TETHERED SYSTEMS CONTROL

MDSSC-SSD

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OUTLINE

- Introduction
- Problem Formulation
- Proposed Approaches
  - Controller Structure
  - Proposed Controllers
- Simulation Examples
  - Deployment
  - Retrieval
- Summary

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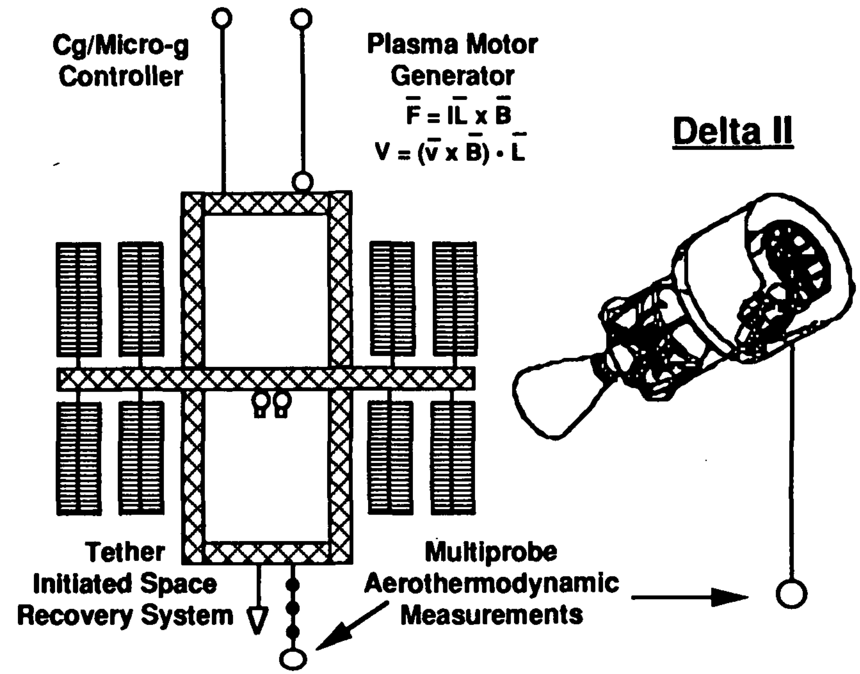
- **Introduction**
  - Tethers can provide
    - Momentum exchange
    - Mechanical/electrical conversion
    - Electrical/mechanical conversion
  - Technology applications
    - Acceleration environment control
    - Payload transportation
    - Electrical power generation
    - Attitude and orbital control

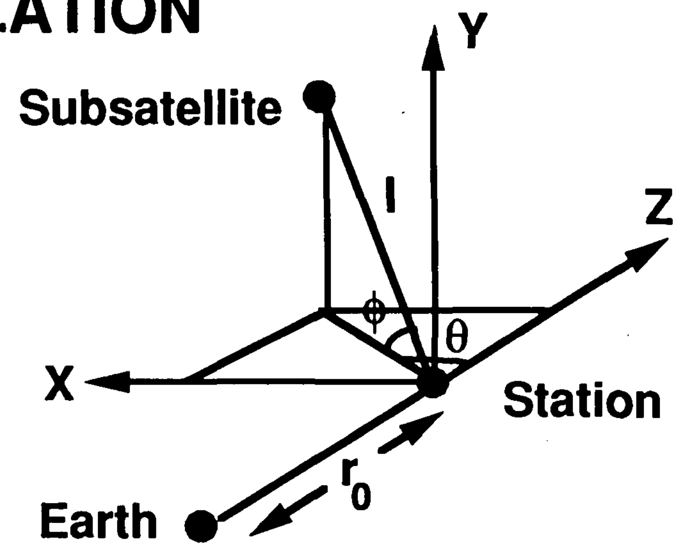


- **Relevance**
  - Project applications
    - Atmospheric science research
    - Payload boost/deboost
    - Spacecraft power generation
  - Advantages
    - Data gathering
    - Application alternatives (Safety)
  - NASA near term activities
    - Delta II/SEDS flight experiment
    - STS/Tethered Satellite System

- **Problem Overview**
  - Operational phases
    - Deployment,retrieval
    - Stationkeeping
  - Dynamics
    - Nonlinear,time-varying,coupled
    - Unstable,elastic,uncertain
  - Performance criteria
    - Libration magnitude
    - Deployment/retrieval time
    - Payload disturbances

