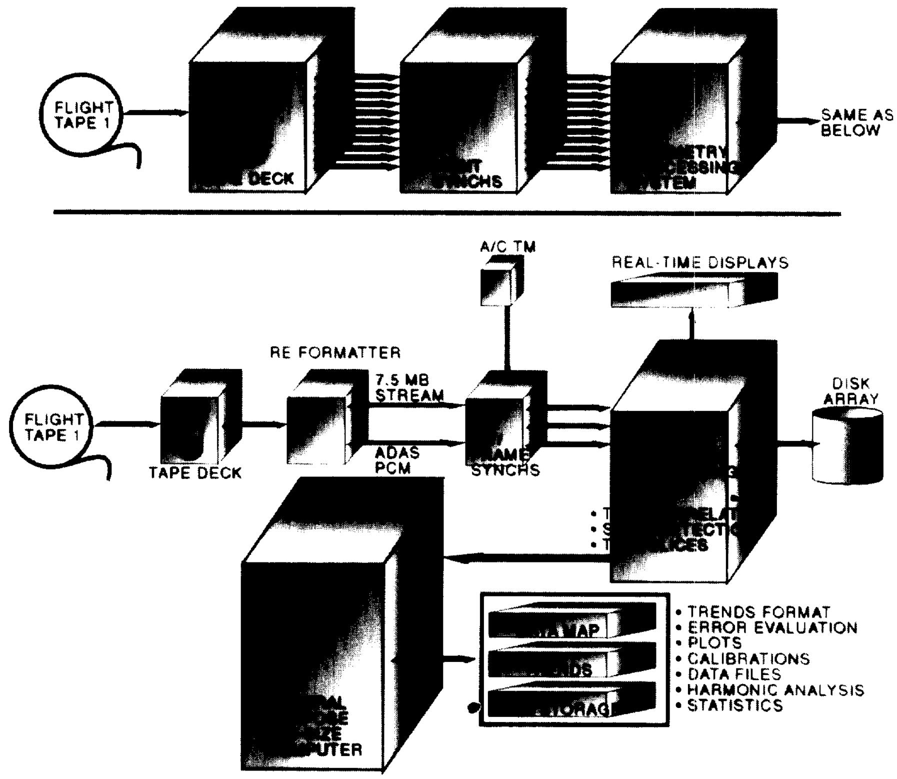


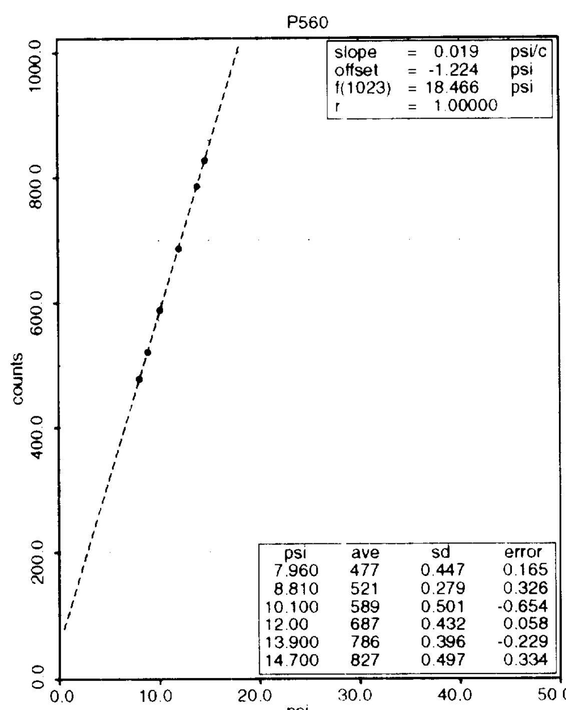

RDAS BLOCK DIAGRAM
FIGURE 2



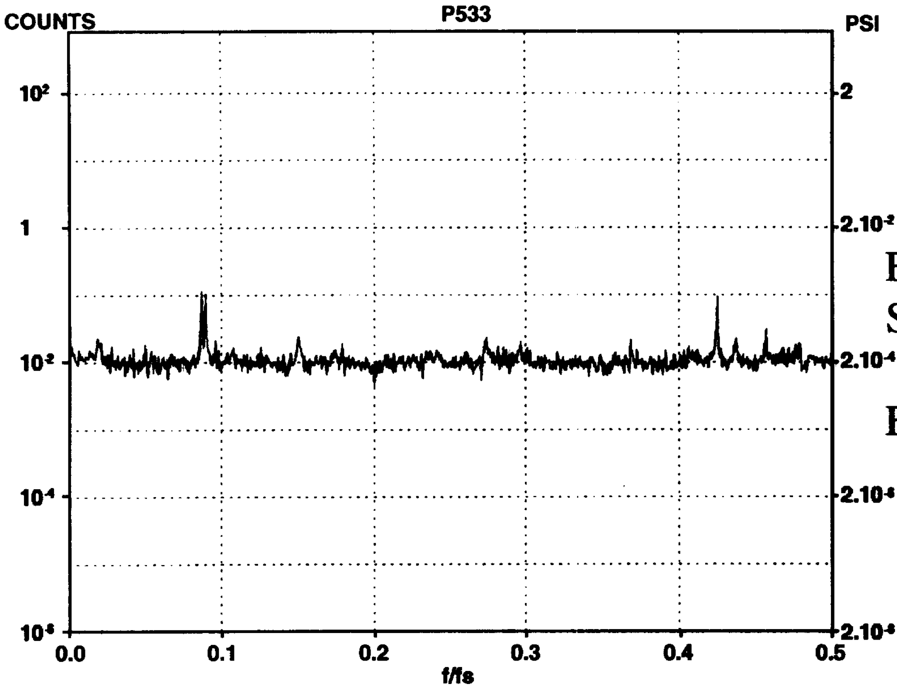
ROTATING DATA
ACQUISITION SYSTEM
