Position and Attitude Determination in Space with Autonomous Formation Flyer (AFF)

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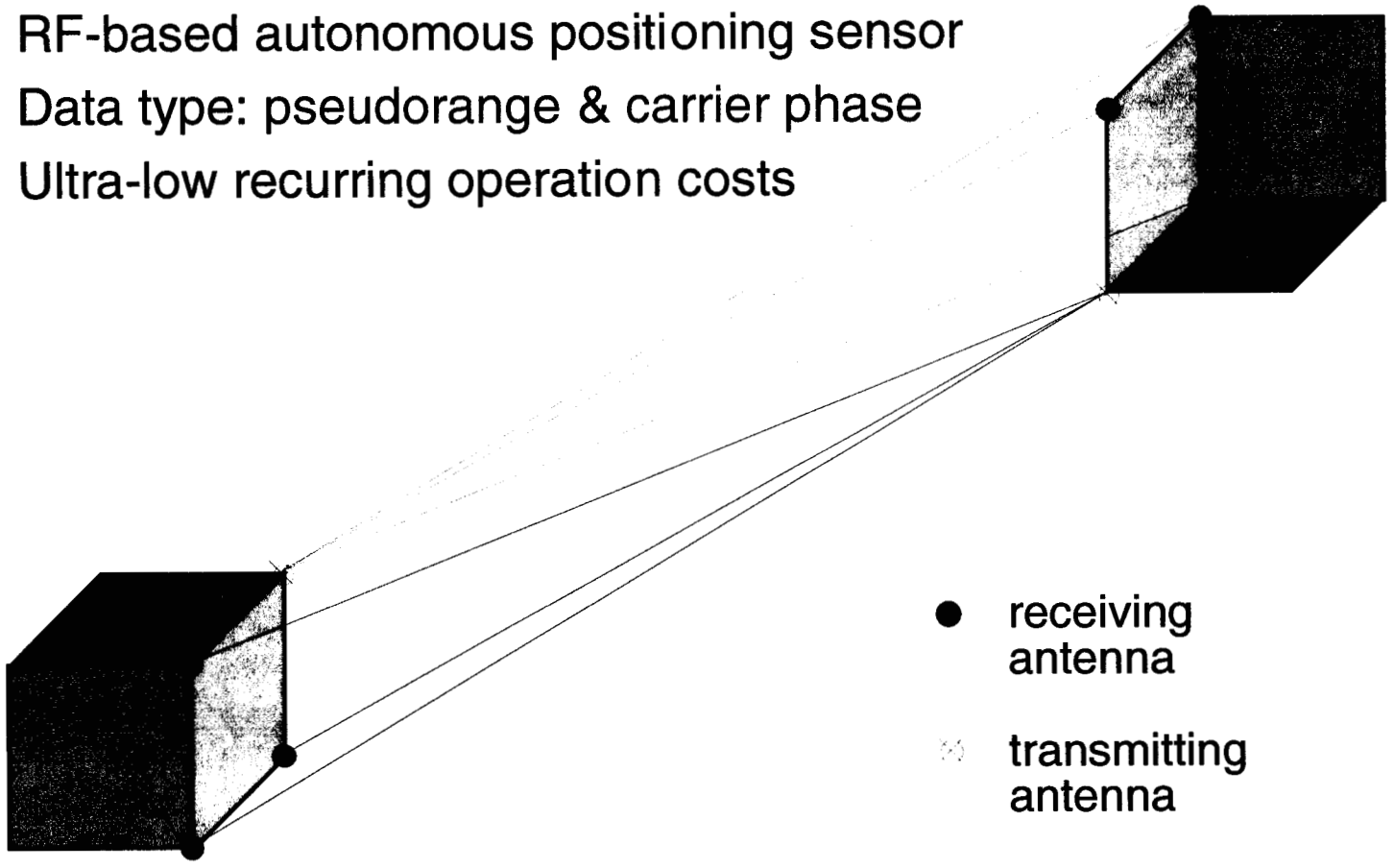
Autonomous Formation Flyer (AFF)