PROBLEM FORMULATION

- **Rigid body simplifications**
  - Point masses (Station and subsatellite)
  - Station mass >> Subsatellite mass
  - Massless, rigid tether
  - Spherical earth
  - Circular orbit



$$\ddot{l} - [\dot{\phi}^2 + \cos^2\phi(\omega_0 + \dot{\theta})^2 - \omega_0^2 + 3\omega_0^2\cos^2\phi\cos^2\theta]l = \frac{Q_l}{m_p}$$

$$\ddot{\theta} + \frac{2\dot{l}(\omega_0 + \dot{\theta})}{l} - 2\tan\phi(\omega_0 + \dot{\theta})\dot{\phi} + 3\omega_0^2\sin\theta\cos\theta = \frac{Q_\theta}{m_p l^2\cos^2\phi}$$

$$\ddot{\phi} + \frac{2\dot{l}\dot{\phi}}{l} + \cos\phi\sin\phi[(\omega_0 + \dot{\theta})^2 + 3\omega_0^2\cos^2\theta] = \frac{Q_\phi}{m_p l^2}$$

- **Observations**
  - Dynamics are nonlinear (trig, products of states)
  - Retrieval dynamics involve negative libration damping

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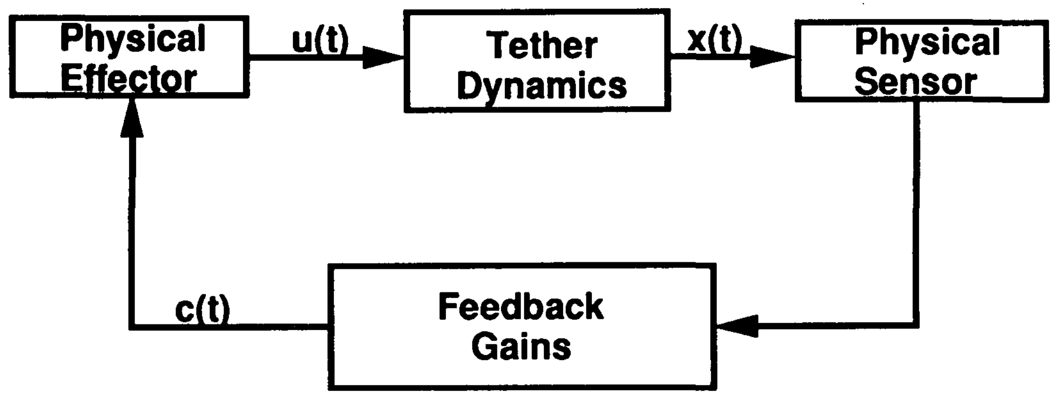
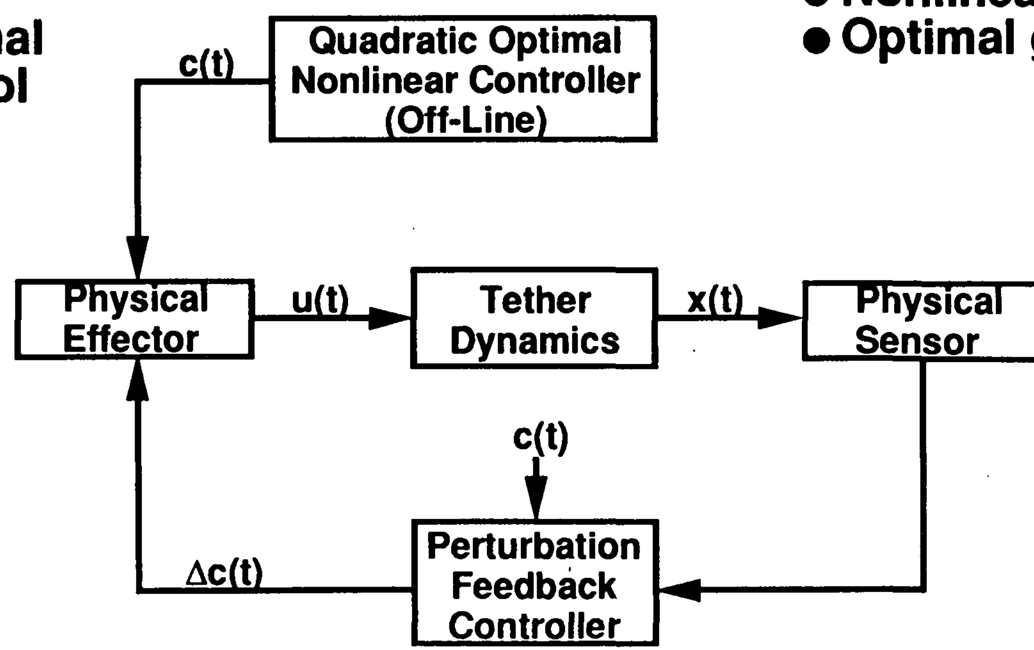
PROPOSED APPROACHES (CONTROLLER STRUCTURE)

