Jet Propulsion Laboratory

Space Navigation -- Recent Advancements & Emerging Trends

Deep Space Navigation
Performance
Challenges
Solutions
Collaboration

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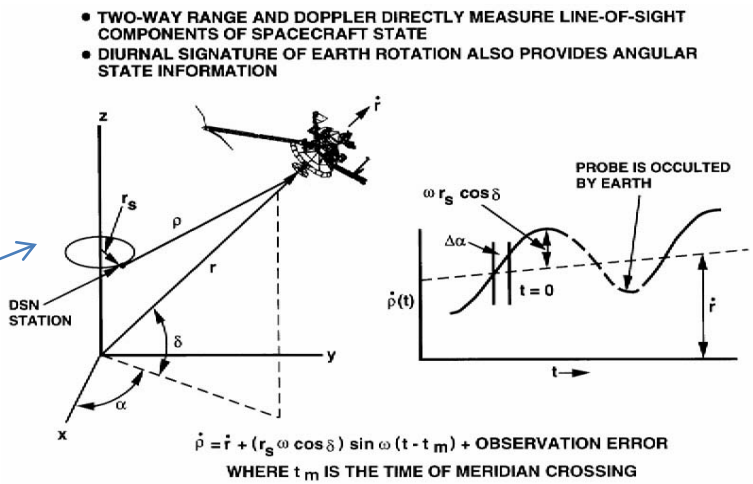
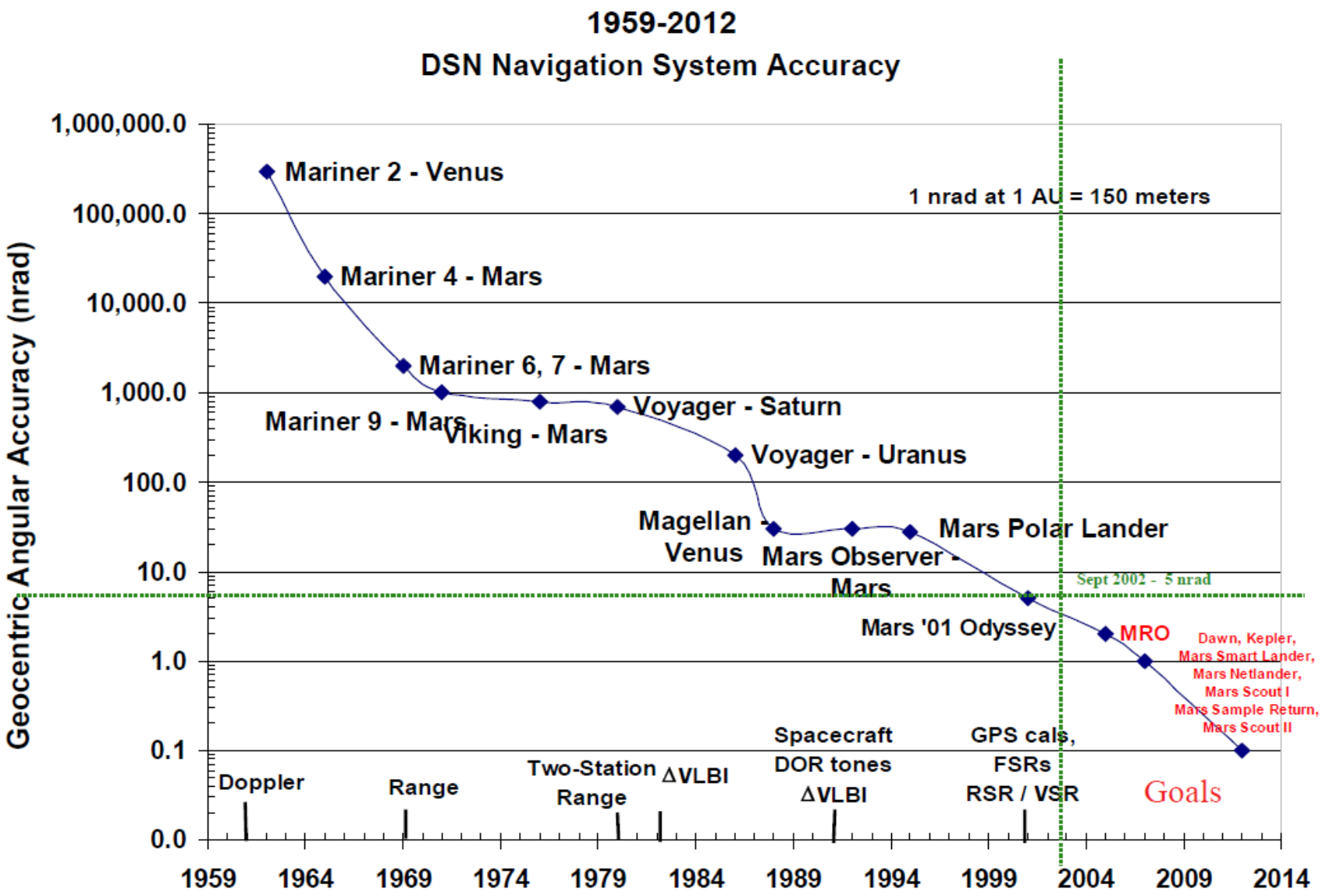
Deep Space Navigation