- RF-based autonomous positioning sensor
- Data type: pseudorange & carrier phase
- Ultra-low recurring operation costs



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Space Technology 3 (ST-3)

- Proposed mission under NASA's New Millennium Program
- 2005 Launch
- Demonstrate technology for precise space interferometry
- 2 spacecraft in heliocentric orbit in formation
- Observe over 100+ galactic optical sources in 3 months

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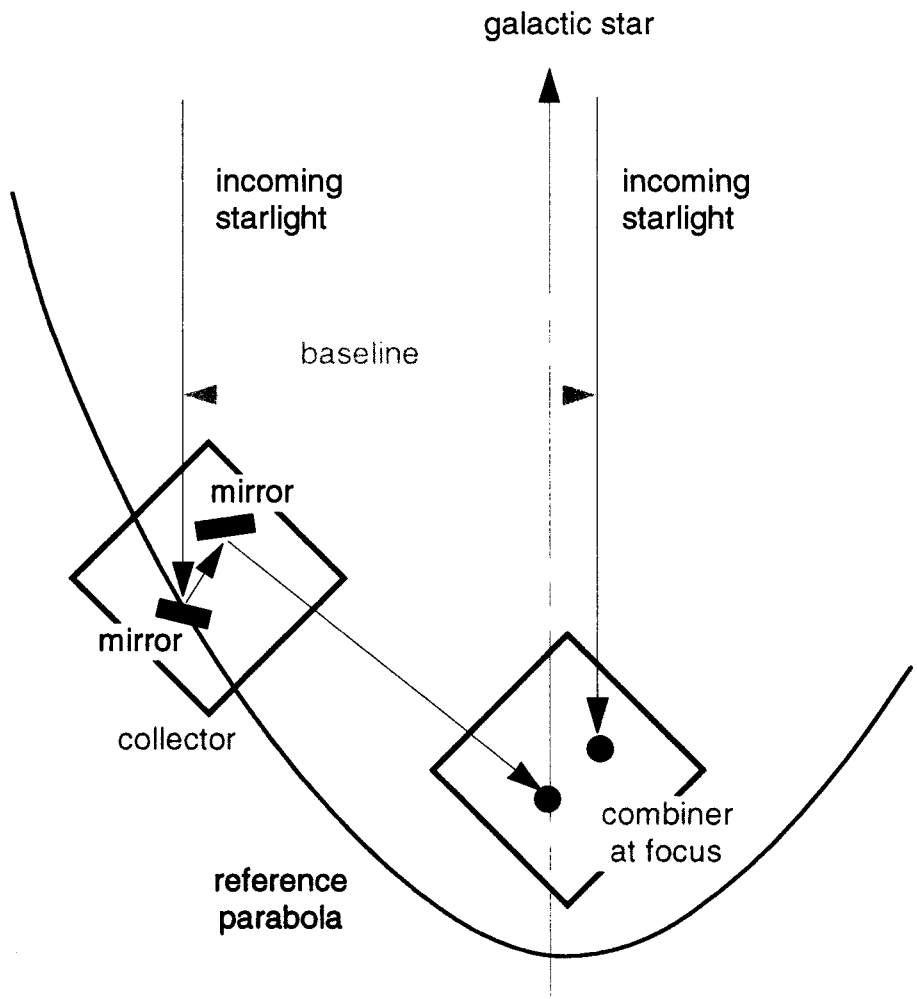
ST-3 Formation Flying