- **Feedback control**



Recent approaches
- Nonlinear feedback
- Optimal gains

- **Quadratic optimal nonlinear control**



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PROPOSED APPROACHES (PROPOSED CONTROLLERS)

- Quadratic optimal nonlinear controllers
  - Tension Optimal Nonlinear Controller
    - Newton-Raphson, steepest descent
    - Divergence (explicit feedback, tension delay)
  - Length Rate Optimal Nonlinear Controller (LRONC)
    - Steepest Descent
    - Direct damping control
  - Suboptimal Nonlinear Controller (SONC)
    - Feedback structure (gain optimization)
    - Powell's Method

- Lyapunov-based nonlinear controllers
  - Mission/distance function concept
  - Mission Function Control (MFC)
  - Lyapunov Optimal Feedback Controller (LOFC)

- Sensor/actuator options
  - Measurements - length, tension, deployment attitude, P/L accels
  - Actuators - spring ejection mechanism, reel, thrusters

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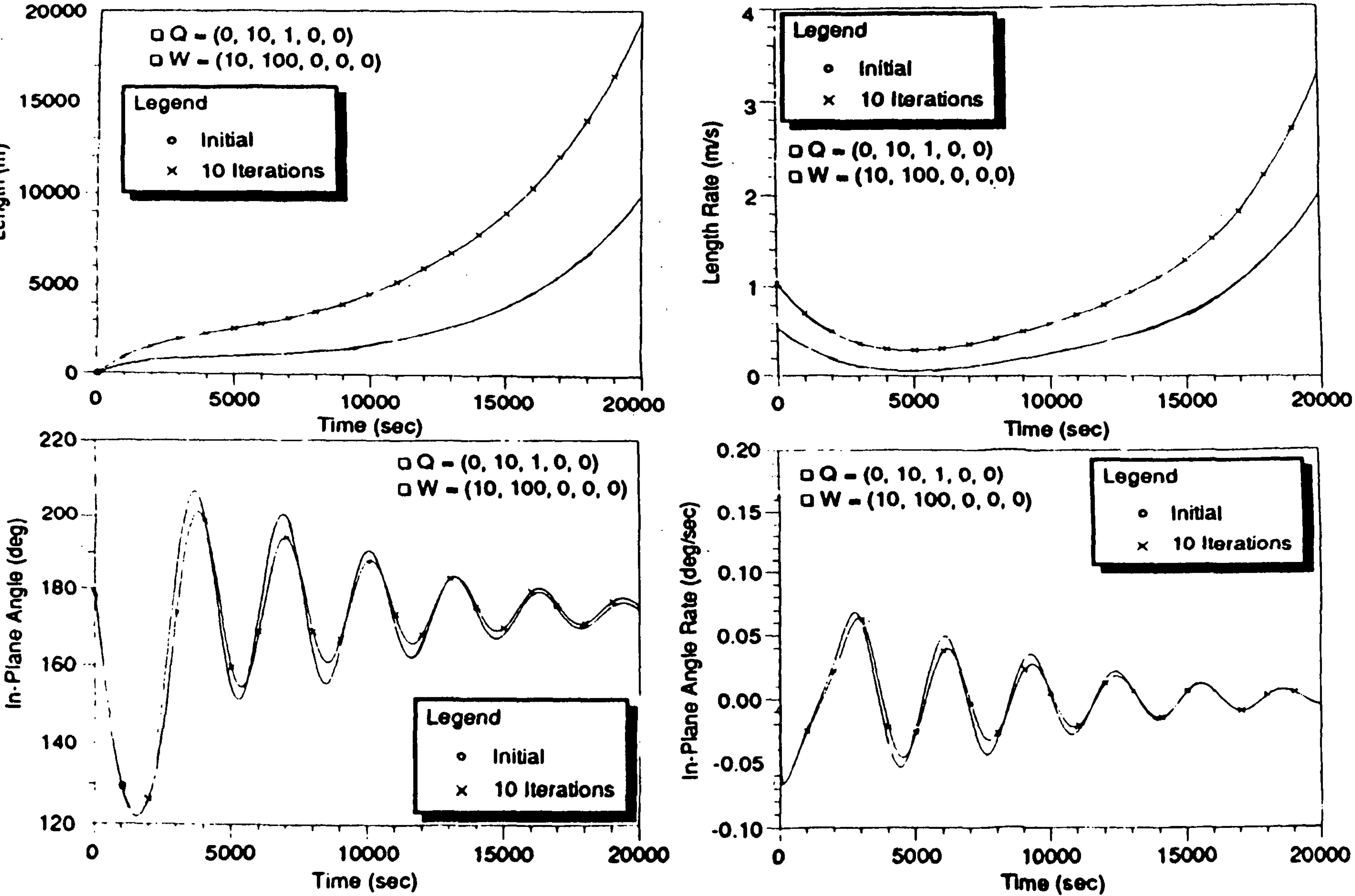
LRONC- DEPLOYMENT TIME HISTORIES



