A QUALITATIVE ANALYSIS METHOD FOR A MOTION SYSTEM OF COMBINED CONFIGURATION

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SUMMARY

Currently, the analysis method of a motion system is dependent upon the pilots' subjective evaluation. This paper describes a method using the data recorded by an instrumented dummy to qualitatively analyze a combined motion system. The function of the dummy is to record the time histories of linear (force) and angular (moment) accelerations imposed on the pilot's station during flight maneuvers. The dummy is a recording device instrumented with three linear accelerometers, three gyros, a seven-tape cassette recorder and two Polaroid instant movie cameras. The pilot's voice evaluation will use one of the tapes. The functions of the two cameras are to monitor and correlate the flight events.

INTRODUCTION

The simulator manufacturers and users customarily use the flight data to verify the math model of a flight simulator and determine the maximum displacement and time derivatives for designing a motion system. However, verifying a motion-simulated device, one is dependent upon the pilots' subjective evaluation. A motion-simulated device may be a motion system, g suit or g seat. Generally, there is a lack of validated data which indicate a device having met the design criteria. If there is no baseline (flight) data available, the analysis would be very difficult. How can we qualitatively analyze or at least interpret the pilots' subjective terms such as confused, distracted, irregular and unrealistic cues? Using the time histories of linear accelerations and Euler angular accelerations imposed on the pilot's station (eyeball or seat) during flight maneuvers, one may correlate the subjective terms with engineering expressions. The linear acceleration consists of three components (A_x, A_y, A_z) measured along the pilot's station coordinates in the directions of X, Y, and Z. The Euler angular acceleration consists of three components, roll ($\ddot{\phi}$), pitch ($\ddot{\theta}$), and yaw ($\ddot{\psi}$) accelerations measured between the pilot's station and inertia coordinates. The results will be very useful to the engineers for studying and improving a combined motion system.

This paper describes the qualitative analysis method and the use of a dummy instrumented with sensors, a recorder, and cameras to record the flight data and events in an aircraft and its simulator. The data recorded by the dummy in an aircraft is the baseline data. The qualitative evaluation of a simulated motion device is the analysis of the comparative results between the baseline and simulator data.

QUALITATIVE ANALYSIS METHOD

Based on our experience, the pilots complain against the low fidelity of a simulator whenever the performance data of the simulator deviate significantly from the flight data. Correcting the deficiencies, one has to modify the performance of the simulator to meet the flight data and refine it to meet the pilots' subjective evaluation. If the complaint is against the motion-simulated device, the correction is solely to meet the pilots' subjective evaluation. Furthermore, flight data is unavailable in a form which is suitable for the study and analysis of a motion-simulated device.

The qualitative analysis method is similar, in principle, to the one being used to verify the flight performance of a simulator. The differences include the collection and utilization of the flight data. The data of interest are the linear accelerations $(A_x, A_y, A_z)_p$ and angular accelerations $(\ddot{\phi}, \ddot{\theta}, \ddot{\psi})_p$ at the pilot's station. The vectorial summation of the linear accelerations will give us the information on the time history of the phase angle and the magnitude of the resultant vector (force). This is the most important data required for providing realistic motion cues. The proposed qualitative analysis method is quite different from the method currently used by the simulator industry in specifying and accepting a motion system. The current method does not include the use of time history of accelerations of flight maneuvers. However, the method does include the use of the performance tests in compliance with the specified tolerances on response frequency, maximum displacement and time derivatives. Obviously, the current method is inadequate to ascertain the fidelity of a motion system (reference 1).

Presently, no single motion-simulated device can provide the realistic cues covering high- and low-dynamic maneuvering and precision tracking. On the contrary, reference 1 cites a number of motion systems including those of special design which provide negative cues to the pilots. A motion system can provide onset cue (jerk, change of acceleration) and very little sustained cue. On the other hand, the g suit and g seat can provide the sustained cue but not the onset cue. Undoubtedly, new simulators will incorporate a combined motion system. Hopefully, the analysis method will lead us to better understanding a combined motion system and to specify a system reasonably. Figure 1 shows the flow diagram of qualitative analysis method.

