MASTER OF SCIENCE
IN
ASTRONAUTICAL ENGINEERING

A FRAMEWORK FOR DESIGNING OPTIMAL SPACECRAFT FORMATIONS

Jeffery T. King-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993
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Advisor: I. Michael Ross, Department of Aeronautics and Astronautics
Second Reader: Fariba Fahroo, Department of Applied Mathematics

This thesis presents a new approach to solving a class of problems arising in the design of satellite swarms. Using the fundamentals of optimal control theory, a framework is developed that captures the essence of "concurrent" design and control of spacecraft formations. This framework is used to articulate a variety of formations including the notion of an aperiodic formation. Additionally, formations that require active control are presented along with their corresponding thrust profile. Based on a deliberate problem formulation, which includes mass as a state variable, it is shown that the numerical approach easily handles nonlinearities. Using the general-purpose dynamic optimization software, DIDO, this thesis demonstrates how a minimum-propellant formation configuration can be easily designed for satellite swarms *without the use of any analytical results*. If a zero-propellant configuration does not exist, then this method automatically determines the minimum fuel and the associated controls required to maintain the configuration. This thesis lends credence to the notion of numerically searching for minimum-fuel formation configurations for spacecraft swarms subject to *arbitrary* nonlinear dynamics. Thus, practical formations may be designed and controlled using this method.

KEYWORDS: Satellite Formation, Formation Design, Optimal Design, DIDO, Swarm

DEVELOPMENT AND CONTROL OF THE NAVAL POSTGRADUATE SCHOOL PLANAR AUTONOMOUS DOCKING SIMULATOR

Robert D. Porter-Lieutenant Commander, United States Navy
B.S., Penn State University, 1989
Master of Science in Astronautical Engineering-September 2002
Advisor: Michael G. Spencer, Department of Aeronautics and Astronautics
Second Reader: Brij N. Agrawal, Department of Aeronautics and Astronautics

The objective of this thesis was to design, construct and develop the initial autonomous control algorithm for the NPS Planar Autonomous Docking Simulator (NPADS). The effort included hardware design, fabrication, installation and integration; mass property determination; and the development and testing of control laws utilizing MATLAB and Simulink for modeling and LabView for NPADS control.

The NPADS vehicle uses air pads and a granite table to simulate a 2-D, drag-free, zero-g space environment. It is a completely self-contained vehicle equipped with eight cold-gas, bang-bang type thrusters and a reaction wheel for motion control. A "star sensor" CCD camera locates the vehicle on the table while a color CCD docking camera and two robotic arms will locate and dock with a target vehicle. The on-board computer system leverages PXI technology and a single source, simplifying systems integration. The vehicle is powered by two lead-acid batteries for completely autonomous operation.

A graphical user interface and wireless Ethernet enable the user to command and monitor the vehicle from a remote command and data acquisition computer. Two control algorithms were developed and allow the user to either control the thrusters and reaction wheel manually or simply specify a desired location and rotation angle.

KEYWORDS: Attitude Determination, Attitude Control, LabView, MATLAB, SIMULINK, Autonomous Docking, Satellite Simulator, Pulse Width Modulation Thruster Control

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