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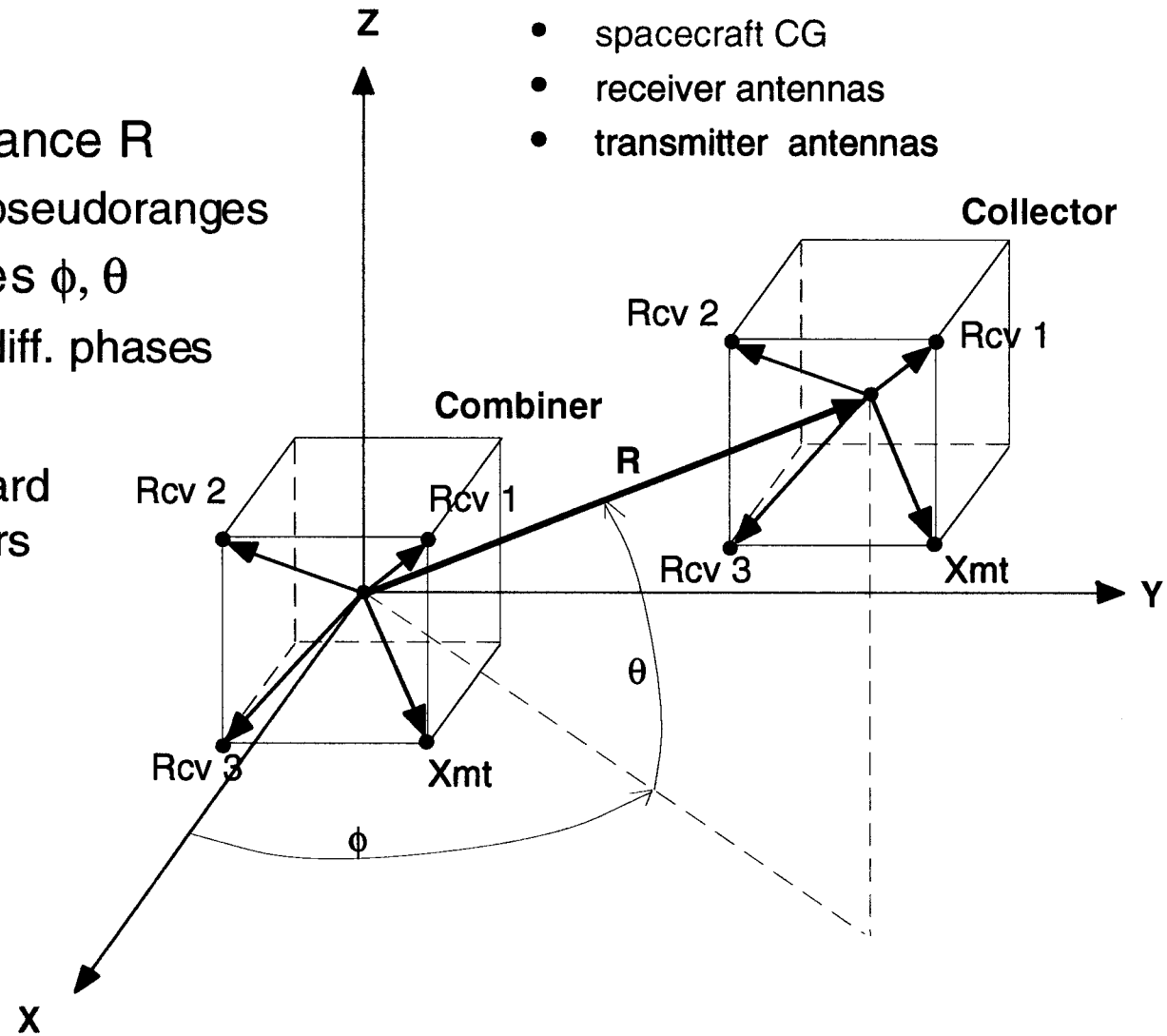
2-S/C AFF System (ST-3)

- Inter-S/C distance R
  - from AFF pseudoranges
- Bearing angles ϕ, θ
  - from AFF diff. phases
- S/C attitudes
  - from onboard star trackers