METHOD OF INTERPRETATION

The instrumented dummy is the device to record the time histories of the flight data in an aircraft or the simulator. The sets of data will consist of the acceleration data, correlated indicators' values, visual scene, and pilot's voice evaluation. Later, three sets of data will indirectly assist the qualitative evaluation. Figure 2 illustrates the time histories of onset, linear, and angular accelerations during a typical takeoff maneuvering. Assuming the coupling effects equal to zero, the longitudinal (A_x) and normal (A_z) accelerations are only sustained values. For a combined motion system, the motion system, g suit and g seat must complement each other and function as an integrated system to provide realistic motion cues to a pilot. After washing out the onset acceleration provided by the motion system, the g suit or g seat must step in and function smoothly and continuously to provide the sustained acceleration cues.

Since all records of the flight data and events are synchronous, the pilot's voice evaluation will help us to locate the negative cues occurring in a certain time interval; the indicators' values will help us to detect the malfunction of the simulator; the visual scene will help us to analyse and correlate the motion cues. Examining the curves in Figure 2 has given us some clues to analyze and interpret the pilot's subjective terms often used in the evaluation. For example, complaint about unrealistic cue will probably occur in the time interval between t_0 and t_1 on the A_x curve. After washing out the onset acceleration, neither the motion system nor g suit could provide the realistic cues in that interval. The complaint about uncommanded and confused cues will probably occur in the time interval between t_1 and t_2 on the A_z or $\ddot{\theta}$ curve. The cause may be due to excessive time lag of the system or out-phase operation. The successful determination of the source of the negative cues is dependent upon the availability of the sets of baseline and simulator data recorded by the dummy. On the other hand, varying the time lag, magnitude of onset and sustained acceleration cues, phase angle, or gain of servo control system, one can easily extend the usefulness of the analysis method to study the pilot's perception of motion cues.

INSTRUMENTED DUMMY

Automotive and aerospace industries employ dummies for various experiments such as car crash tests and rocket assisted personnel ejection respectively. In the task, we will instrument the dummy with three linear accelerometers, three gyros and two Polaroid instant movie cameras (Figure 3). The accelerometers will sense the variation of longitudinal, lateral and vertical accelerations. The gyros incorporated with signal processors will provide the angular-acceleration signals. Avoiding the use of expensive telemetry system, a seven-tape cassette recorder installed in the dummy will record the time histories of accelerations imposed on the pilot's station and the pilot's voice evaluation. After completing a maneuver, the signals recorded on the tapes will drive a strip-chart recorder to obtain hard copies of the records. Driving a visual system, the pilot's station should be at the pilot's eyeball while driving a motion-simulated device, should be at the pilot's seat. To eliminate any errors due to the geometrical location, the dummy must sit on the pilot's seat as a human pilot. Therefore, a two-seat aircraft and simulator would be ideal to carry out the experiments. Figure 4 shows that the improper use of the station coordinates could lead to the computational errors particularly under high-dynamic maneuvering. The first camera located near the dummy's eyeball will record the actual scene from an aircraft or simulated visual scene from a simulator. The second camera located near the chest part of the dummy will monitor the indicators' values displayed on the instrument panel of an aircraft or a simulator. Synchronizing the operations of the sensors, gyros, recorder, and cameras is mandatory. Matching the data with the events, one should regularly mark the equal time interval on all tapes. Otherwise, there is no way to analyse the data.

CONCLUSION

The writer believes that in addition to the current method, the qualitative analysis method using the time history data of linear and angular accelerations at the pilot's station during flight maneuvers will definitely enhance the understanding of a combined motion system. One can use the results of the analysis to correlate the subjective terms with engineering expressions to develop a high fidelity combined motion system.

REFERENCE

"Simulator Comparative Evaluation," Tactical Air Cmd, USAF TAWC, Eglin AFB, FL, Nov 1977.

