DYNAMICS AND CONTROL OF THE SATELLITE POWER SYSTEM

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The SPS is the largest space system conceived to date that appears feasible with reasonable extensions of existing control technology. It represents a class of large platform-like structures (Fig. 1) that are several orders of magnitude larger than any of the other large space systems (multiple-payload platforms, parabolic reflectors, etc.) currently in planning within NASA. The SPS has in common with all large space systems many control problems that are widely recognized within the controls community. These problems include attitude errors due to disturbances, potential instabilities due to truncated modes and other model errors, lack of damping, and inaccurate preflight knowledge of the vehicle dynamics. The qualitative nature of these problems (model errors, concentrated stresses due to large actuator size, etc.) has emerged as a result of studies in the general area of control of large space structures. However, there is a need at this time, to investigate the dynamics and control problems specifically related to the Satellite Power System (SPS), to assess performance of selected control concepts, and to identify and initiate development of advanced control technology that would enhance feasibility and performance of the SPS system. This paper reports on the initial stages of such a study.

One of the areas that has been under intense investigation is that of modeling for controller design. This is widely recognized to be a major and as yet unsolved problem in achieving precise control of large space systems (Fig. 2). This problem arises because, to satisfy performance requirements, the control system must have the means for predicting very accurately the vehicle dynamic response. This is done with a dynamical model that constitutes an integral part of the control system design. The resulting performance is critically dependent on the accuracy of this model. Paradoxically, development and on-board implementation of precise large structure models is difficult if not impossible because of the many degrees-of-freedom, nonlinearities, parameter uncertainties, difficulties in pre-flight dynamics testing, and limitations in on-board computational capability. Hence, the model in the control system design is at best a truncated approximation of the actual vehicle dynamics. A systematic selection of this approximate model is required in order to retain the significant vehicle dynamics in the controller design, to optimize on-board computations and to ensure satisfactory control in spite of the inevitable model errors.

Three distinct approaches have been developed in order to systematically select the controller design model (Fig. 3). The models consist of a hinge-connected multibody model to conduct attitude dynamics and control studies, a continuum model to perform parametric studies of control/structure interaction dynamics and a complete flexible multibody model for performance prediction based on a comprehensive description of the vehicle dynamics. Parametric analysis based on these models has revealed properties of vehicle dynamics (such as mode shapes and frequencies) in terms of the structural parameters (Fig. 4). This parametric model has been used to demonstrate the application of system identification techniques to the SPS dynamics and control. A quasi-inertial mode of operation (Figs. 5-7) has been assessed parametrically and the role of damping on the attitude dynamics investigated. Structural deformations and local slopes arising as a result of dynamic load conditions have been obtained and related to the pointing accuracy and transmitting efficiency of the microwave transmission system (Fig. 8). Current efforts are directed toward application of distributed control and shape determination concepts to the collector and antenna models.

CONFIGURATION

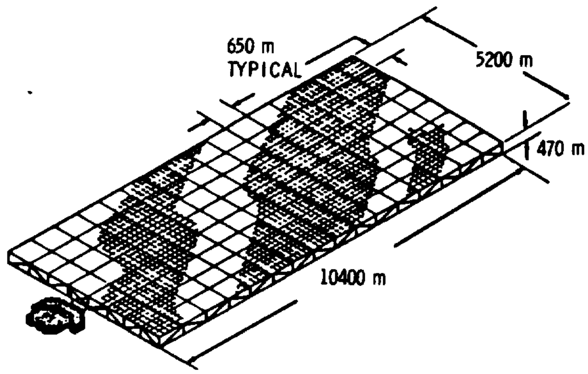
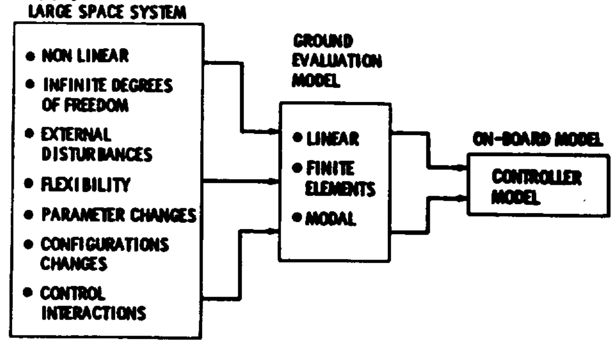


FIG. 1



- LARGE STRUCTURES ARE INFINITE-DIMENSIONAL SYSTEMS THAT CANNOT BE COMPLETELY MODELED
- MODEL ORDER REDUCTION IS REQUIRED TO MINIMIZE ON-BOARD COMPUTATIONS AND IMPLEMENTATION COMPLEXITY