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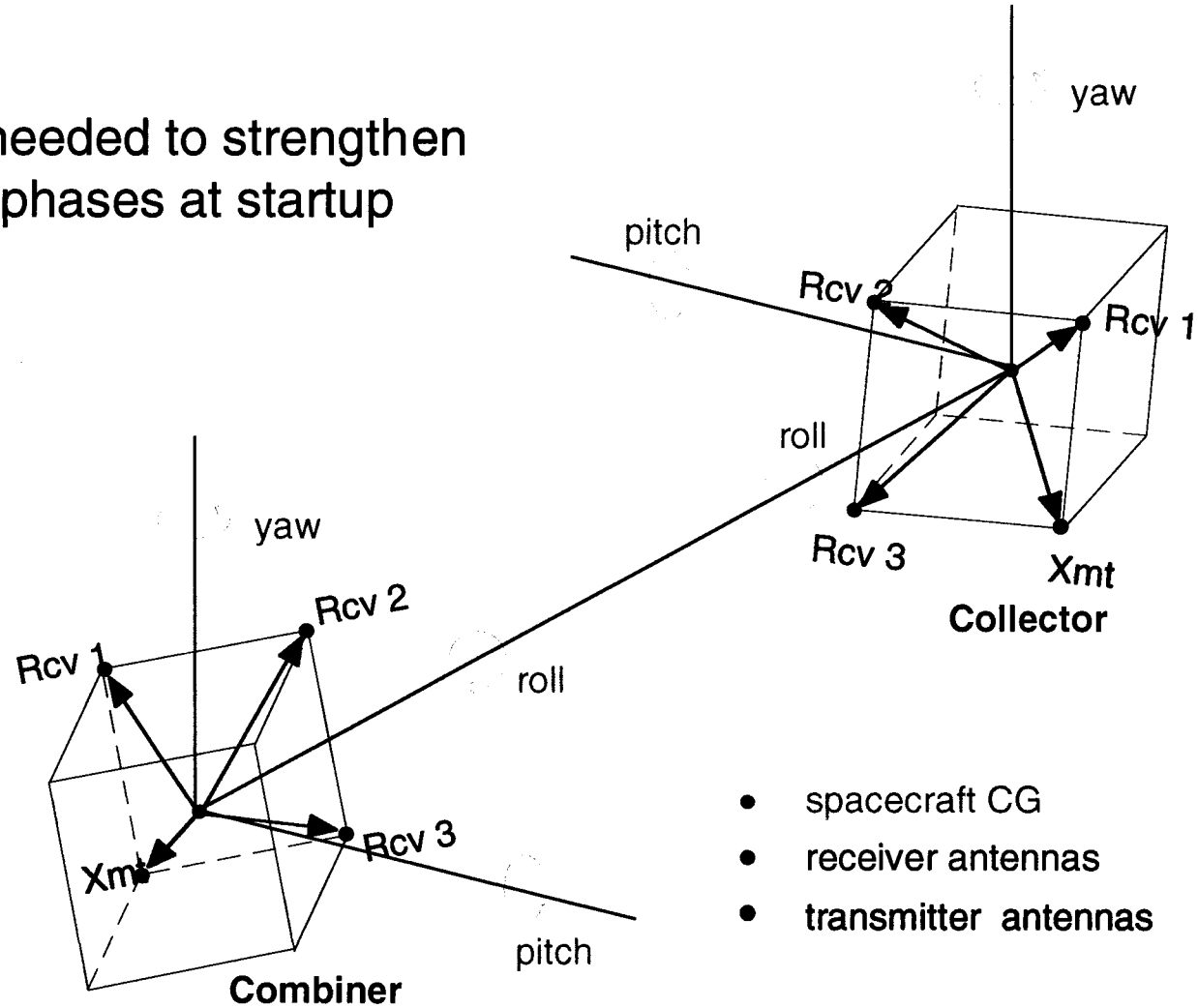
Spacecraft Relative Rotations

- Rotations needed to strengthen differential phases at startup



- spacecraft CG
- receiver antennas
- transmitter antennas

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Estimated Parameters

Parameter	a priori σ	Model	Constraints
R	2 km	random-walk	100 m/sec$^{1/2}$
ϕ, θ	0.5 rad	random-walk	0.05 rad/sec$^{1/2}$
Δt	∞	white-noise	—
B (total of 2)	∞	white-noise	—
ΔB (total of 4)	1 m	bias	constant