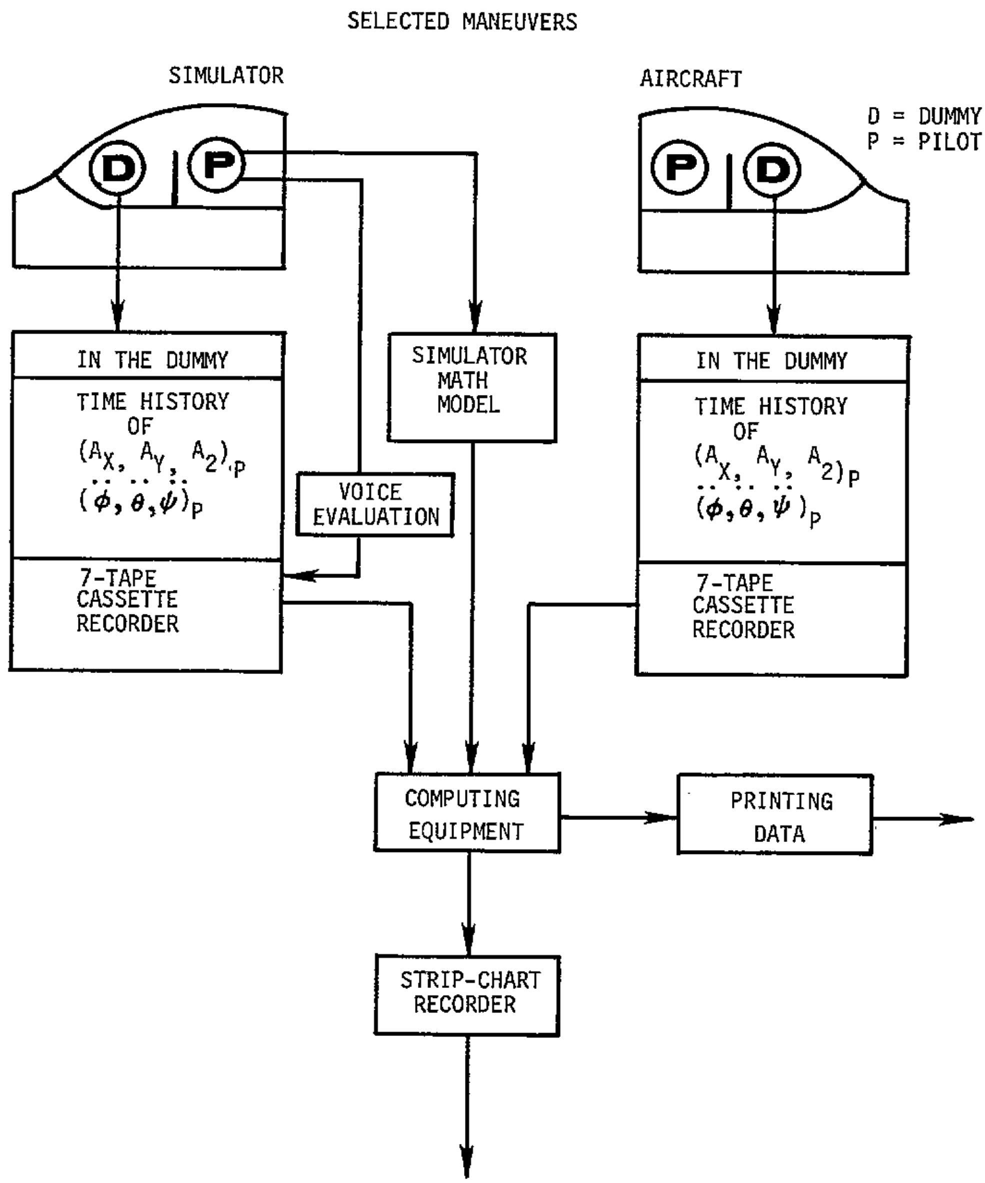


Figure 