Jet Propulsion Laboratory
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A New Method for Asteroid Impact Monitoring and Hazard Assessment

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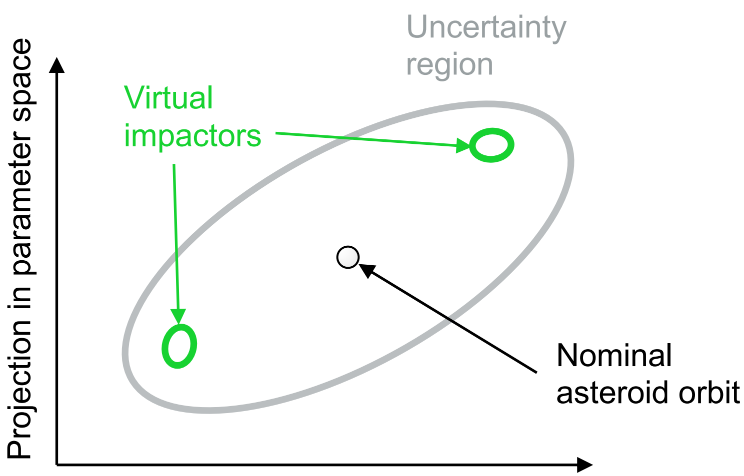
Introduction

Motivation for a new impact monitoring algorithm

Goal of Impact Monitoring

Identify and characterize all virtual impactors (VIs) compatible with the orbital uncertainty distribution.

VI: region in parameter space leading to impacts along the same dynamical path.*



Challenges

1. Many VIs that must be separated.
2. Impact probabilities (IP) are usually small (~10^{-7}).
3. Nongravitational parameters must be handled automatically.
4. Pathological cases (Earth-like orbits, nonlinearities).

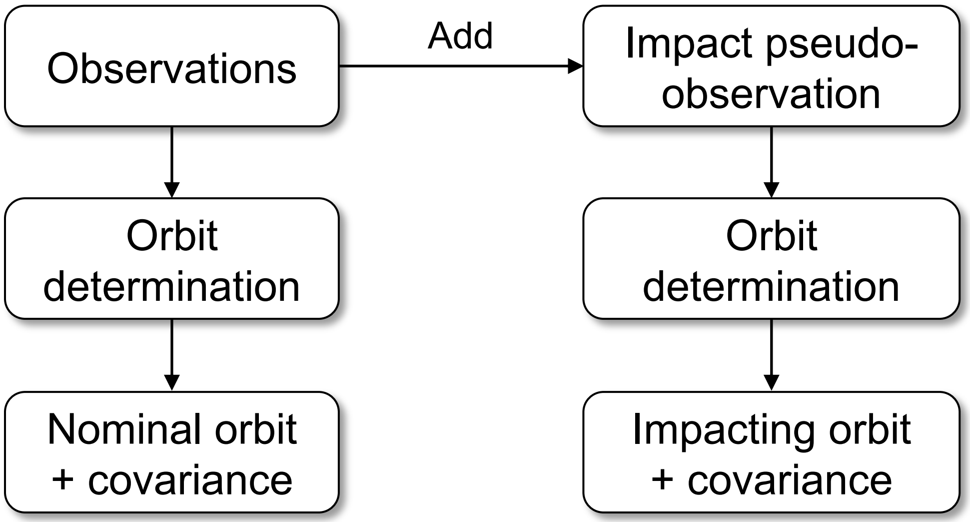
- **Monte Carlo:**
  1.✗ 2.✗ 3.✓ 4.✓
- **Line of Variations (LOV):***
  1.✓ 2.✓ 3.✗ 4.✗

Increased rate of NEA discoveries calls for a more robust method

*Milani, A. et al. (2005): "Nonlinear impact monitoring: line of variation searches for impactors," Icarus, 173, 362-384

