RENDEZVOUS GUIDANCE

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■ **Outline**
- Introduction
- Problem Formulation
- Proposed Approaches
- Summary
- Panel Discussion

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- **Introduction**
  - Space Station onboard software provides maneuver commands to cooperative unmanned vehicles attempting to rendezvous.
  - Constraints affecting rendezvous include, station safety, fuel consumption, time limitations, etc.
  - Several targeting algorithms may be employed to obtain the relative guidance maneuver commands.
  - Two of these targeting algorithms will be addressed.
    - — Lambert Targeting (point to point guidance).
    - — Linear Quadratic Targeting (LQT) (closed loop guidance).

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- Problem Formulation
  - Onboard software responsible for unmanned vehicles in the Command and Control Zone (CCZ).
  - CCZ dimensions: 12 km radially, thickness of 8 km
  - The rendezvous maneuver brings the vehicle to a holding point at the edge of the proximity operations zone (POZ).
  - POZ dimensions: 1km sphere centered at the Station.

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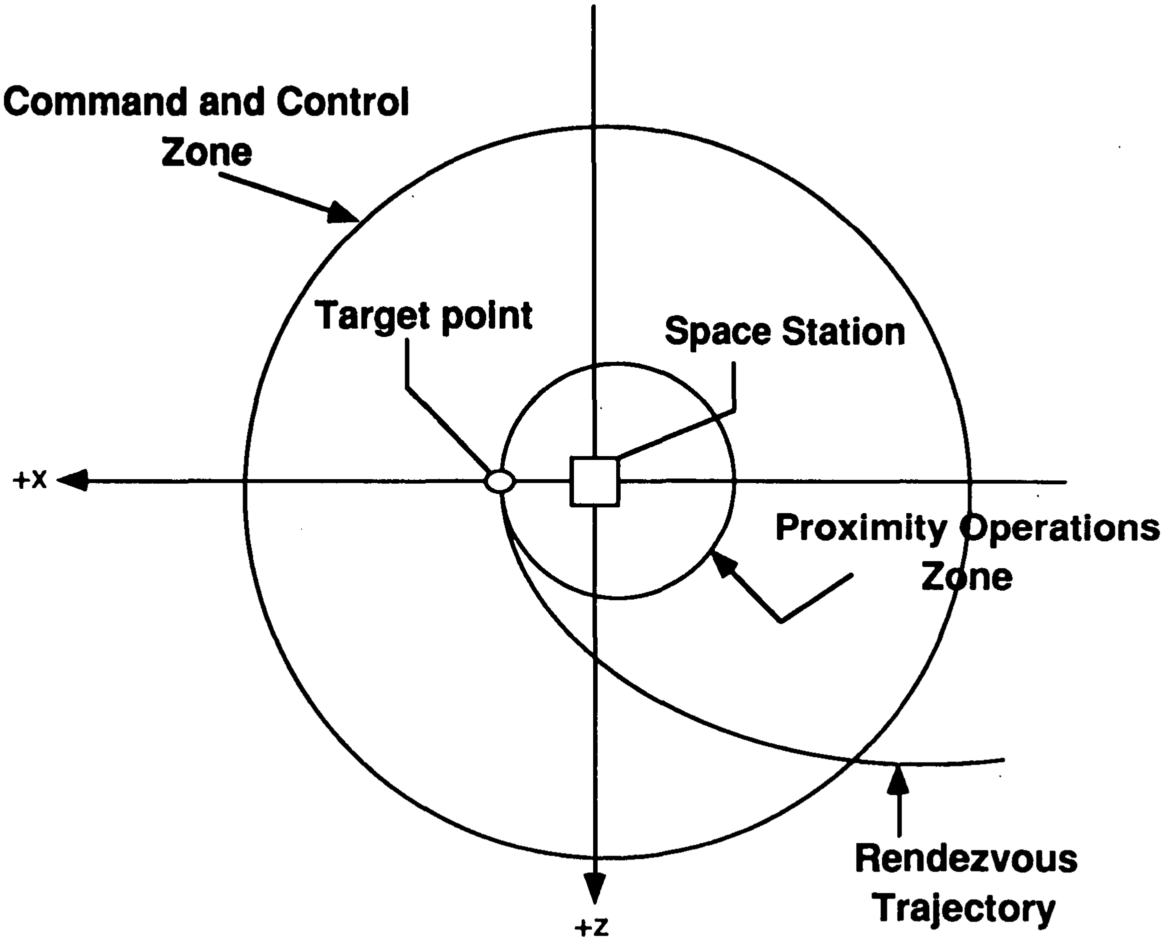
- A generic rendezvous scenario in LVLH coordinates.



