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N94- 26286

Autonomous Rendezvous and Docking for Space Station Freedom

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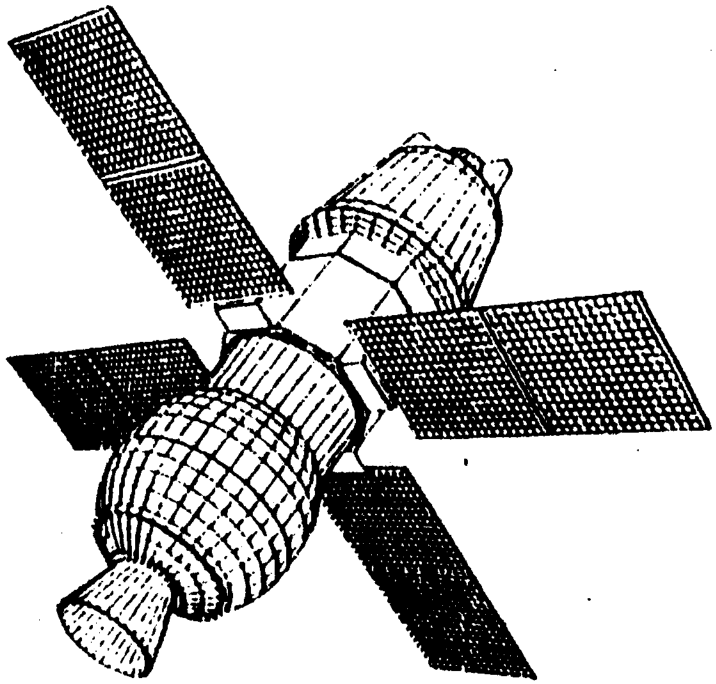
LANGLEY RESEARCH CENTER

PROPOSED AR&D INITIATIVE



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AUTONOMOUS RENDEZVOUS AND DOCKING STUDIES FOR SPACE STATION *FREEDOM*

OVERVIEW OF WORK IN PROGRESS AND PLANS FOR 1993

March 17, 1993

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REQUIREMENTS FOR AR&D EXPERIENCE

Space Station:

"... reinitiate and complete efforts to develop operational scenarios and requirements for rendezvous, proximity operations, capture, and attached operations of transfer vehicles ***other than the Space Shuttle.***"

(R. Kohrs memo - Nov. 30, 1992)

Earth Sciences:

"Communications continue in good working order...GOES-5 is ***no longer controllable because of insufficient fuel.*** On January 28, 1989 a revised transmission schedule was implemented."

(APT Information Note 89-1 - March 13, 1989)

Technology Validation:

"... the primary recommendation of the committe [is] that NASA establish a national space facility for the development of space automation and robotics, one element of which is a ***telerobotic research platform in space.***"

(Annual Report of the Langley GN&C Technical Committe - September, 1992)

OPPORTUNITY FOR LOW COST AR&D FLIGHT EXPERIENCE

Langley researchers have proposed cooperation with the Space Automation and Robotics Center (SpARC) of the Environmental Research Institute of Michigan (ERIM) on their AR&D experiment planned as part of the COMET Program.

SpARC is a NASA Center for the Commercial Development of Space (CCDS).

COMET, the COMmercial Experiment Transporter is an orbital system operated by the University of Tennessee Space Institute (UTSI) exclusively for use of the CCDS's.

SpARC will make use of the first two COMET Service Modules, following completion of on-orbit experiments, to attempt AR&D.

This series of two missions (4/93 and 11/94) are already funded Conestoga launches out of Wallops Is.

Langley was asked to provide simulations and analysis of the mission, recommend algorithm enhacements, and perform ground-based hardware testing and simulation, if appropriate.