(RDAS)
FIGURE 1




TELEMETRY PROCESSING SYSTEM FIGURE 3




PRESSURE CALIBRATION
FIGURE 4




FREQUENCY SPECTRUM

FIGURE 5

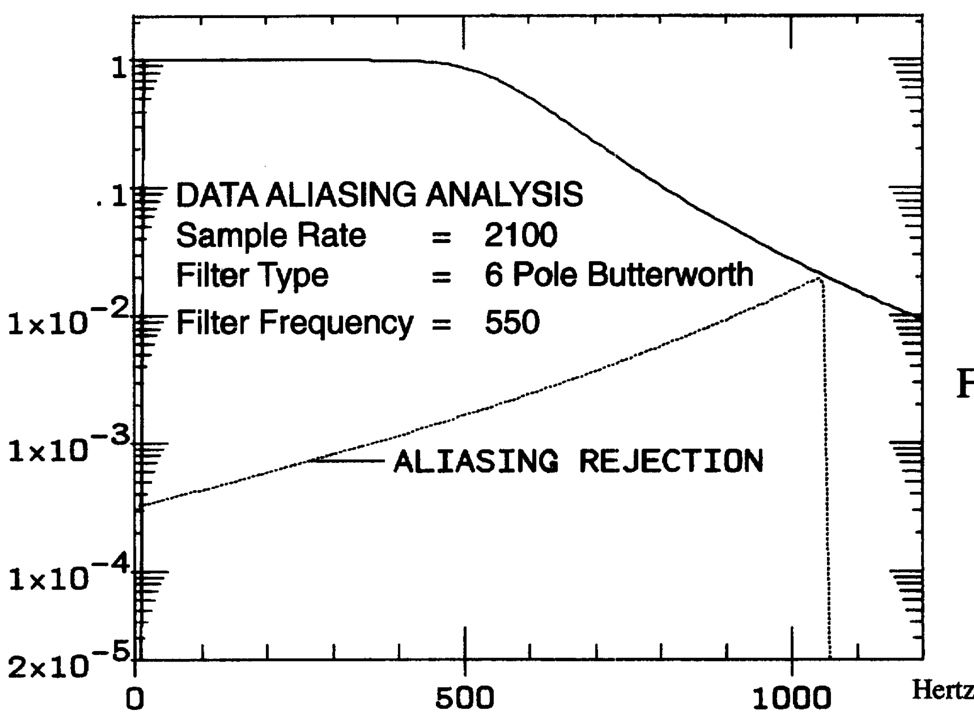



FIGURE 6