- 'Deep Space' – why the distinction from Earth Orbit Navigation?
- Characteristics of Earth Orbit Navigation
  - Dedicated spaceborne assets available (e.g. GPS/GLONASS/etc., TDRSS)
  - Geometrically rich data, almost always available
    - GPS receiver can provide real-time position solutions at rates > 1 Hz
    - Can use this or raw observations to compute position and velocity of spacecraft
  - Coverage global in low Earth orbit, can be used out to Geosynchronous orbit and beyond
- Characteristics of Deep Space Navigation
  - Primarily done with radiometric data collected from large ground-based antennas
  - Geometrically poor, sometimes sparse data which provide only single dimensional measurements to infer multi-dimensional state
  - Long round-trip light times require either good predictions (precise measurement and dynamics modeling) or on-board control and sometimes both

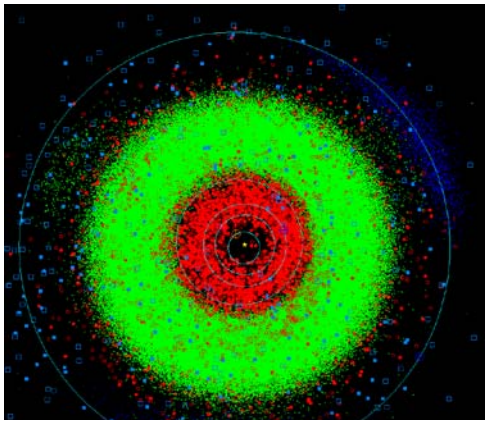


Historical Performance

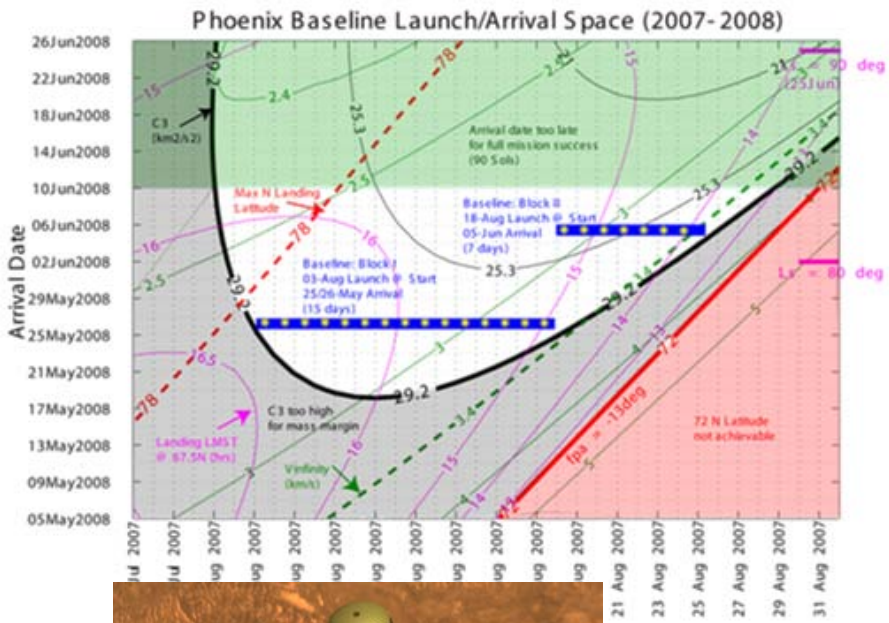


Deep Space Navigation Challenges

- Need for Good Maps
  - Mission Design with little *a priori* environment information (mass, shape, spin direction, etc.)

