Developing a Control System for ARES II

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by

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Abstract

A great deal of analysis and testing is conducted at the NASA Langley Research Center to support the development of safe and reliable helicopter rotor systems. This work is performed by the Rotorcraft Aeroelasticity Group located in the Transonic Dynamics Tunnel (TDT) facility. Over the past two decades a wide variety of tests have been successfully conducted in the TDT and their results have contributed significantly to the understanding of aeromechanical phenomena in rotor systems. This has led to improved tools for analysis and design, and ultimately to the development, of improved rotor systems. The TDT facility is ideally suited for these tests due to its unique ability to use a heavy gas as a working medium. This allows the model to be scaled such that the results obtained may be readily extrapolated to full scale.

Until recently, the rotor system to be tested has been mounted on a fixed balance which is attached to the longeron which is attached to the stand through a single pitching degree of freedom. The testbed used is known as the Aeroelastic Rotor Experimental System (ARES I) and is shown in the test section of the TDT in Figure 1. ARES I has been used extensively and is well suited for rotor dynamics, loads and performance tests. Another testbed is available to investigate specific rotor/body dynamic coupling. It allows for pitch and roll of the balance relative to the longeron and uses elastomeric springs and rotary viscous dampers to control the stiffness and damping of the pitch and roll axes. This system is referred to as ARES 1.5 and is shown in Figure 2. In order to extend the experimental capabilities to investigate the full rotor/body dynamic coupling present in a rotorcraft, a very ambitious project has been undertaken to design and construct a six degree of freedom system that can be controlled so as to emulate the inertial characteristics of a prescribed model fuselage. The electronic and mechanical hardware for this system has already been designed and constructed. This system is known as ARES II. The mechanical layout of this new testbed is shown in Figure 3 without the rotor system. The rotor and its drive system are mounted on the balance which is attached to the longeron via six hydraulic actuators. This six degree of freedom parallel linkage is referred to in the literature as a Stuart Platform. By properly adjusting the length of the hydraulic actuators it is possible to position and orient the balance relative to the longeron. The longeron is attached to the stand via a pitch degree of freedom to allow testing over various forward flight regimes.

One major task remaining to complete this testbed is the design and synthesis of a control system. To do this properly requires an understanding of the kinematics and dynamics of the system and robust control design. A brief description of the development of a control design over the course of the Summer of 1992 is given below. It was first necessary to determine the kinematics relating the motion of the various components of the testbed. Next, the equations of motion used to describe the dynamics of the system were derived using a Newton/Euler formulation for the sake of simplicity. A FORTRAN simulation was then written to support the control design effort. The topology of the control system was chosen based on the required functionality and simplicity. It consists of three main components. A diagram showing its layout is presented in Figure 4. The first, and most critical component, is six wide bandwidth inner loops to control the motion of each of the hydraulic actuators. The second is the nonlinear transformation relating the desired balance

location and orientation to the required actuator lengths. This allows one to prescribe the desired behavior of the balance over a wide range of frequencies. The final component is a two mode input system. One mode simply allows for direct operator control of the balance position and orientation (switch in the upper position in Figure 4). The other mode allows the operator to prescribe a c.g. location, mass and moments of inertia of a model fuselage and have the balance respond to the rotor forces and moments as if it had the prescribed characteristics (switch in the lower position in Figure 4).

Accomplishments to date include:

1) Familiarization with the electronic and mechanical hardware
2) Familiarization with the intended use of ARES II
3) Determination of the kinematics
4) Derivation of the system dynamics and a FORTRAN simulation model
5) Determination of a control system topology

Work that remains to be done:

1) Finish verification of the simulation model
2) Inner loops controlling the hydraulic actuators need to be closed
3) Implementation of the control in digital/electronic hardware
4) Effects of stand flexibility need to be evaluated