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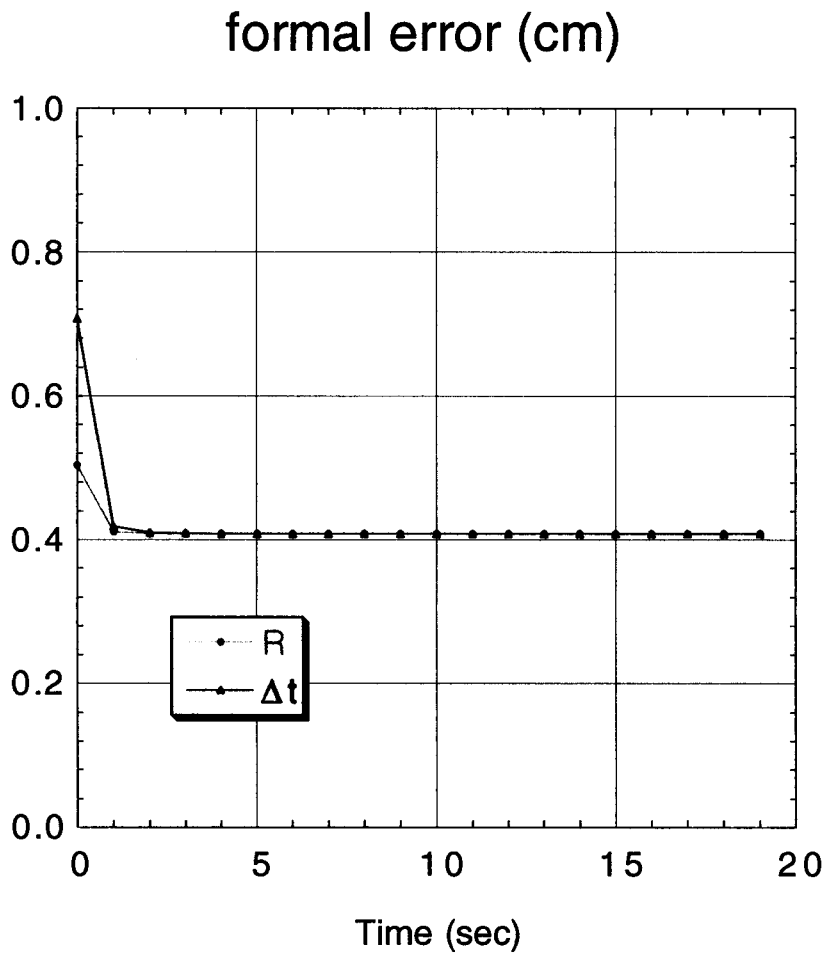
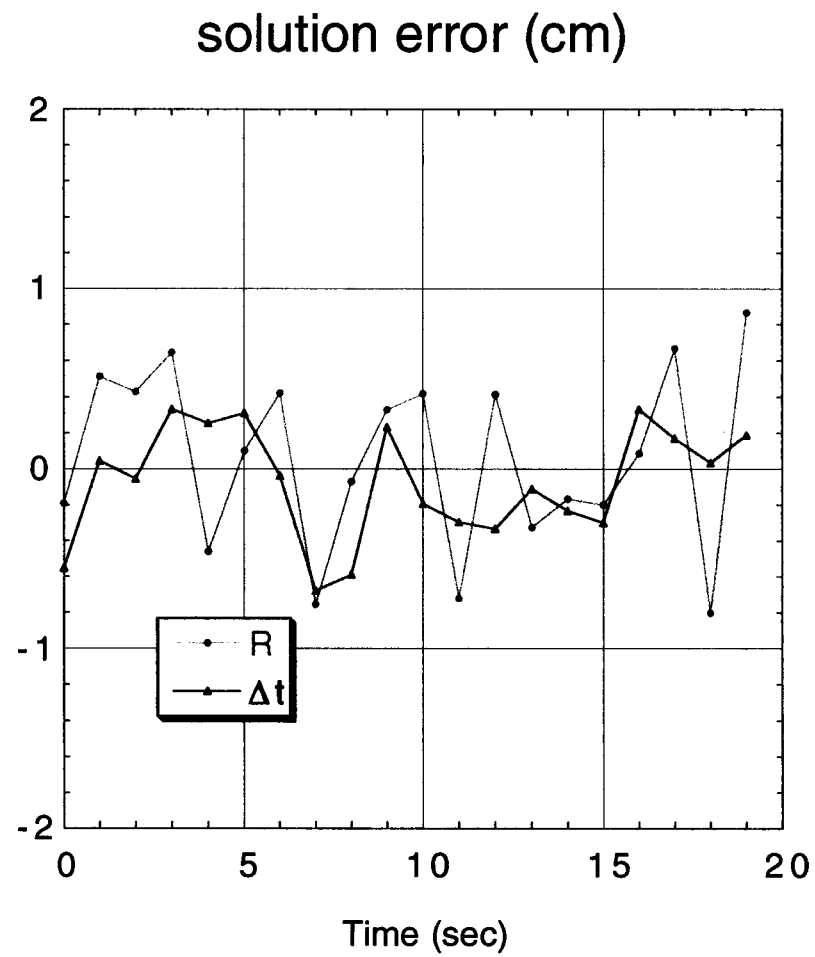
Simulation Analysis Assumptions

