SECOND GENERATION AUTONOMOUS OPTICAL NAVIGATION SYSTEM

S. Synnott

December 6, 2001
Deep Space 1 Autonomous Navigation

Ed Riedel, Shyam Bhaskaran, Don Han, Brian Kennedy, Steve Synnott, Mike Wang, Robert Werner
Jet Propulsion Laboratory
California Institute of Technology
Performance of AutoNav on Approach to Braille

Flight OD vs. Ground Radio OD 7/21/99

Position error (km)

Velocity error (m/s)

1999 DOY

9/23/99 - JER12
AUTONOMOUS OPTICAL NAVIGATION

"REQUIREMENTS" FOR SECOND GENERATION SYSTEM
(BEYOND DS1 DEMO)

- POINTABLE CAMERA (GIMBAL-MOUNTED CAMERA)

- CAMERA SENSITIVE TO 11th MAG OBJECTS

- LESS AUTONAV-GROUND TEAM INTERACTION
  (2.0 PEOPLE TO LESS THAN 0.5)

- AUTONAV COMPUTER
AUTONOMOUS OPTICAL NAVIGATION

COMPARISON OF NEW SYSTEM TO DS1

• CAMERA AND DETECTOR
  - 5 cm APERTURE vs 10 cm DS1
  - HALF THE RESOLUTION BUT
    • 10 TIMES THE SENSITIVITY, AND
    • 10 TIMES SMALLER GEOMETRIC DISTORTION

• 24 mrad (1.4° FOV) vs 13 mrad (0.75° FOV)

• NEGLIGIBLE PATTERN NOISE vs 50 e− FOR DS1

• NEGLIGIBLE SCATTERED LIGHT vs HUNDREDS TO THOUSANDS OF e− FOR DS1

• NOISE OF NEW SYSTEM ≤ 20e−
AUTONOMOUS OPTICAL NAVIGATION
DATA PROCESSING

- IMAGE PROCESSING
  - AUTONOMOUSLY DETECTING OBJECTS IN FOV
  - CENTROIDING IMAGES OF STARS AND BEACONS

- TRAJECTORY AND PARTIAL INTEGRATION

- TRAJECTORY ESTIMATION (FIT IMAGE LOCATION DATA)

- DATA EVALUATION/REJECTION

- MANEUVER COMPUTATION
AUTONOMOUS OPTICAL NAVIGATION
DATA EVALUATION AND
ERROR "TRAPPING"

• COMPARISON OF IMAGE BRIGHTNESSES TO APRIORI
  EXPECTATIONS

• COMPARISON OF RESIDUALS IN ~10 FRAMES TAKEN WITHIN
  MINUTES OF EACH OTHER

• COMPARISON OF LOCAL TRIANGULATION ESTIMATES USING
  PAIRWISE WIDE ANGLE BEACON LINES-OF-SIGHT

• EVALUATION OF POST FIT RESIDUALS FROM TRAJECTORY
  ESTIMATION PROCESS
AUTONOMOUS OPTICAL NAVIGATION
AUTONOMOUS OBSERVATION PLANNING

• INPUTS
  – FILES OF BEACON ASTEROIDS/PLANETS’ EPHEMERIDES
  – STAR CATALOG
  – SPACECRAFT TRAJECTORY

• OBSERVATION PLANNING ACQUISITION
  – AT ANY TIME, SAMPLE BEACON POSITIONS FOR
    SUITABLE STAR BACKGROUNDS, SUN CONSTRAINTS,
    S/C CONSTRAINTS
  – TEST FOR LOCAL ORBIT DETERMINATION “STRENGTH” –
    EX: ORTHOGONAL LINES-OF-SIGHT
  – COMMAND GIMBAL POINTING AND CAMERA EXPOSURE