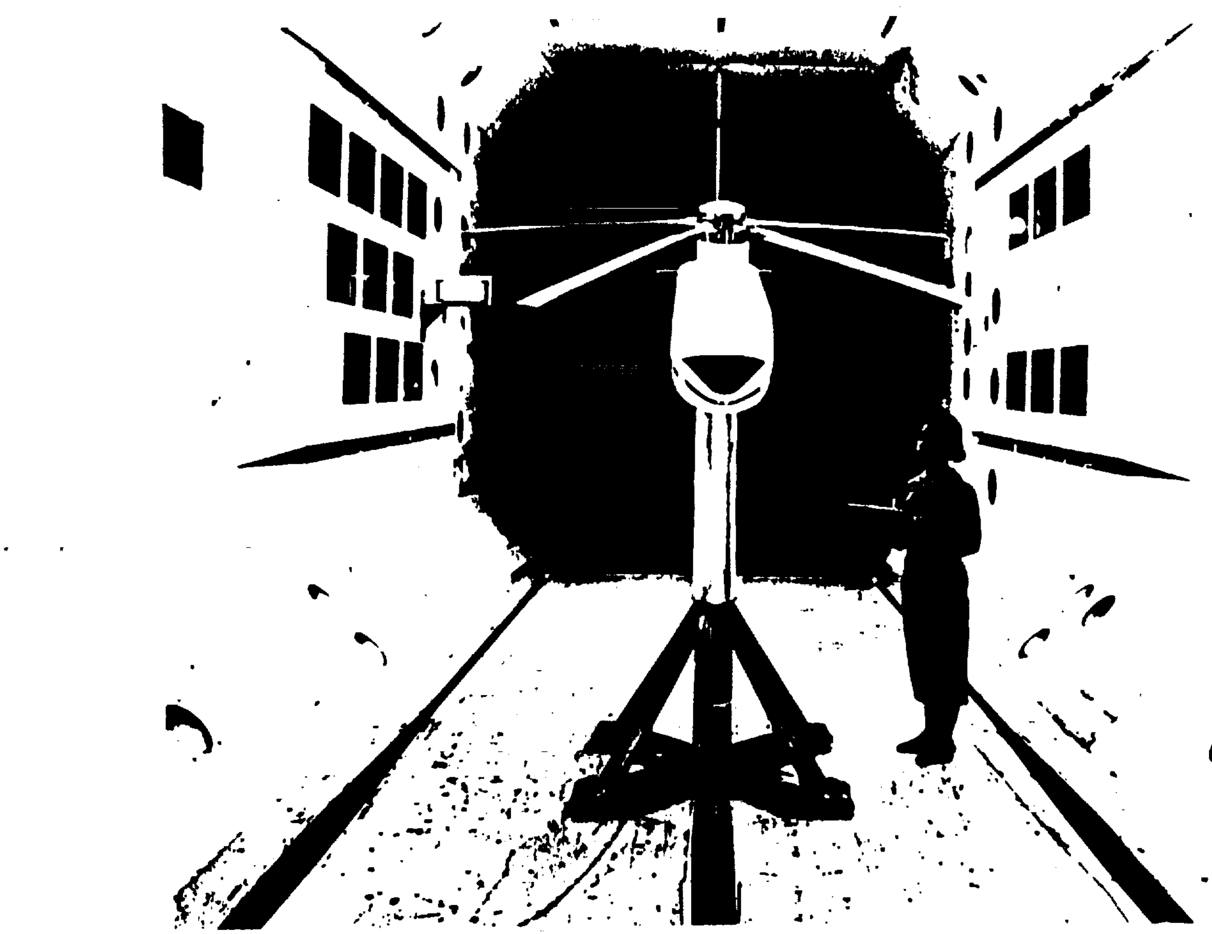

Figure 1 ARES I

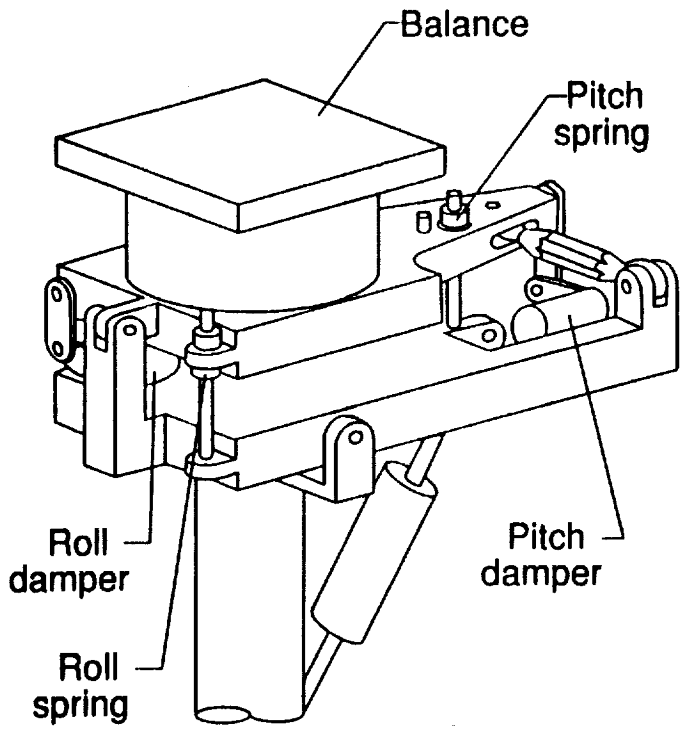

