PROXIMITY OPERATIONS IN SPACE STATION ENVIRONMENT

by

Brandt Rhodes / Senior Engineer
Guidance, Navigation & Traffic Management - Proximity Operations
McDonnell Douglas Space System Co., SSD (Houston)
Phone: (713) 280-1500 x 3227 Fax: (713) 280-1583

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PROXIMITY OPERATIONS
INTRODUCTION

- Proximity operations encompasses all free-flying vehicle relative motion within 1 km radius sphere of the Station, the proximity operations zone (POZ)
- U.S. efforts traditionally include manual piloting of an active chase vehicle about a passive target
- Primary active vehicle is the Shuttle
  - Greatest effects on Station components and operations
  - Highest frequency of interaction
- Station era may involve unmanned cooperative vehicles
  - Potential candidates for automated flight
    - — Man-Tended Free-Flyer (MTFF) - currently plans Station visits
    - — Assured Crew Return Vehicle (ACRV)
    - — Flight Telerobotic Servicer (FTS)
  - Remote manual piloting from Station cupola or ground
    - — Shuttle- and Station-based OMVs / OTVs
    - — Crew Equipment Retrieval System (CERS)
    - — Flight Telerobotic Servicer (FTS)
- Direct influences on system design, SE&I and operations

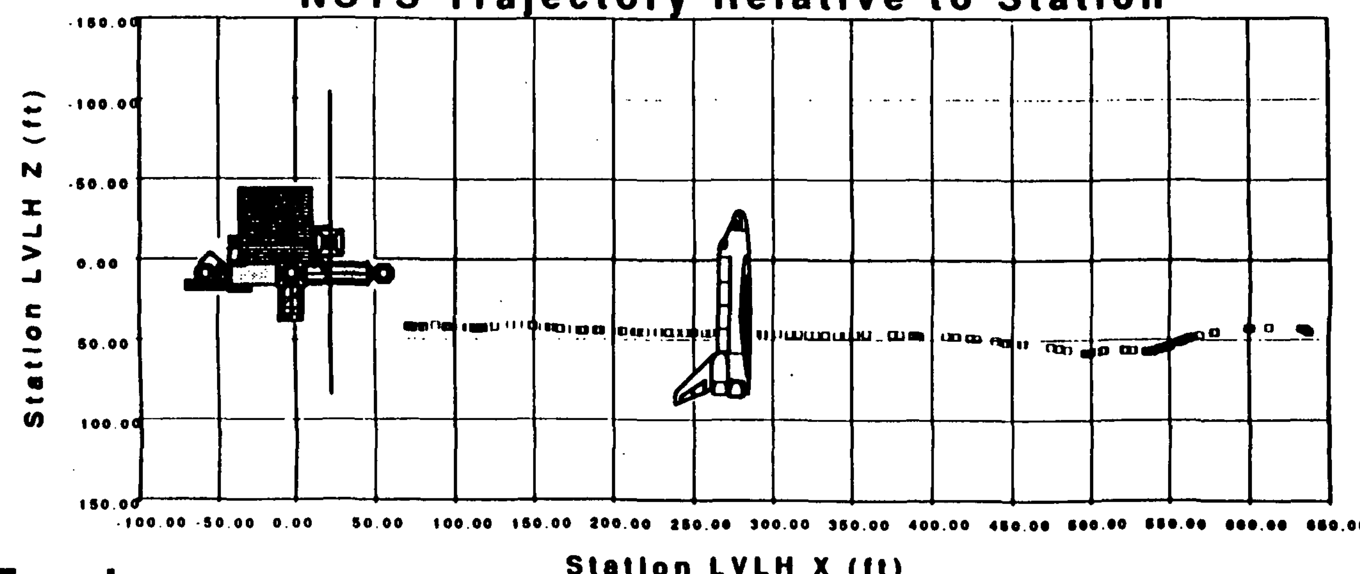
PROXIMITY OPERATIONS
TASK REQUIREMENTS & CONSTRAINTS

