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CONTROL POWER REQUIREMENTS OF VTOL AIRCRAFT

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SUMMARY

This progress report covers the second three-month period of effort on NASA Grant No. NGR-05-004-051. During this period Mr. Peter Levin, a master's candidate developed a performance and direct operating cost program for pure jet lift VTOL aircraft (similar to the one already developed for tilt-wing VTOL aircraft). A moment of inertia subroutine has, also, been added to provide data for the flight control system studies.

Mr. John Seevers, the doctoral candidate, has been reviewing the literature on VTOL control systems and has proposed a possible system concept which he plans to simulate on a digital computer. This concept is described more fully below. Professor John Brewer, a specialist in modern control theory, is acting as Mr. Seevers' adviser in these areas.

Professor Hoffman made visits and held extensive conferences with the personnel of the USAF Flight Dynamics Laboratory and the NASA Electronics Research Center in September. In addition, he attended the V/STOL Technology and Planning Conference sponsored by the USAF Flight Dynamics Laboratory. These conferences have been enormously useful in helping to define the present state of the art of VTOL flight control system design and to identify unsolved problem areas for future work. Mr. Seevers is now in the process of trying to digest the information in the large number of reports brought back by Dr. Hoffman.

PROPOSED Ph.D. THESIS TOPIC OF MR. JOHN SEEVERS

Except under severe and unusual conditions most commercial aircraft operate in a quasi-steady manner without large deviations from this state.

For small perturbations in the aircraft's behavior it is reasonable to represent the dynamic system as a set of linear differential equations. Therefore, we are approaching the control problem initially from a linear standpoint, with consideration being given to the non-linear region particularly that due to control power saturation. This is to say that we are trying to evolve a control system that will produce the optimum response for the linear range and still have the ability to handle the extreme cases satisfactorily.

Thus far we have established an acceptable linear dynamic systems model for the aircraft in the hover phase of flight for small perturbations. That is to say, the motion of the aircraft is described by the usual six coupled linear differential equations in six unknowns which can be reduced to the standard two sets of three linear differential equations with three unknowns. As done elsewhere, these equations have been expressed in terms of inertia and mass ratios so that one solution covers as many aircraft as possible.

Modern control techniques are being applied to the dynamic system and one possible control system has been proposed. This scheme is basic and can be applied not only to hover, but to transition and conventional cruising flight as well. This modern control system uses a modal controller in an inner loop to stabilize the aircraft against gust disturbances and a decoupling controller in an outer loop to facilitate the flight path control. This system should allow the aircraft to respond rapidly and positively to nullify the effect of disturbances and also should reduce the work load of the pilot or autopilot, since each aircraft control would correspond to one degree of freedom of the aircraft. Furthermore, this approach may permit the designer to follow a relatively simple and straightforward design procedure to arrive at a high performance flight control system. A schematic is shown in Figure 1 where the

lines represent vectors of three components. The control power required to stabilize and control the aircraft can be measured directly as the output of the "Control Force and Moment Generator" block in the diagram.

We intend to verify this control scheme through analog and digital simulations and to compare our results with those obtained from a classically designed controller.

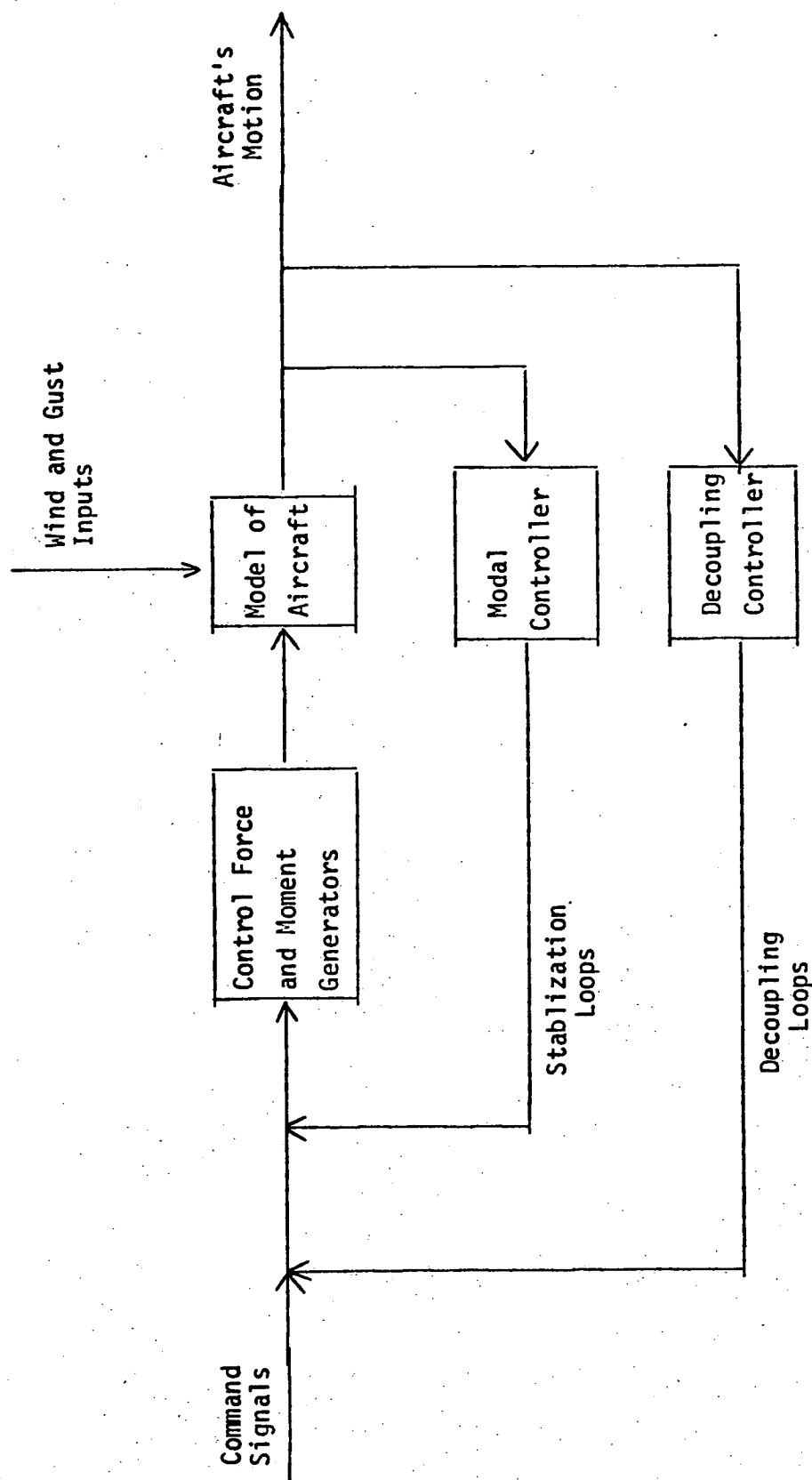


FIGURE 1 Schematic of a Possible VTOL Modern Control System concept