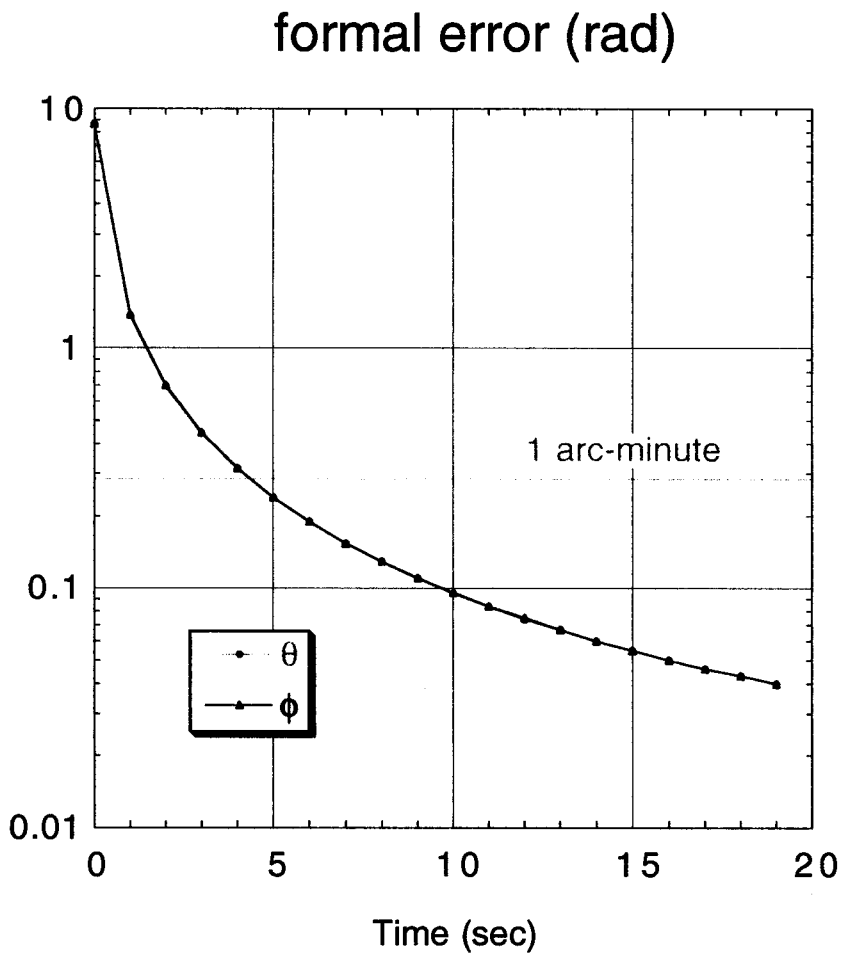
- Data span: 20 epochs
- Data interval: 1 sec
- Data noise: 1 cm pseudorange
  10 μm carrier phase
- Parameter deviations from truth:
  - R 1 km
  - (ϕ, θ) (-0.2, 0.5) radian
- Relative S/C rotation: 0.02 rad/epoch
  (in ΔRoll only)

