Section 22b

Enhanced Formation Flying
(JPL Algorithm)
Abstract

**WHAT:** Flight validation of autonomous navigation/formation flying technology

**WHY:** Formation fly EO-1 with Landsat-7 to obtain co-registered images for EO-1 camera validation

**WHEN:** Launch Nov. 2000, flight validation July-Sept. 2001

**HOW:** Use a simple algorithm that takes advantage of onboard GPS positioning to determine orbital maneuvers needed to maintain orbital formation between EO-1 and Landsat-7
**Formation Flying Description**

Maximum Ground Track Difference Between EO-1 and LS-7 is ±3 km

- **EO-1**
- **LS-7**
- **TDRSS**
- **GPS**

60 ± 6 sec (450 ± 45 km)

No Crosslink

3 km
Autonomous Navigation is defined as autonomously determining and controlling the orbit of a spacecraft

Autonomous formation flying is a type of autonomous navigation

Formation flying involves maintaining the translational and/or rotational states of two or more spacecraft

Benefits of JPL Autonomous Navigation Algorithm:

- Minimal memory and onboard processor requirements (<100kB RAM)
- Simple, Relies on GPS Onboard Navigation Solutions (Position Only):
  - No numerical integration required
  - No navigation (Kalman) filtering required
- Autonomous, Landsat-7 maneuvers are only routine data transmitted to EO-1
- Applicable to many future Earth science missions
- Reduced mission operations ground team effort and size
Autonomous Navigation Elements for JPL Algorithm
Onboard GPS Provides Good Positioning . . . but not Velocity

(TOPEX/Poseidon)
Semimajor Axis Requires Better Velocity Knowledge than Onboard GPS (unfiltered) Can Provide.
Another Way to Get Semimajor Axis (The JPL Algorithm)

\[ \text{Predicted Maneuver Time: Set } \text{LO}_\text{fit} = \text{East Boundary Value} \]
\[ \text{Solve for } t \]
\[ \Delta V = f(m_0, m_1, m_2, \omega_e, a_e V) \]

\[ a = a_0 + \dot{a}(t-t_0) \quad \text{where } \dot{a} = f(m_2) \]
Landsat-7 Altitude Decay is Proportional to that of EO-1

\[
\frac{\dot{a}_{\text{EO-1}}}{\dot{a}_{\text{LS-7}}} = \frac{C_D \frac{A}{m} \rho V^2}{C_D \frac{A}{m} \rho V^2} = \left(\frac{A}{m}\right)_{\text{EO-1}} \left(\frac{A}{m}\right)_{\text{LS-7}}
\]

where:
- \(C_D\) = Coefficient of Drag
- \(A\) = Area
- \(m\) = mass
- \(r\) = Atmospheric Density
- \(V\) = Circular Velocity
Conclusions

- **Ground validations are complete using GPS telemetry data**
- **Flight validations will begin on July 18, 2001**
- **Benefits of autonomous navigation**
  - Ground tracking network for navigation not required
  - Reduces mission operations ground team effort and size
  - Applicable to many future Earth science missions
- **Benefits of the JPL algorithm:**
  - Minimal memory and onboard processor requirements (<100kB RAM)
  - Simple, Relies on GPS Onboard Navigation Solutions (Position Only):
    - No numerical integration required
    - No navigation (Kalman) filtering required
  - Autonomous, Landsat-7 maneuvers are only routine data transmitted to EO-1