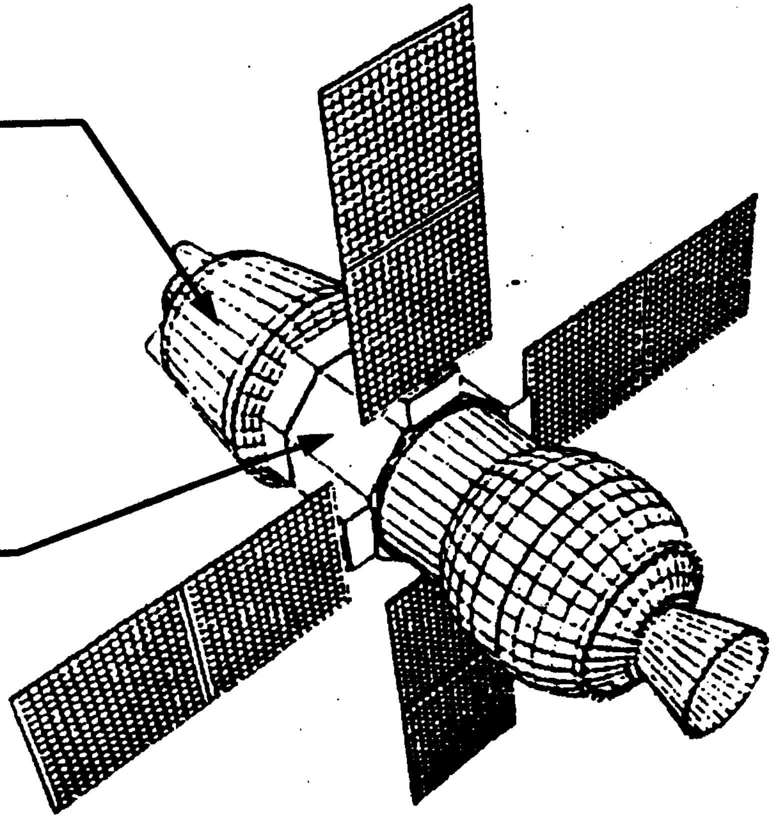
COMET SPACECRAFT PERFORMANCE

Recovery Module