1. Analysis Flow Diagram

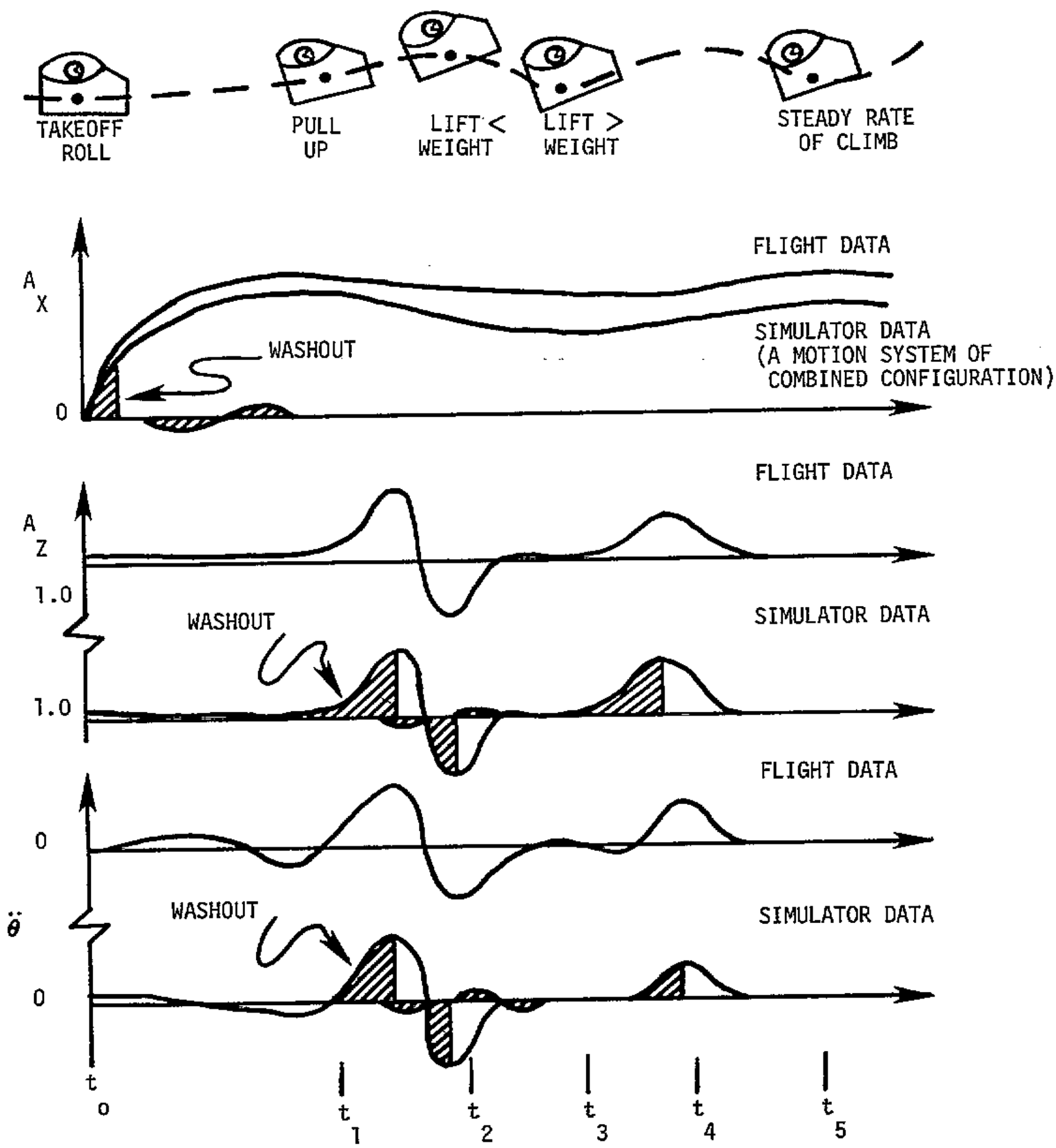