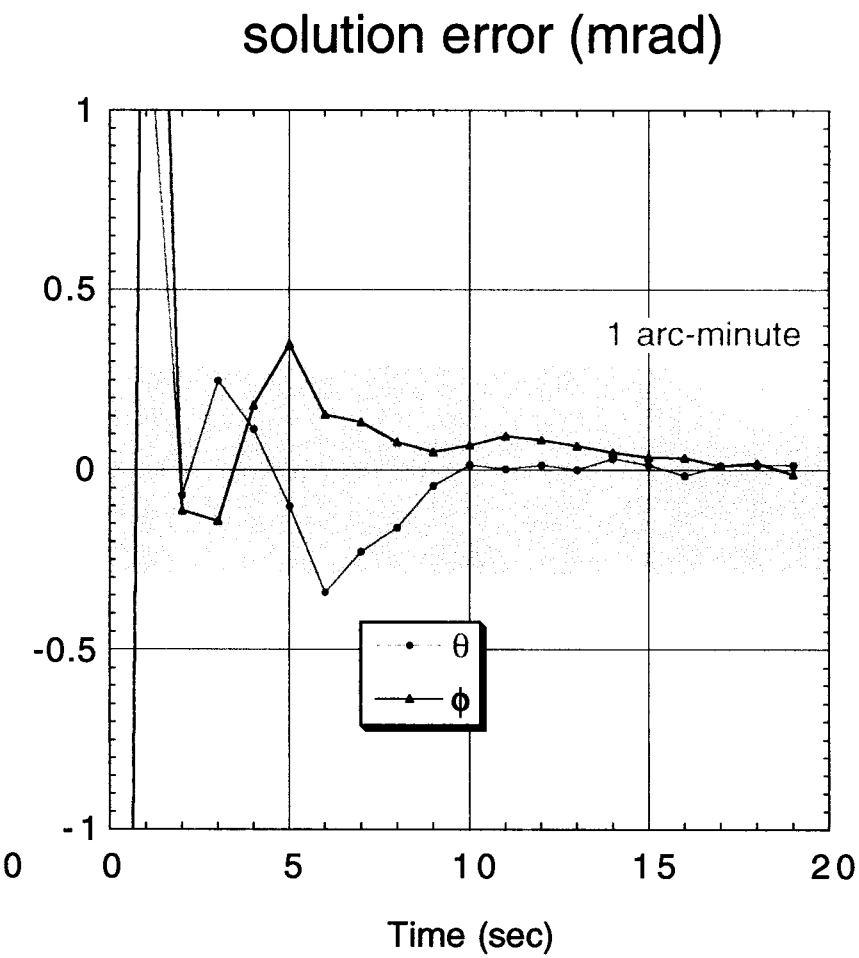
Formal Error and Actual Solution Error for R and Δt