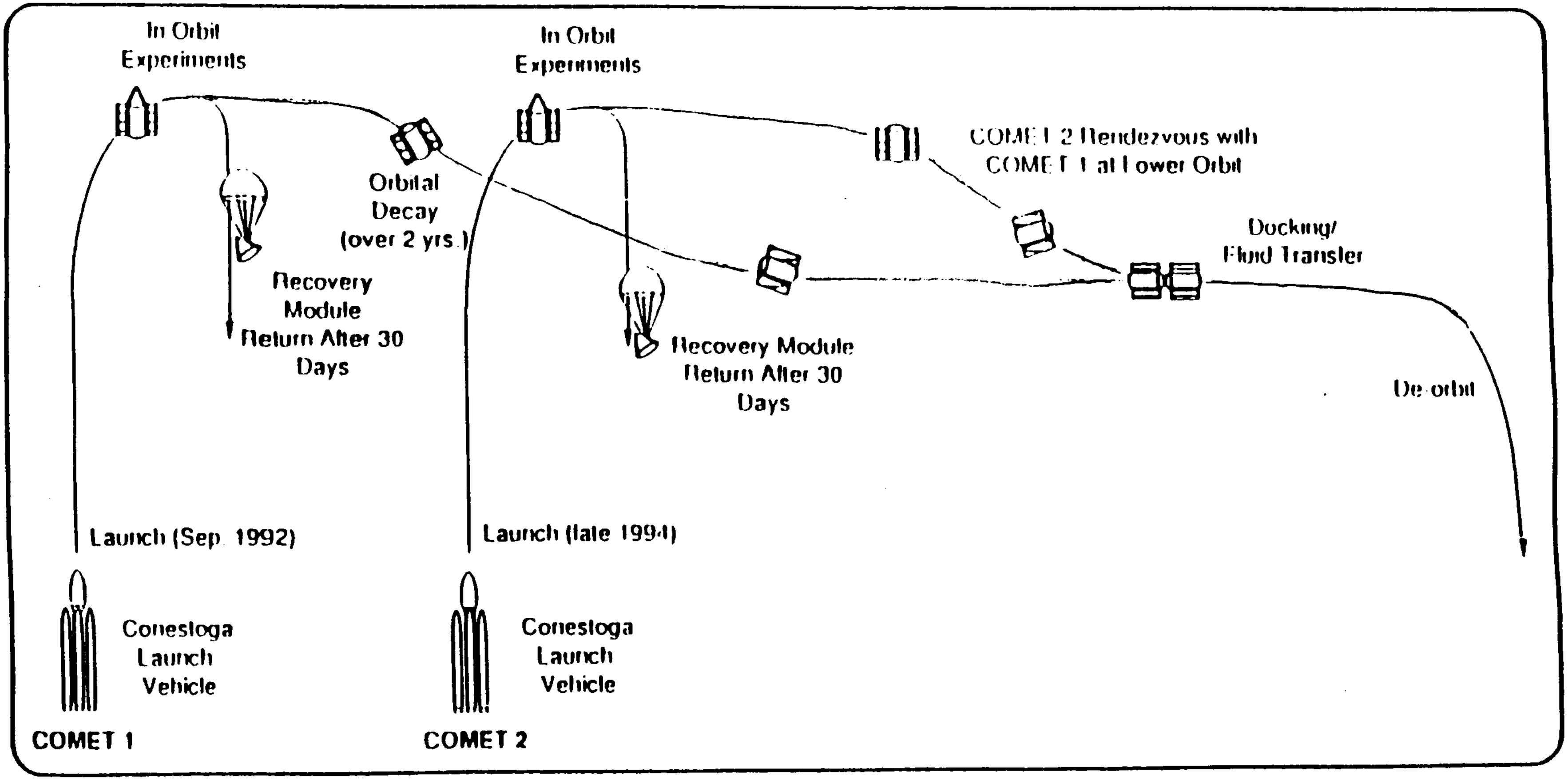
Mission Duration: 30 days
Payload Mass: 300 lbm
Payload Volume: 10 cu. ft.