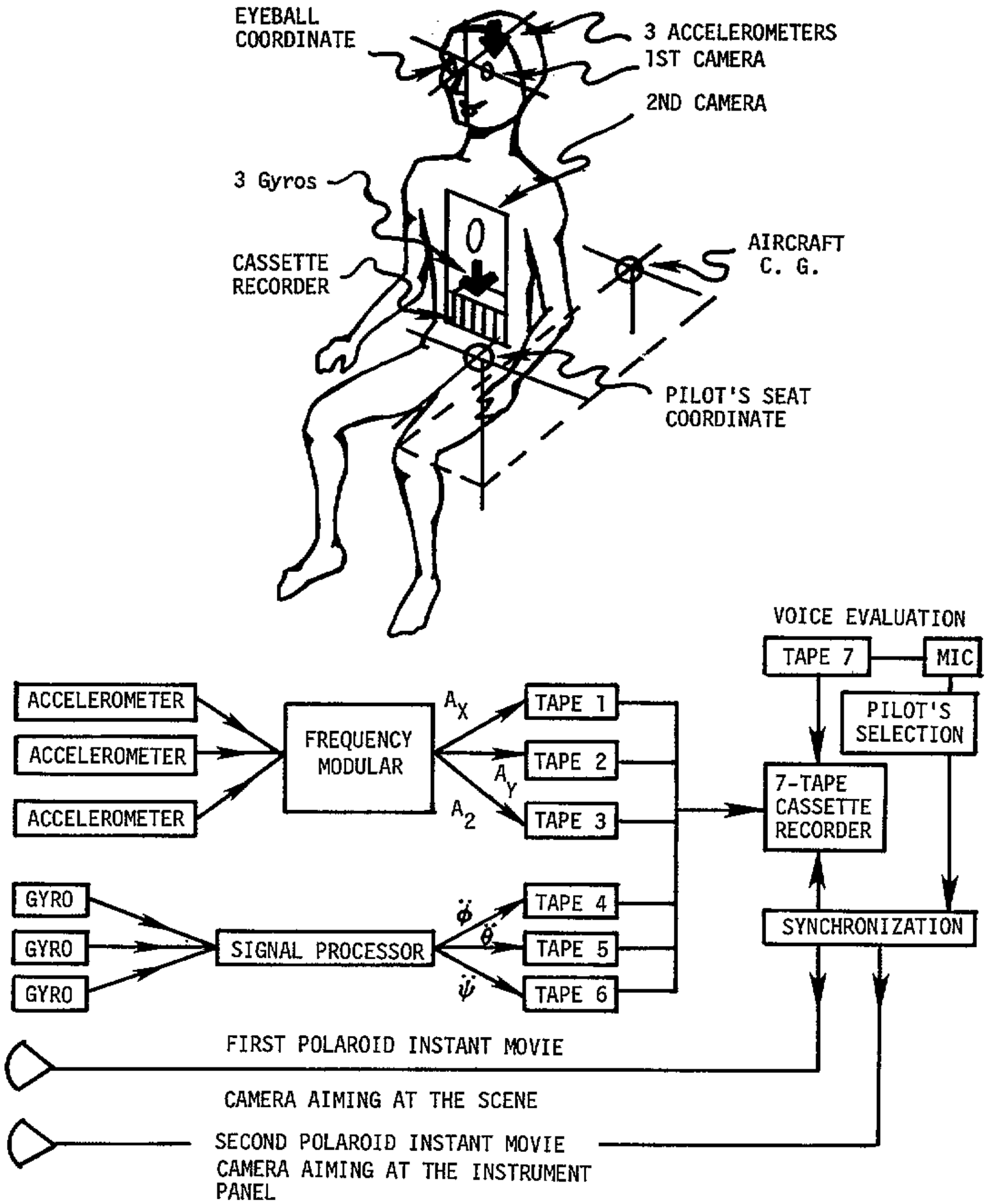