Formal Error and Actual Solution Error for θ and ϕ

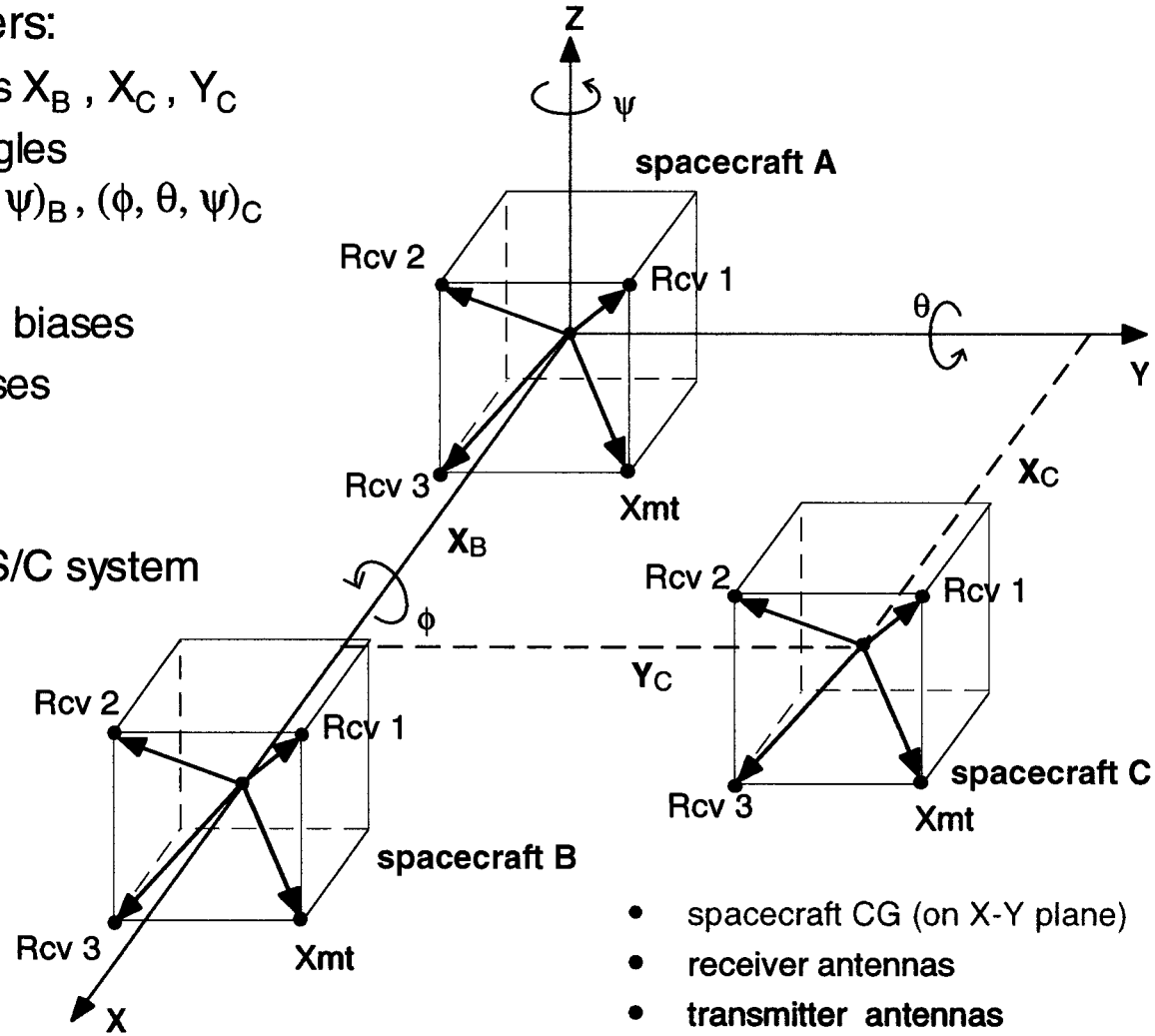




3-Spacecraft AFF System

- Estimated parameters:
  - 3 S/C coordinates X_B , X_C , Y_C
  - 9 S/C attitude angles
    $(\phi, \theta, \psi)_A$, $(\phi, \theta, \psi)_B$, $(\phi, \theta, \psi)_C$
  - 2 clock offsets
  - 6 common phase biases
  - 12 diff. phase biases

- Expected accuracy:
  - comparable to 2-S/C system



- spacecraft CG (on X-Y plane)
- receiver antennas
- transmitter antennas

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Summary

- ST-3 positioning accuracy with AFF:
  - relative ΔRoll rotation essential at startup
  - < 5 mm inter-S/C distance (R)
  - < 1 arc-min bearing angles (ϕ, θ)

- AFF future applications:
  - Mars infrastructure
    real-time positioning with single snapshot of range and angle measurements
  - Formation flyers
    planet finders, planet imagers, space interferometers