ADAPTIVE CONTROL SYSTEM PROGRAM

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At the Ames Research Center we have been conducting a theoretical study of adaptive control systems. This study has emphasized basic concepts and methods of analysis. One system which showed considerable promise is the type which uses the principle of high forward loop gain in connection with an on-off controller to obtain a response that is relatively insensitive to variations in aircraft parameters. In the strict sense of the word this system is not truly adaptive; however, it does have two distinct advantages - it is simple in concept and can be analyzed by conventional methods. On the other hand the action of the relay or " on-off" switch does result in a limit cycle oscillation which may be objectionable in some applications.

During this program, linear methods of analysis based on the root locus concept were used. Also a simple means of predicting the frequency and amplitude of the limit cycle oscillation was developed. Mr. McLean will discuss this program in his paper and also will show the results of an example application involving a normal acceleration system in a hypothetical air-to-air missile.

Our future plans are best illustrated by this slide. The chart shows, at the top, the theoretical work which is essentially complete and which will be discussed by Mr. McLean. The next two boxes show two parallel extensions of this basic study now in progress. These involve applications to conventional aircraft and also to re-entry vehicles.

First with regard to the conventional airplane application - the airplane chosen is the F-102 and preliminary simulation studies are now underway. This airplane was chosen because of its high performance AFCS which can be adapted for this program with minimum number of changes to hardware or instrumentation. Since the essential modifications involve only circuitry, flight tests of this system can be started with a minimum amount of development. It is planned to apply this adaptive principle to both the pitch and roll channels. In the pitch channel a normal acceleration command system will be used for the initial tests. This mode of control is normally employed in the F-102 for the automatic attack mode and is also the type of system previously studied in the missile example.

It is hoped that flight tests will not only demonstrate the feasibility of this particular adaptive system approach but will also provide a positive

check on the effects of the limit-cycle or chatter frequency. In this regard there are several questions to be answered. First, can the chatter frequency and amplitude be predicted adequately; what are tolerable limits on chatter amplitude; and is there objectionable coupling with airplane structural modes? Furthermore, these tests should give some idea of how well the adaptive system can cope with rapid changes in aerodynamic parameters such as encountered through the transonic region and in low-speed, high angle of attack flight.

The first part of the flight program involves automatic control with command inputs supplied by knob adjustment. The next step, as presently planned, would involve direct pilot control by means of a side-arm or information stick controller. These tests would be mainly pilot opinion studies, and again one of the main areas of interest would be the effects of chatter.

Now turning to the right side of the chart we have a project involving the control of re-entry type vehicles. At present a study is being made to define the control requirements of such vehicles which will traverse the entire flight regime from orbital speed and altitude to landing. This regime will involve reaction controls for attitude control at high altitudes, aerodynamic control at low altitude, and perhaps a mixed mode of operation during an intermediate portion of the flight. This program involves simulation studies of a representative configuration with conventional and also with adaptive type autopilots in order to determine the relative merits of the two concepts.

Later, more complete studies will be made of systems which are controlled directly by the human pilot. For these tests a two-degree-of-freedom motion simulator will be used to assess the effects of aircraft rolling and pitching motions on the pilot's ability to control the vehicle. This again will be a pilot opinion type of study.

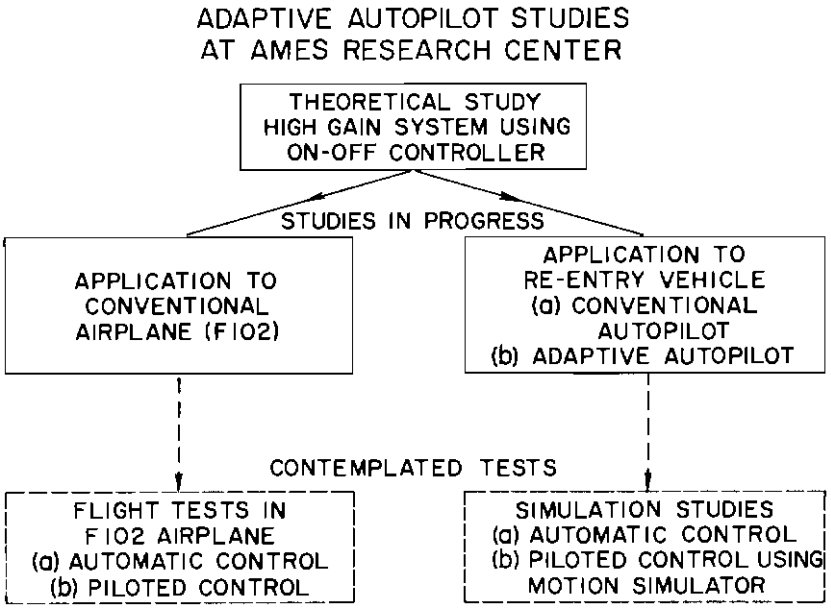

Fig 1