Figure 2   ARES 1.5

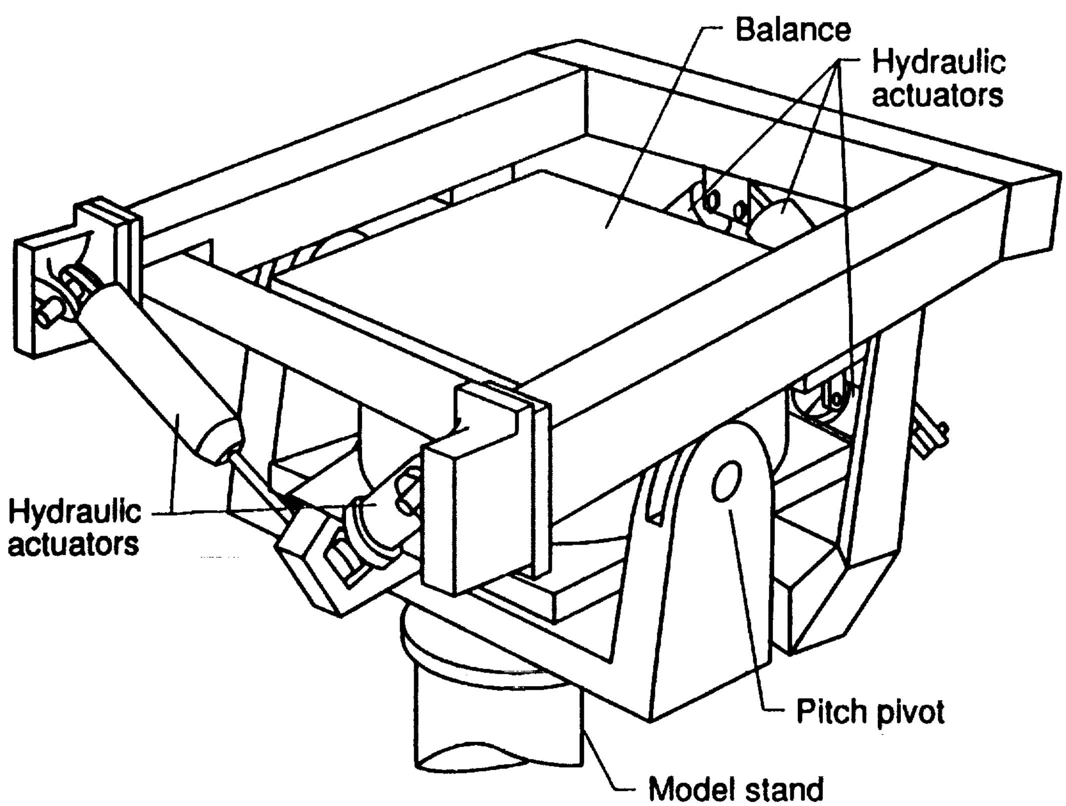