- **Flight techniques / procedures development accounts for**
  - Lighting / visibility constraints
  - Trajectory and attitude control
  - Plume impingement & environment effects
  - Docking / berthing contact conditions
  - Structural clearances
  - Contingency planning
  - Crew timelines
  - Ground rules
  - Fuel usage
- **Flight performance directly dependant on**
  - Flight techniques development and piloting skill
  - Control system authority, capacity and performance
  - Propulsion system functionality and effectiveness
  - Relative navigation sensor accuracy and precision
  - Orbital environmental effects

PROBLEM FORMULATION

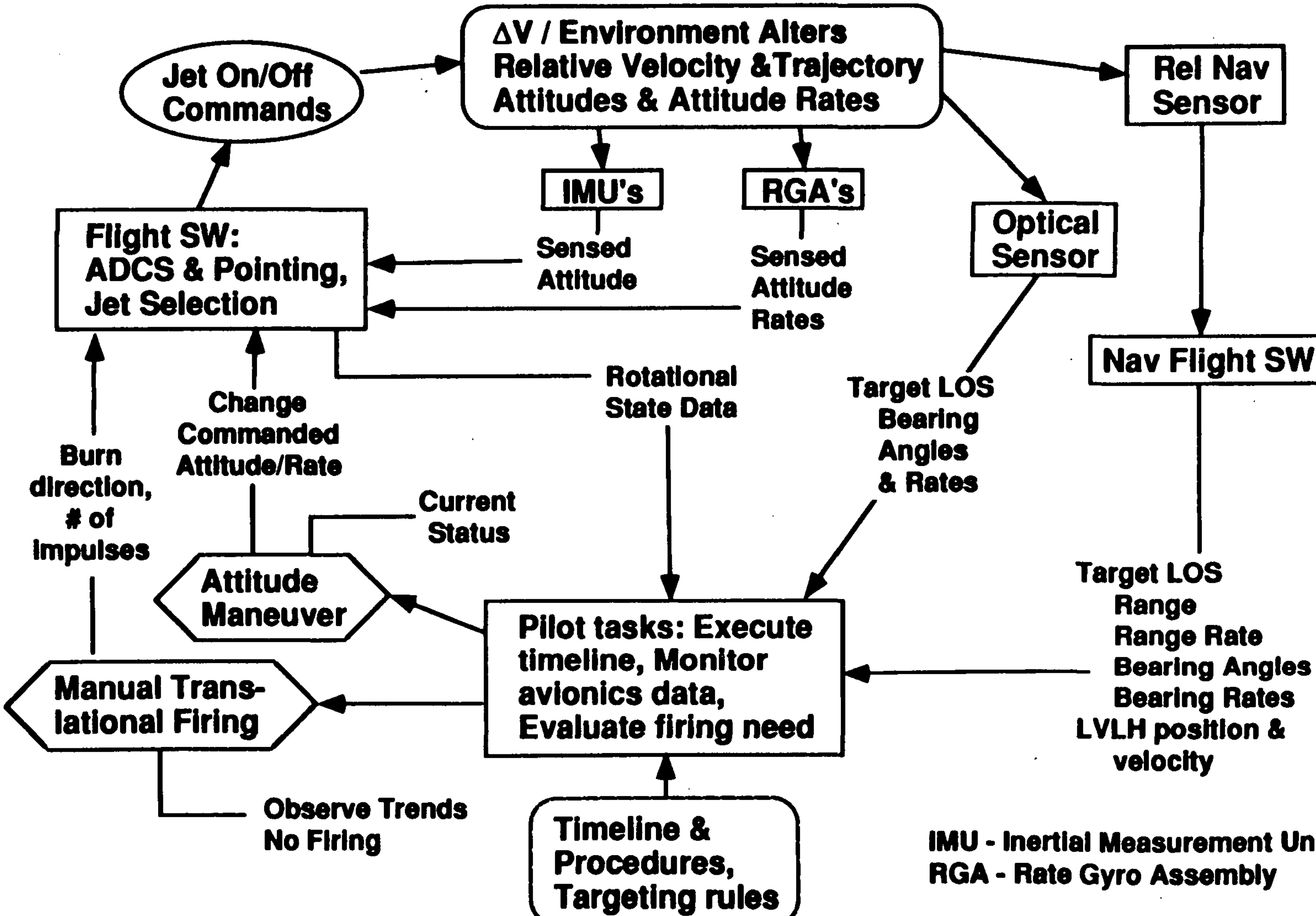
- Control task is regulating the six degree-of-freedom (DOF) relative motion between vehicles to achieve the desired trajectory
  - Chaser performs translational and rotational maneuvers
  - Target drifts or actively maintains an attitude profile
  - Critical flight parameters wrt relnav sensor line of sight (LOS)
- Traditionally, flight profile manually flown by refined procedures -
  - Relative state control is split into three distinct aspects:
    - — Rotational attitude and attitude rates
    - — Range, closing or opening velocity
    - — Cross range, bearing angles & rates
- Vbar approach as example trajectory -