Impact Pseudo-Observation I

Finding VIs using an orbit-determination program



Impact pseudo-observation

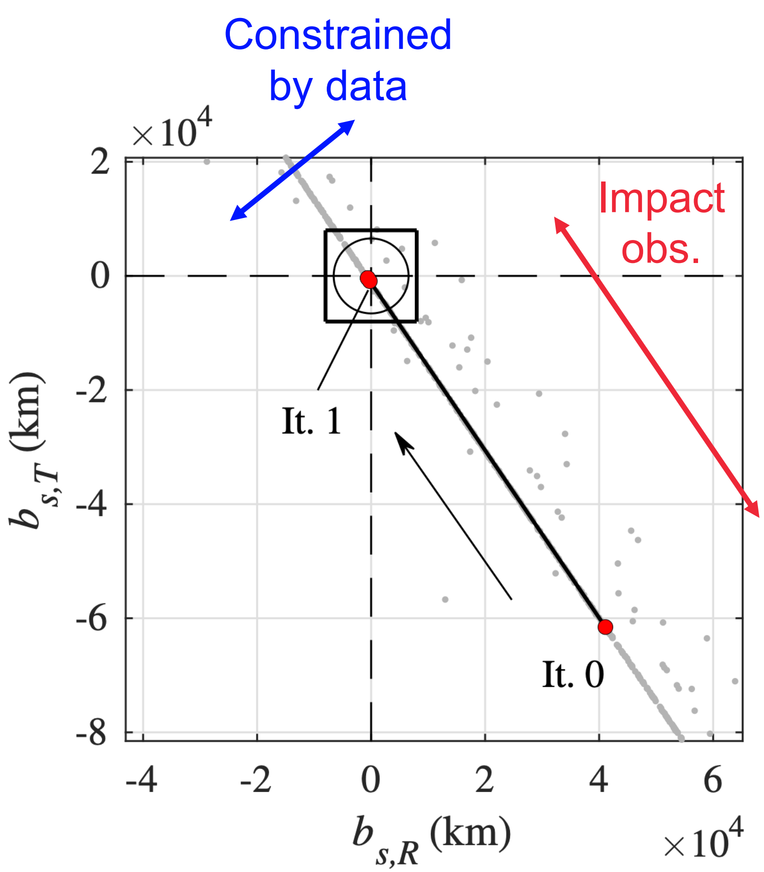
Add the impact condition as an observation:

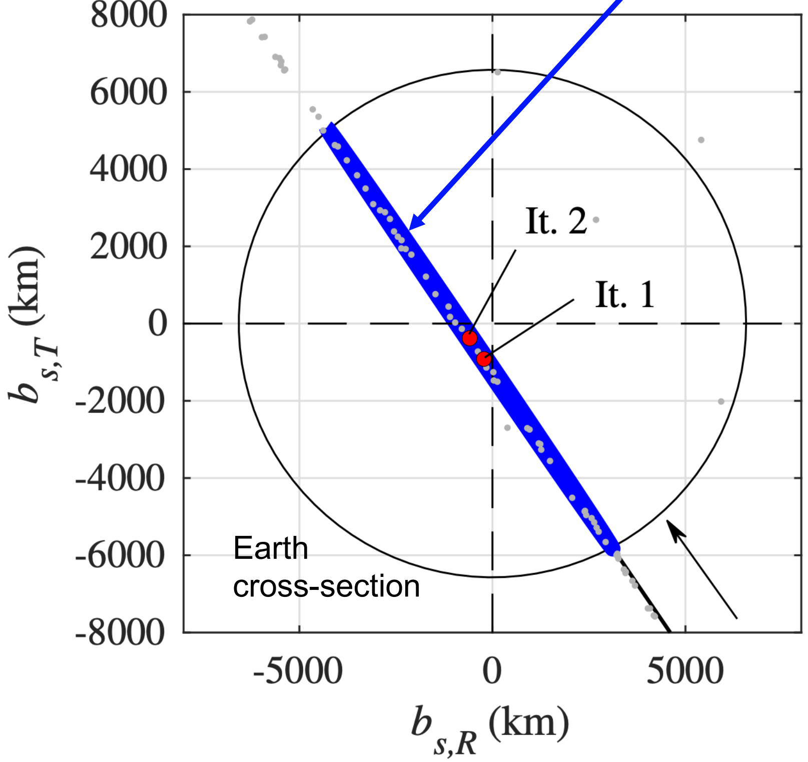
- The residuals are the B-plane coordinates at the time of close approach.
- The uncertainty is a fraction of the Earth radius.

- No simplifying assumptions about the dynamics or the uncertainty distribution in parameter space.
- The covariance of the fit approximately models the VI in parameter space.
- Use the same operational OD program used to produce the nominal orbit.

Impact Pseudo-Observation II

Finding VIs using an orbit-determination program





Sentry-II

A new automatic impact-monitoring system at JPL

Operation of Sentry-II

1. **Initial MC exploration**: detect close approaches for further investigation.
2. **Find VIs**: run OD filter extended with the impact pseudo-observation.
3. **Characterize the VIs**: use importance sampling to estimate the IP.

Features and Comparison with Sentry (LOV based)

- Sentry-II has been running and mirroring Sentry for a few months.
- Sentry-II handles nongravitational parameters systematically.
- More robust in pathological cases.
- Median runtimes for 100-year exploration and IP down to 10^{-7}:
    - Monte Carlo: 14 days (20,000 min)
    - Sentry: 20 min
    - Sentry-II: 40 min
- Sentry-II provides the nominal orbit and the uncertainty of each VI
  $\Longrightarrow$ useful for negative observation campaigns.

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