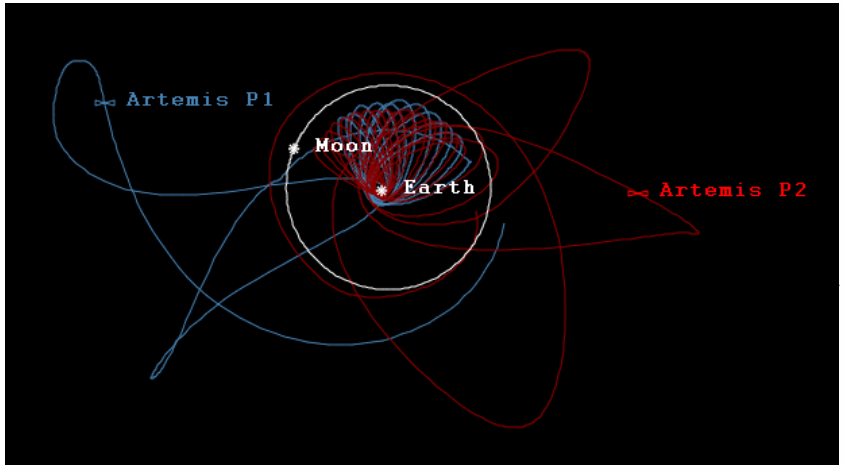


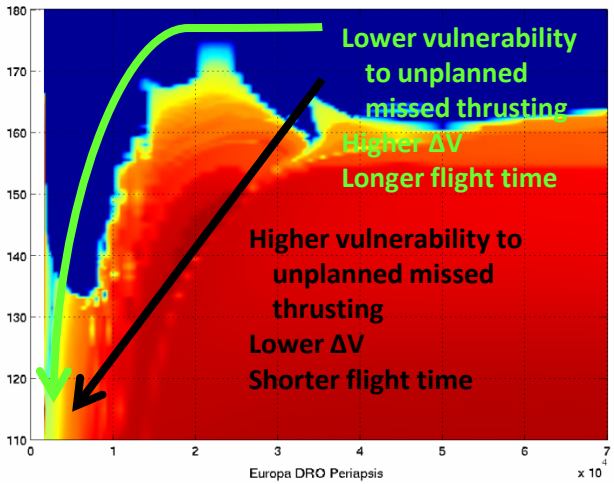
- Route Planning
  - Increasingly complex arena for new mission/trajectory designs



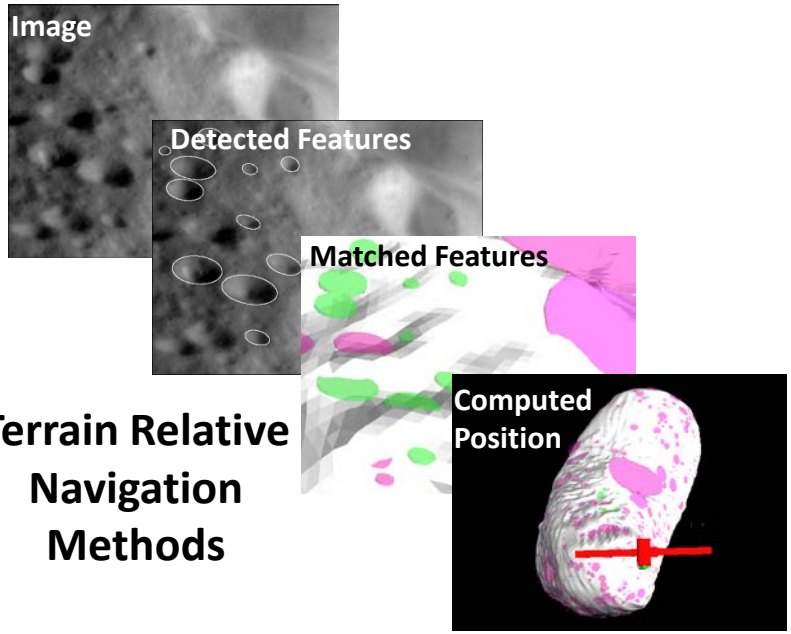
- Navigation to/from Targeted Points
  - Stronger integration of flight path control, attitude control, and structural dynamics
  - Increasing need for on-board autonomy, decentralized ops.
  - Incorporation of new capabilities

Examples of Deep Space Navigation Technical Solutions



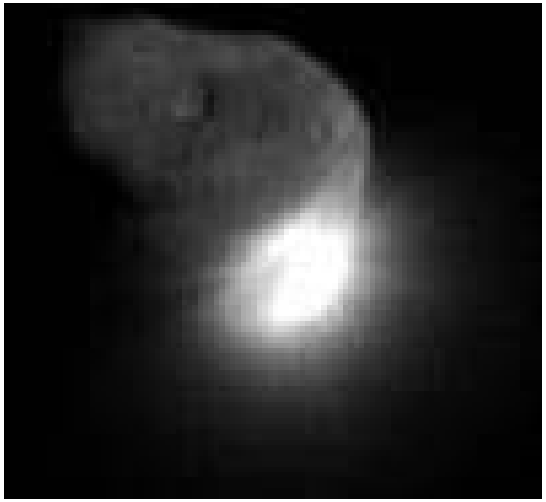


Low-Energy, Low Thrust Trajectory Sensitivity Analyses



Terrain Relative Navigation Methods

On-Board Navigation



Deep Space Navigation Technical Solutions (cont.)

- Collaboration is an important component of Deep Space Navigation
  - Sharing of tracking resources can enhance navigation performance, robustness
    - Common interfaces (CCSDS), processes facilitate this
  - Cross-checking ('Shadow Navigation') of navigation calculations can provide independent cross-verification and validation. This requires
    - Technical Interchange Meetings
    - Shared test cases
    - Rehearsals, Operations co-location
- Collaboration has increased over the past decade and is expected to continue into the future
  - Coordination of assets *in situ*
    - Comm support for arriving spacecraft
    - Collision avoidance
  - Coordination of Earth-assets
    - Shared-baseline Delta-DOR
  - Other possible trends: more sophisticated exchange interfaces, software
- The International Symposium on Space Flight Dynamics (ISSFD) helps foster collaboration efforts in areas including Deep Space Navigation
  - 22nd ISSFD: March 1st – 5th, 2011, São José dos Campos, Brazil (org. by INPE)
  - 23rd ISSFD: 2012, Pasadena, CA, USA (org. by NASA/JPL)

Questions?