Service Module

Mission Duration: 130+ days
Payload Mass:150 lbm
Payload Volume: 15 cu. ft.



AR&D MISSION PROFILE



ANALYSIS IN SUPPORT OF THE COMET AR&D MISSION

Independent Assesment of R-bar VS V-bar Approach

Controllability of Loosely Coupled Configuration

Approach Trajectory Optimization and Simulation

Contact Dynamics - Impact on Attitude Control of Target

Definition of AR&D Standards

ANALYTICAL MODELS IDENTIFIED FOR THREE REGIMES OF MISSION

Approach Trajectory

Loosely Coupled Configuration

Contact Dynamics

MODEL FOR APPROACH/PROXIMITY OPS.

RCS Control of Pursuit Vehicle

Translational Control Only

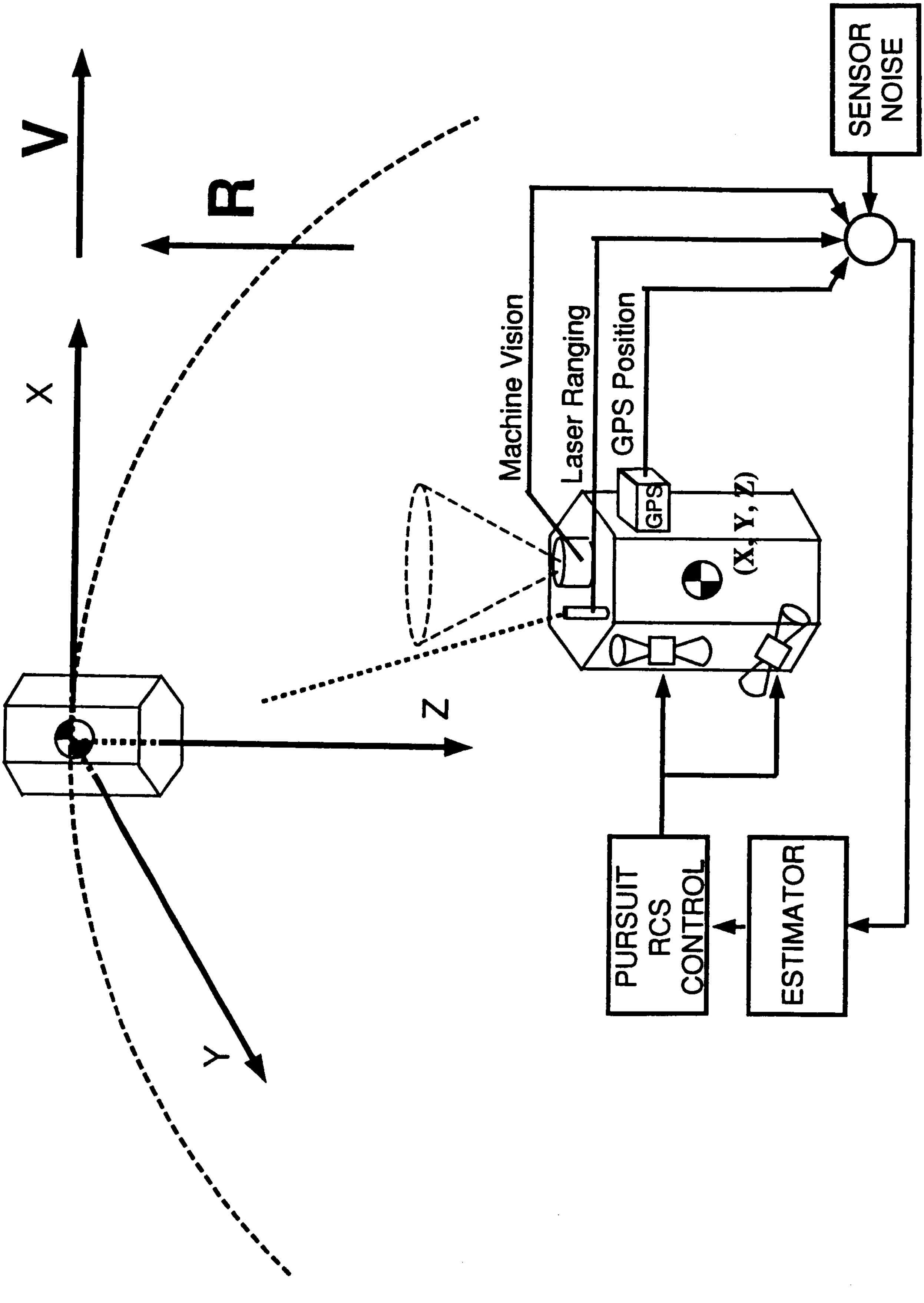
Dynamics Described in the Target Vehicle's Reference Frame by the "Euler-Hill" Equations:

