FINAL REPORT ON CONTRACT NAS 8-20179 - STUDY OF CROSS-CORRELATION SYSTEMS ANALYSES

MAC 511-10

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CONTENTS

1. INTRODUCTION

This report is the final management summary of the results obtained on NASA Contract NAS 8-20179, entitled "Study of Cross-Correlation Systems Analyses." The original contract started on June 29, 1965 and continued through February 28, 1966. The primary goals of this contract were to: (1) survey commercially available hardware suitable for acquiring and analyzing dynamic pressure data for both wind tunnel and flight dynamic pressure measurement programs, and (2) study the errors associated with practical analysis equipment. On March 1, 1966 the contact was extended until August 31, 1966. The primary effort of the extension was to assist the Unsteady Aero-Dynamics Branch in a selection of equipment for the dynamic pressure measurement program and to begin an evaluation of the accuracy of the hardware procured.

In the section that follows, the tasks undertaken and the results obtained are described through a brief summary of the documents that were issued by MAC under this contract. In the final section of the report, recommendations for future activities, based upon the results obtained under this contract, are given.

2. SUMMARY OF TASKS AND RESULTS

In this section the reports and then the memos issued under this contract are summarized.

Technical Reports

"Techniques and Errors in Measuring Cross-Correlation and Cross-Spectral Density Functions," by R. D. Kelly, L. D. Enochson, and L. A. Rondinelli, dated February 1966.

This report discusses both techniques for the measurement of cross-correlation and cross-spectral density functions and errors in these measurements. Analog, digital, and hybrid data reduction techniques presently in use are discribed. In addition, those techniques used in the radar and communication fields that appear useful for the specific application of interest (dynamic pressure measurements) are detailed. The error formulae cover both statistical uncertainity errors from the analysis of records with finite bandwidth and a finite duration and the hardware related errors. Particular emphasis is placed on phase errors throughout the entire measuring system from the transducer to the analyzer. Both static and dynamic phase errors are covered. In addition, errors from analyzer parameters (filter bandwidth, scan rate, etc.) extraneous additive noise, finite transducer size, and magnetic tape recorder velocity non-uniformities are discussed. This report was published as NASA CR-74505.

"Survey of Dynamic Pressure Data Acquisitions and Analysis Equipment," by R. D. Kelly and J. H. Wise, dated February, 1966.

This report contains the results of a survey of commercially available dynamic pressure data acquisition and analysis equipment. Included in the survey are transducers, signal conditioners,

multiplex systems, tape recorders, cross-correlation analyzers, and cross-spectral density analyzers. Systems suitable for the measurement of dynamic pressures during both wind tunnel and during flight test programs are covered. The performance capabilities of the various instruments are compared in tabular form. Recommendations are made on specific equipment for satisfying both the flight test and wind tunnel test requirements of the Unsteady Aerodynamics Branch.

"Data Reduction System Requirements - Cross-Correlation of Dynamic Pressure Measurements from Wind Tunnel Tests of the 4% SATURN Model," by R. D. Kelly, dated June 1966.

This report describes the characteristics that are required in a cross-correlation analysis system for it to be suitable for the analysis of the data obtained during wind tunnel tests of the 4% SATURN V model. A functional form for the cross-correlation was assumed and the analyzer parameters calculated. The analysis characteristics described in this report are time delay resolution, time delay range, record length, and sampling pulse requirements for A/D conversion. This report should provide a guideline for the analysis of the wind tunnel data.

"Special A/D Conversion Technique," by R. D. Kelly, dated July 1966.

This report describes a special A/D conversion technique suitable for the analysis of large quantities of cross-correlation or cross-spectral density functions in a short period of time, particularly when very small time-delay resolution is required in the correlation function analyses or when very high frequencies are present in the cross-spectal analyses. The acquisition of large

quantities of high frequency data in a short period of time dictates the use of analog tape recording. Conversely, the analysis of large quantities of data in a short period of time dictates the use of a digital computer. The technique described in this report permits the conversion of analog data into a digital format with practical conversion equipment and digital tape equipment performance characteristics. In addition, a modification to the basic scheme results in a method of reducing the errors associated with time-base instability of the analog tape recording.

"Calibration and Laboratory Evaluation of the Kissler Pressure Transducer and Charge Amplifier," by LTV Research Center, Western Division, dated August 1966.