NSTS Trajectory Relative to Station



PROBLEM FORMULATION
(CONTINUED)

- **Flight parameter flow / pilot interaction for proximity operations task**



IMU - Inertial Measurement Unit
RGA - Rate Gyro Assembly

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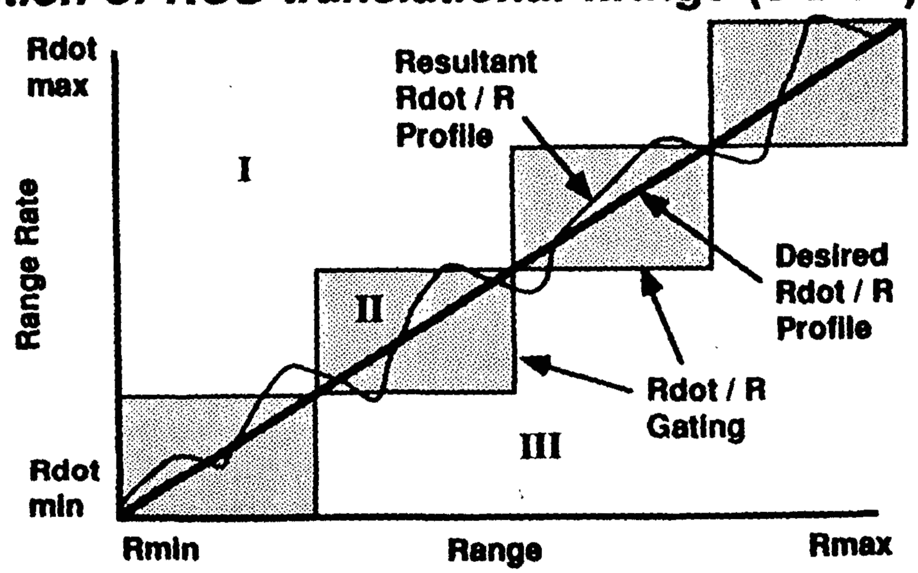
PROBLEM FORMULATION
(CONTINUED)