$$x'' - 2\omega z' = A_x$$
$$y'' + \omega y = A_y$$
$$z'' + 2\omega x' - 2\omega z = A_z$$

4 States in Dynamic Model: Relative (X, Y, Z) Position of Pursuit Vehicle with respect to the Target and Propellant Expenditure

Enhancements:

- Sensor Noise
- Visibility of Laser Ranging and Machine Vision
- GPS Constellation Geometry
- Model of GPS Reciever


V
R
X
Y
Z
Machine Vision
Laser Ranging
GPS Position
GPS
(X, Y, Z)
SENSOR NOISE
PURSUIT RCS CONTROL
ESTIMATOR

MODEL FOR LOOSELY COUPLED CONFIGURATION

Baseline COMET Attitude Controller on Target Vehicle

2 Sensors:

- Magnetometer
- Horizon Sensor

5 Actuators:

- 2 Reaction Wheels
- 3 Magnetic Torquers

Attitude Dynamics Only:

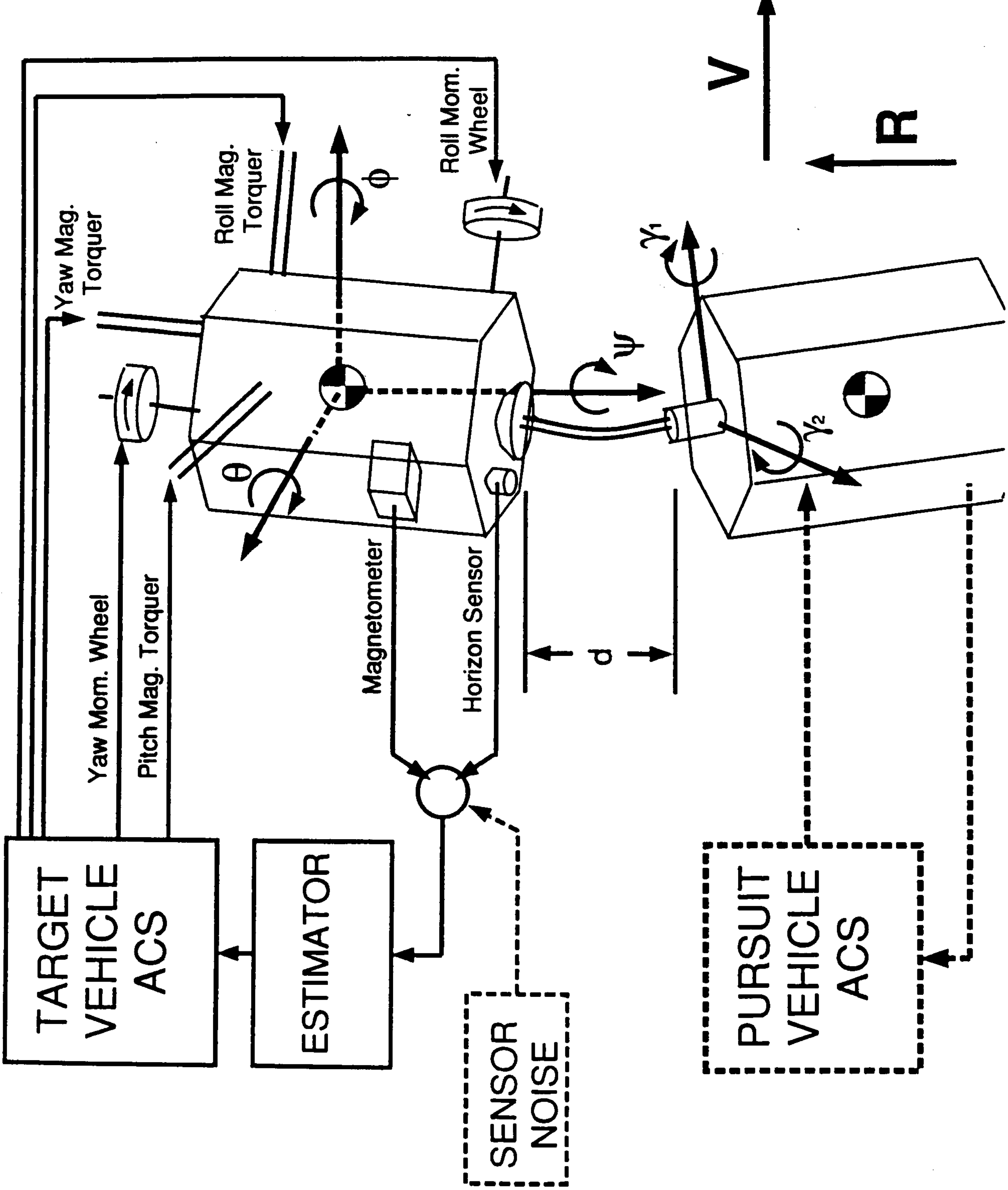
$$I\, d\omega/dt = -\omega \times I\omega + 3\omega^2 u \times Iu + M_{AERO} + M_{CONTROL} + M_{DOCK}$$

6 States in Dynamic Model:

- 3 Attitude of Target Vehicle
- 1 Length of Retraction of Probe
- 2 Bending of Probe

Enhancements:

- Sensor Model: Horizon sensor visibility, Magnetic Field Model
- Sensor Noise
- External (Random) Disturbances


TARGET VEHICLE ACS
ESTIMATOR
SENSOR NOISE
PURSUIT VEHICLE ACS
Yaw Mom. Wheel
Pitch Mag. Torquer
Magnetometer
Horizon Sensor
Yaw Mag. Torquer
Roll Mag. Torquer
Roll Mom. Wheel
d
V
R