FIG. 2

CONTINUOUS MODEL

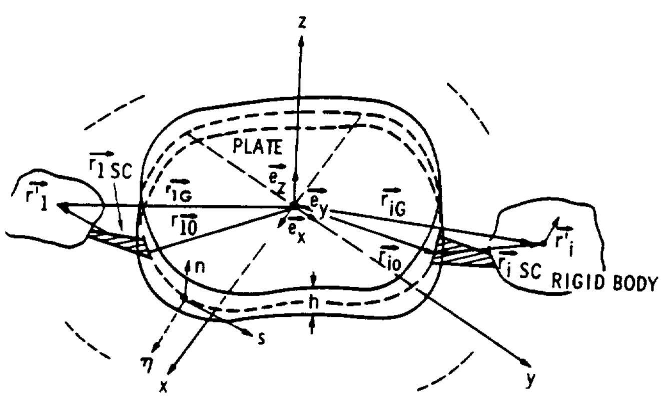


FIG. 3a

FLEXIBLE MULTI-BODY MODEL

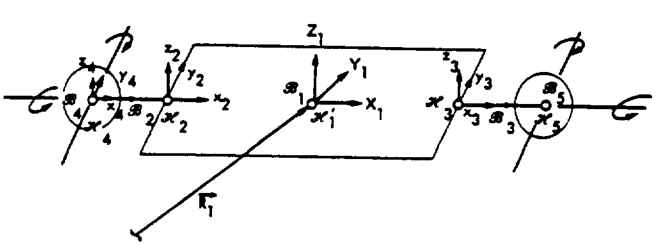


FIG. 3b

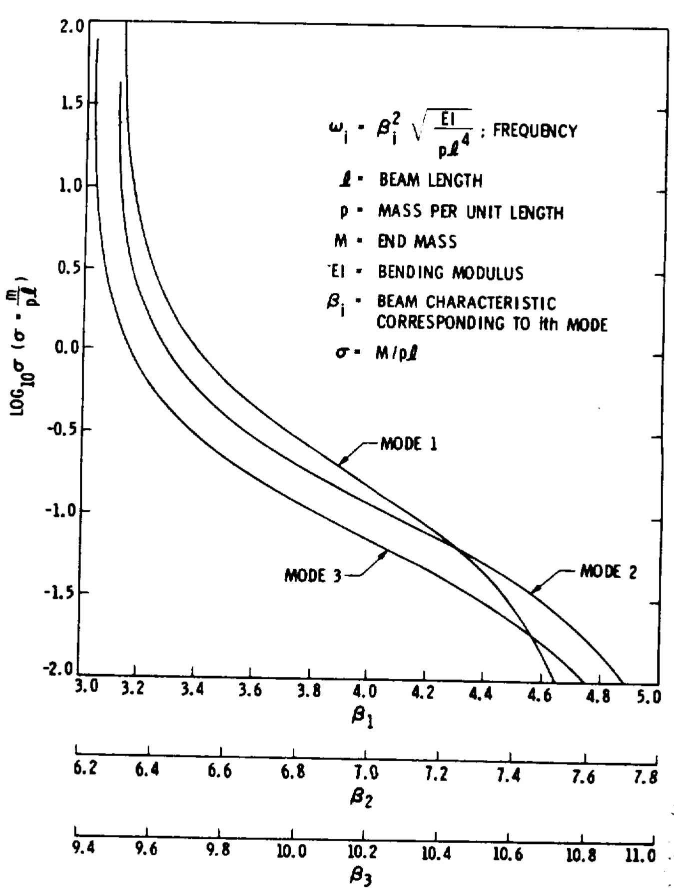


FIG. 4

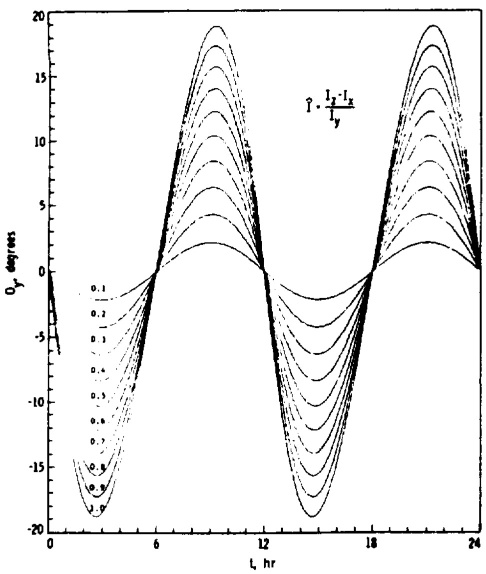


FIG. 5

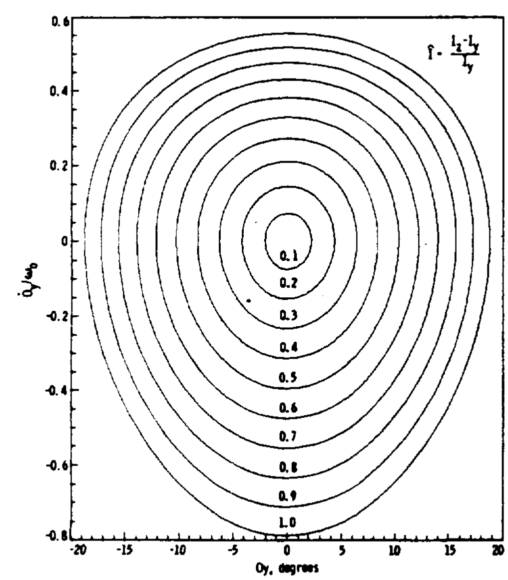


FIG. 6