Figure 3   ARES II

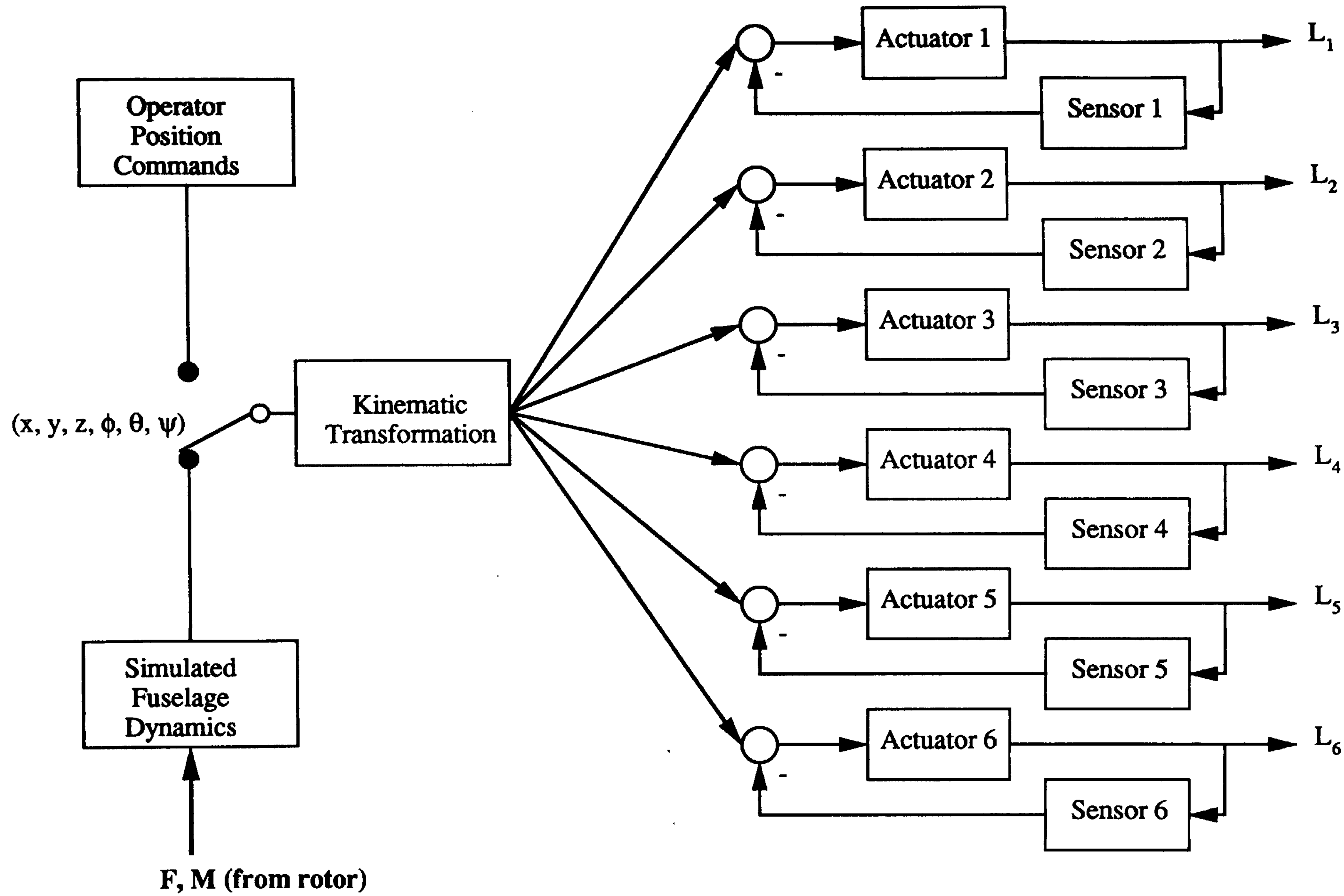

Figure 4 ARES II Control System