MODEL FOR CONTACT DYNAMICS

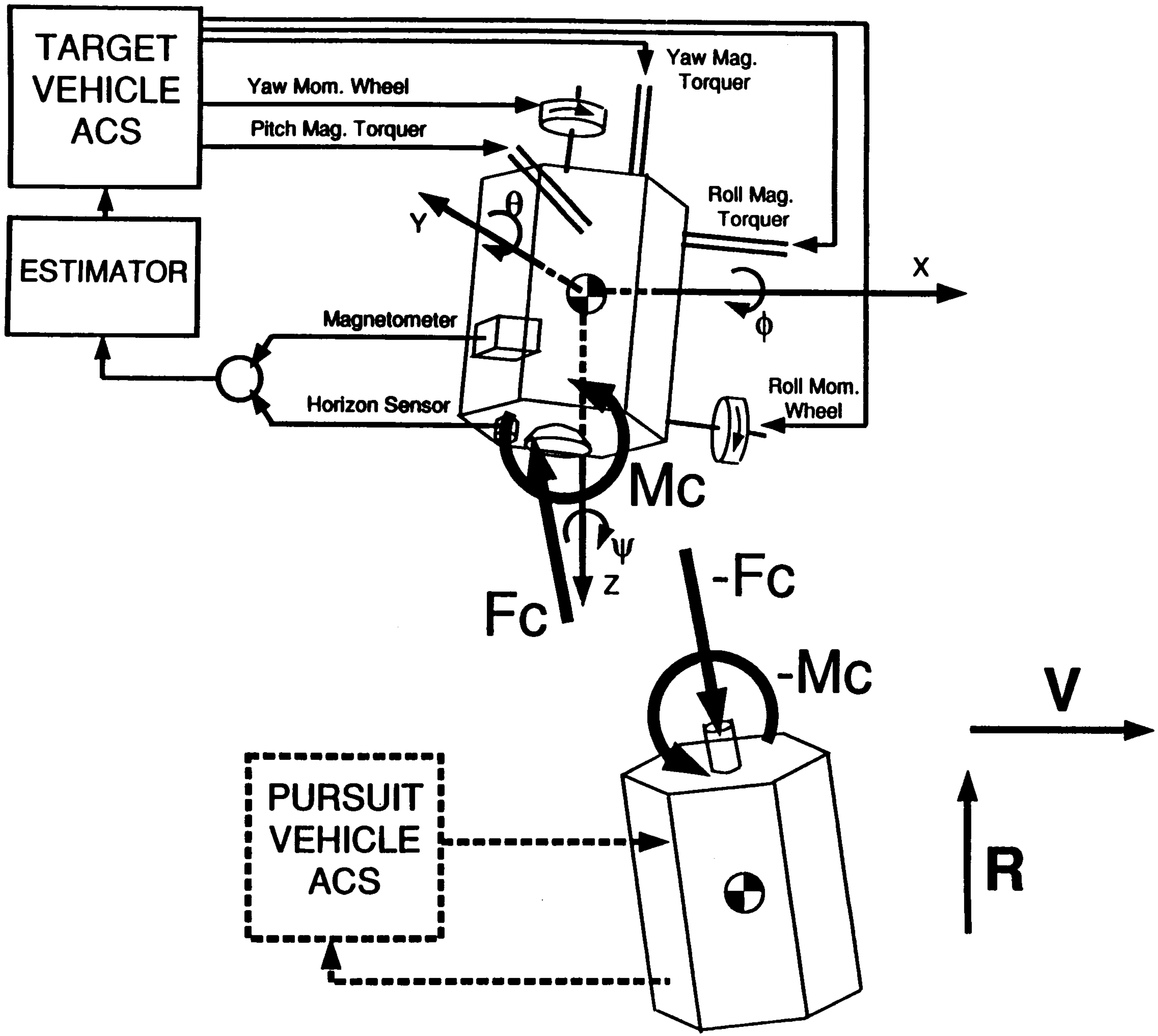
Attitude Control of Target Vehicle Alone

Same Spacecraft Model and ACS as for Coupled Control

Analytical Model for Contact Forces and Moments

Experimental Contact Force Estimates:

- Air Bearing Vehicles Tested by SpARC
- MSFC Mechanisms Laboratory
- Full Simulation with Two Air Bearing Vehicles on MSFS Flat Floor


TARGET VEHICLE ACS
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Roll Mom. Wheel
Magnetometer
Horizon Sensor
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-Mc
PURSUIT VEHICLE ACS
V
R

APPLICATION TO SPACE INFRASTRUCTURE

In-Space Demonstration of AR&D Technology

Validation of Analytical (and Ground Based Hardware ?) Models Against Actual Flight Data

Feasibility Studies for Use of Small Logistics Carriers

Definition of Uniform Standards and Common Interfaces for AR&D (along with AIAA)

CONCLUSIONS
AND
FUTURE PLANS

Need for Autonomous Rendezvous and Docking Technology Development Identified

Analytical Support Available

Potential for Ground-Based Testing and Simulation at MSFC

Opportunity for Flight Experience, Model Validation, and Data Exchange through Participation in COMET ARD Mission

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