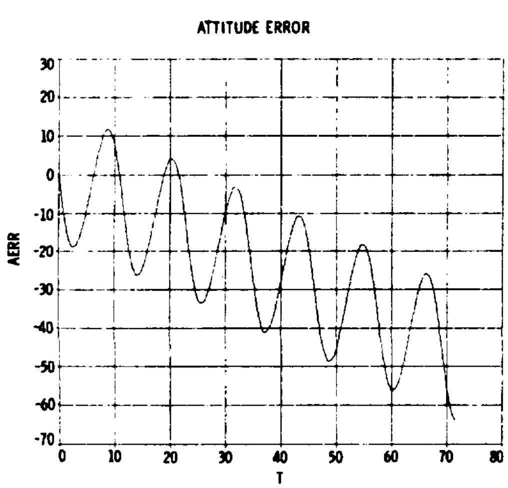


FIG. 7

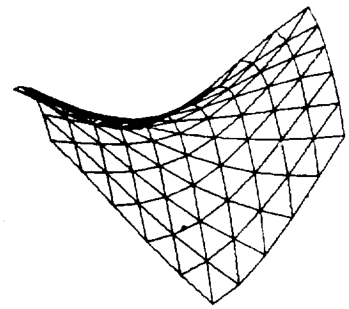


FIG. 8a

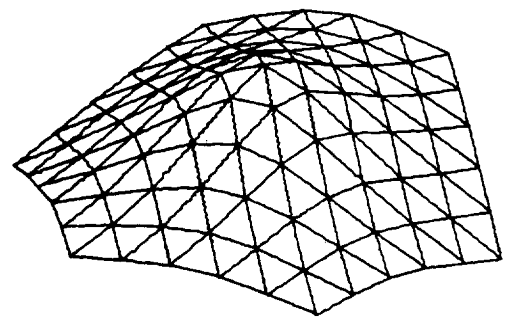


FIG. 8b

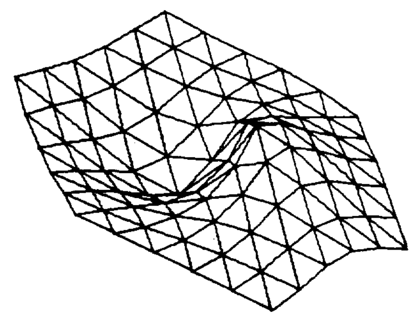


FIG. 8c

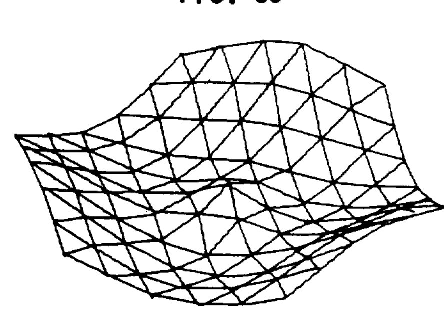


FIG. 8d

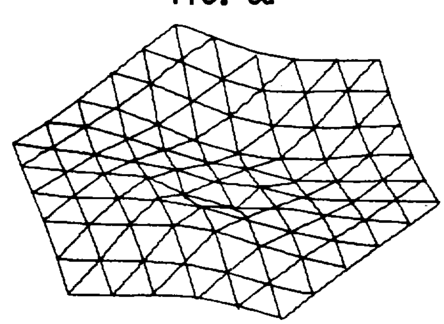


FIG. 8e