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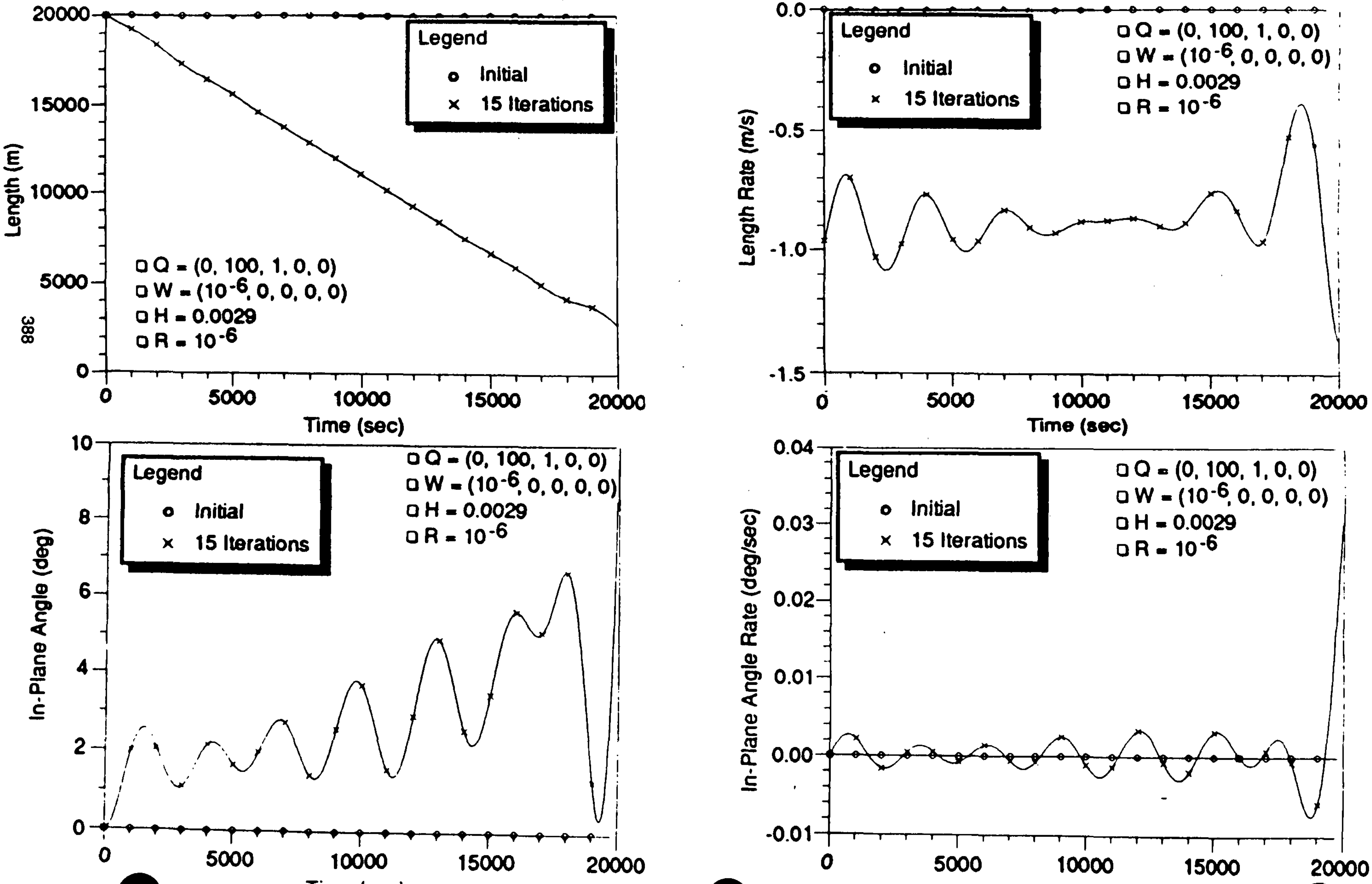
LRONC - RETRIEVAL TIME HISTORIES



SUMMARY

- Tethered systems have many potential applications
- Tether dynamics encompass typical spacecraft control issues (stability, nonlinearities, coupled dynamics)
- Tether control improvements could provide benefits in such areas as retrieval stability and mission timelines
- Question - Can fuzzy logic control techniques help with the tethered systems control problem ?

Topic: Tethered Systems Control
Presenter: Dan Nowlan

No notes were taken during this presentation.