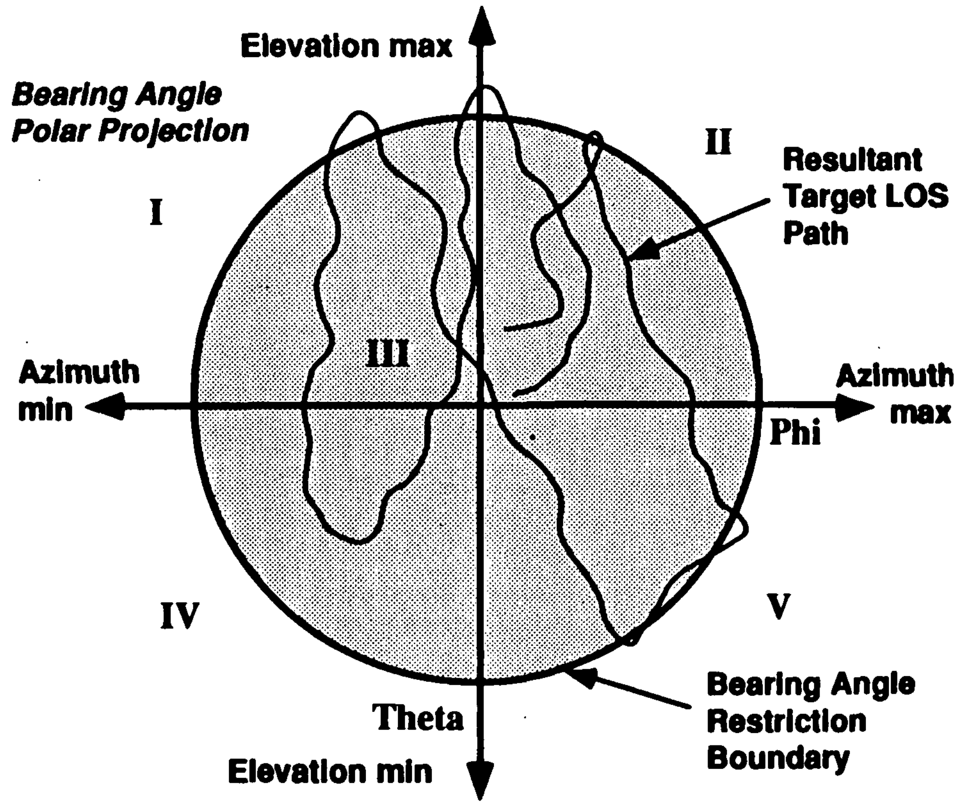
- Rotational state (3 DOF) automatically maintained by attitude determination / control and pointing systems
  - Command activation as a function of time and / or position
- Piloting task centers on execution of RCS translational firings (3 DOF)
  - Range rate flown as function of range / time, the relation may be
    - — Simply linear (see plot)
    - — Based on non-linear empirical data
  - Gate boundaries sized to subject vehicle and desired profile tightness
  - Firing Decision Logic



REGION	Rdot State	Thrust Reaction
I	Constant or Increasing	Decrease Rdot
	Close to Box & Decreasing	N/A, follow trend
II	Moderate or no Δ in Rdot	N/A, follow trend
	Rapid Δ in Rdot	Decrease Δ rate
III	Close to Box & Increasing	N/A, follow trend
	Constant or Decreasing	Increase Rdot

PROBLEM FORMULATION

- Cross range flown as function of LOS bearing
  - — Translational burns ≈ normal to LOS
  - — Data from CCTV, COAS, relative nav avionics
- Angle boundaries sized to subject vehicle and desired profile tightness
- Firing Decision Logic independant for azimuthal and elevation parameters in each zone



REGION	Phi dot State	Thrust Reaction	Theta dot State	REGION
II, V	Constant or increasing	Induce neg rate	Constant or increasing	I, II
	Decreasing	N/A, follow trend	Decreasing	
I, IV	Constant or decreasing	Induce pos rate	Constant or decreasing	IV, V
	Increasing	N/A, follow trend	Increasing	
III	|Phi dot| > Phi dot max	Decrease rate to below max	|Theta dot| > Theta dot max	III

SUMMARY

- Techniques exist that model, augment, automate prox ops piloting
- Overall task requires flexibility for broad application and poses multiple requirements constraints
- Automation may be applied to specific aspects of the prox ops task
- Traditional simulation paper pilots are tuned for their environment
  - Contributing vehicle factors:
    - Digital autopilot (DAP) / RCS configurations
    - Propulsion system characteristics
    - Sensor data quality
  - Tuning parameters:
    - Frequency of response
    - Number of input impulses per response
    - Filtering and / or trend evaluation of the sensor data
- Could fuzzy logic provide a way to develop generic automatic flight control applicable to various active vehicles for prox ops?

Topic:	Proximity Operations
Presenter:	Andy McGuire
Comment:	Work has been done during the last two years on automatic flight control with a demonstration in 1988. --> Rotational Controller containing 31 rules.