This report describes the performance of the wind tunnel transducer and charge amplifier combination under laboratory and certain selected environmental tests (The environmental tests that were performed on the units were vibration, temperature, and acoustic noise). Five transducing systems are evaluated. The performance measurments include linearity, frequency response, phase shift, and noise threshold.

Technical Memos

"Review of the Dynamic Pressure Measurement System for the SATURN 40% Model Flight Test Program" by R. D. Kelly, dated 14 September 1965.

This memo presents conclusions and recommendations on the two proposed instrumentation systems (one by the White Sands Missile Range and the other by the Astrionics Division of MSFC) for the flight test of the 40% SATURN model/Little Joe booster combination.

"Phase Measurement Errors Caused by Magnetic Tape Recorders," by R. D. Kelly, dated 14 September 1965.

This memo briefly summarizes phase errors that occur through the use of analog magnetic tape recording and makes recommendations on how to minimize these errors in practice.

"Evaluation of Instrumentation Accuracy - MSFC Wind Tunnel Tests Conducted at Ames Research Center," by R. D. Kelly, dated 22 February 1966.

In this memo, an analytical estimation is made of the instrumentation errors associated with the data acquisition system used by the Ames Research Center to obtain some wind tunnel data for the Unsteady Aerodynamics Branch of Marshall Space Flight Center.

"Environmental Testing Program for the SATURN 4% Model Fluctuating Pressure Instrumentation," by T. D. Schoessow, dated 18 June 1966.

This memo describes tests designed to evaluate the performance of the wind tunnel data acquisition system. Both bench-type performance tests and environmental qualification tests are described.

"Commercially Available Acoustic Calibrators," by T. D. Shoessow, dated 25 July 1966.

This report describes the results of a special survey of commercially available high-level, high-frequency, portable acoustic calibrators. The purpose of this survey was to determine if any suitable calibrators were commercially available for in-place high frequency acoustic calibration of the 4% SATURN V model instrumentation in the wind tunnel.

"Wind Tunnel Instrumentation Evaluation Tests," by R. D. Kelly and T. D. Schoessow, dated 12 August 1966.

This memo describes a set of tests designed to evaluate the performance characteristics of the wind tunnel data acquisition system while installed at the test facility. In addition, test equipment necessary for these evaluation tests are listed.

"Evaluation of the Analysis Equipment Accuracy - McDonnell Cross-Spectral Analog System," by P. E. Rentz, dated 31 August 1966.

In this report, an analytical estimation is made of the accuracy of the cross-spectral density system used by McDonnel Aircraft Corporation to analyze some wind tunnel data for the Unsteady Aerodynamics Branch of MSFC.

"Comments on Pressure Transducer Evaluation," by T. D. Schoessow, dated 31 August 1966.

This memo contains a description of the results obtained by the LTV Research Center during their calibration and environmental evaluation of five dynamic pressure transducers and their associated charge amplifiers.

3. RECOMMENDATIONS FOR FUTURE ACTIVITIES

Based on the experience gained during this contract, the following tasks are recommended to the Unsteady Aerodynamics Branch for implementation:

1. Analyze the errors associated with the wind tunnel instrumentation. Since the necessary data to determine the amplitude, phase, and noise threshold level performance of the entire wind tunnel measurement system has been collected, it is strongly recommended that this data be analyzed and the error associated with this measurement system be determined. In addition, it is felt that the data collected should provide some correction factors for extension of the overall accuracy of this instrumentation system.
2. Complete the tape dynamic phase error measurements. It is recommended that experiments be performed to evaluate the errors occurring from non-uniform velocity of analog magnetic tape recorders. An analytical model for this error was developed under the contract and the experiments are required to check on the validity of the analytical model.
3. Investigate the feasibility of the special A/D conversion technique. It is recommended that the special A/D conversion technique described in Section 2 be checked by assembling a breadboard model of an operating system. If the system is feasible it will permit the analysis of greater quantities of data per analysis dollar than is presently possible and indeed may well be the only practical method to obtain the time delay resoluation and accuracy required.

4. Assist the Unsteady Aerodynamics Branch in the analysis of the data obtained during the wind tunnel tests.
5. Investigate practical techniques for performing phase calibration of small microphones at high frequencies and high levels.
6. Evaluate the performance of the transducer systems after the wind tunnel tests are completed in order to determine any permanent shifts that may have occurred in the performance of these instruments due to the wind tunnel environment.