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- **Proposed Approaches**
  - **Lambert Targeting Solution**
  - **Relative guidance solves the rendezvous targeting error function for zero.** $\delta(\bar{x})=f_c(\bar{x};t)-f_t(t)=0$
    - $f_t(t)$ **is the target state at the rendezvous time** t, $f_c(\bar{x};t)$ **is the rendezvous vehicle state.**
    - $\bar{x}$ **is the control vector**

      $\bar{x}=\begin{bmatrix}\Delta\bar{V}_1\\ \Delta\bar{V}_2\end{bmatrix}$ **where** $\Delta\bar{V}_1$ **and** $\Delta\bar{V}_2$ **are the impulsive maneuver burns**
    - **The vector prediction function is defined as,** $f(\bar{x};t)=\begin{bmatrix}\bar{R}\\ \bar{V}\end{bmatrix}$ **where as** $\bar{R}$ **and** $\bar{V}$ **are the inertial position and velocity vectors of the vehicle performing the rendezvous at time** t.
    - f **evaluated with a predictor and** $\delta(\bar{x})$ **with Newton's method.**
  - **Lambert Targeting only satisfies the end conditions.**

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- **Proposed Approaches (cont.)**
  - **Linear Quadratic Targeting (LQT) Solution**
  - **The LQT scheme is a closed loop optimal control problem.**
  - **Forces the system to track a desired trajectory over a given time interval.**
  - **Using the Clohessy-Wiltshire equations our system is modelled as:** $x_{k+1} = Ax_k + Bu_k, \quad k > i$ **,with system output being** $y_k = Cx_k$.
  - **It is desired to make the output state follow a desired reference state** r_k **over a time interval** $[0,N]$ **so the cost function can be minimized.**

$$J_i = \frac{1}{2}(y_n - r_n)^T P(y_n - r_n) + \frac{1}{2}\sum_{k=i}^{N-1}\left[(y_k - r_k)^T Q(y_k - r_k) + u_k^T R u_k\right].$$

  - x **is the system state,** u **is the control, and the weighting matrices are** $P \geq 0, Q \geq 0, R > 0$, **with all three being symmetric.**

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- **Proposed Approaches cont.**
  - **The reference trajectory is the desired rendezvous trajectory.**
  - **The weighting matrices, are user specified.**
    - **— P weights the terminal state values, Q weights the state trajectory values, and R weights the control values.**
  - **By manipulating the weighting matrices you can sculpt the resulting trajectory to fit endpoint dispersion constraints, fuel consumption constraints, etc.**
  - **Advantage over Lambert targeting**
    - **— Desired trajectory can be arbitrary. (Can be contrary to orbital dynamics)**

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- Summary
  - Lambert Targeting results in fairly high end-point dispersions .
  - Can reduce dispersions by incorporating mid-course correction burns.
  - Lambert Targeting is bound to orbital dynamics during the coast phase of the maneuver.
  - LQT can significantly reduce endpoint dispersions with little or no additional fuel consumption.
  - LQT can follow any reference trajectory desired regardless of orbital dynamics involved.
  - The LQT weighting matrices must be reinitialized with each new reference trajectory in order to perform optimally.
  - Fuzzy Logic Control has been discussed as being potentially applicable to the rendezvous guidance control.
  - (Opening question for Panel discussion)

    Can Fuzzy Logic control offer any advantages over LQT in computational simplicity, or ability to eliminate weighting matrix reinitialization.

Topic: Path Planning Control
Presenter: Malcolm McRoberts

No notes were taken during this presentation.