Figure 2. Takeoff Maneuver



INSTRUMENTATION

Figure 3. Instrumented Dummy

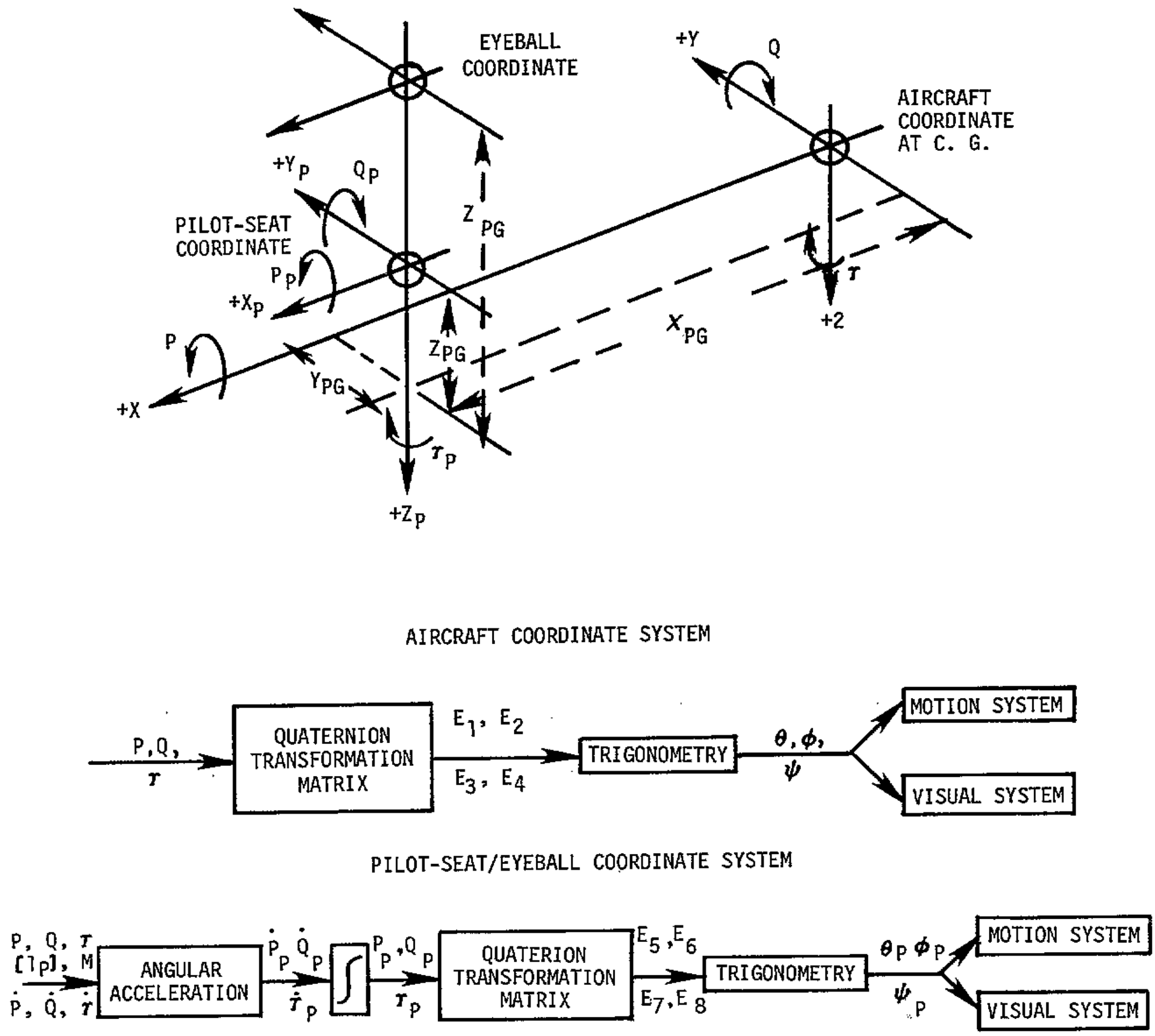


Figure 4. Euler Angles Computation Referred to Different Coordinate System

ABOUT THE AUTHOR

MR. DAVID YIH is an Aerospace Consultant associated with the Experimental Computer Simulation Laboratory at Naval Training Equipment Center. From 1964 to 1968, he was a project engineer in charge of development of a high-enthalpy wind tunnel and fuel cell at Naval Weapons Laboratory. Prior to that, he was a project engineer at Curtiss-Wright, for X19 VTOL aircraft from 1962 to 1964. From 1954 to 1962, he was a research associated at New York University in charge of development of air pollution and supersonic and shock wind tunnels. Mr. Yih received his B.E. degree in mechanical engineering from Hangchow University, Hangchow, China and the M.E. degrees in mechanical and aeronautical engineering from New York University. He also did graduate work in electronic engineering at Newark College of Engineering.