MARS GLOBAL SURVEYOR

Mapping Orbit

D. J. CASEY

INTRODUCTION

- MAPPING ORBIT REQUIREMENTS
  - LOW-ALTITUDE - RESOLUTION, ACTIVE INSTRUMENT POWER
  - NEAR-CIRCULAR - UNIFORM HEIGHT OVER SURFACE
  - NEAR-POLAR - GLOBAL COVERAGE
  - SUN-SYNCHRONOUS - UNIFORM ILLUMINATION, CONSTANT LOCAL TIME
  - "SHORT" REPEAT CYCLE - FREQUENT REVISITS
- BASELINE
  - 378 KM INDEX ALTITUDE, 2 P.M. DESCENDING NODE
  - 6917 REVS IN 550 DAYS - 7 DAY NEAR REPEAT
  - FROZEN - ELEMENTS CHOSEN SO PERIAPSIS IS "FIXED"
- CURRENT EFFORT
  - UPDATE MAPPING ORBIT USING Mars50c GRAVITY MODEL
    - Konopliv and Sjogren, FEBRUARY 1995
    - BASED ON VIKING AND MARINER 9 DOPPLER TRACKING DATA
    - SIMILAR TO GMM-1 ("Goddard-Smith")
      - BETTER PEAK VALUES FOR VOLCANOES
      - LIKELY OVERESTIMATE OF C_{21} AND S_{21} DUE TO MARINER 9 GAS LEAKS
  - BEGIN LOOSE LONGITUDE CONTROL STUDIES

REPEAT ORBITS

- DESIGNED SO THE ORBITER COMPLETES *R* ORBITS WHILE THE BODY (PLANET) COMPLETES *D* REVOLUTIONS
- $Q = R / D$, COMPLETELY DETERMINES THE GROUND TRACK SPACING AND PATTERN AT THE EQUATOR
  - $S = 360° / Q$ = SEPARATION OF SUCCESSIVE GROUND TRACKS
  - $S_i = S / D$ = SEPARATION OF ADJACENT GROUND TRACKS AT END OF CYCLE
- NODAL PERIOD $P_n = f(a,e,i,J_2)$ FOUND SUCH THAT THE LONGITUDE CHANGE DURING ONE REV EQUALS *S*

  $P_n * (\Theta_{DOT} - \Omega_{DOT}) = S$

  WHERE Θ_{DOT} IS THE PLANET ROTATION RATE, $\Omega_{DOT} = f(a,e,i,J_2)$ IS THE "NODAL REGRESSION" DUE TO OBLATENESS, J_2 IS A COEFFICIENT DESCRIBING MAGNITUDE OF OBLATENESS EFFECTS
- MGS REPEAT CYCLE *Q* IS 6917 / 550 = 12.576, *S* IS 28.625°, S_i IS 3.1 KM
  - $Q \approx 25 / 2 = 12.5$, SO IS A 2 DAY "NEAR REPEAT ORBIT"
    - OFFSET OR WALK IS $R_{near} * S_{nominal}$ mod 360° = -4.37° = -260 KM (EAST)
  - $Q \approx 88 / 7 = 12.571$ —> 7 DAY NEAR REPEAT, WALK IS 58.6 KM EAST
  - $Q \approx 327 / 26 = 12.577$ —> 26 DAY NEAR REPEAT, 24.7 KM WEST WALK

FROZEN ORBITS

- OBLATENESS CAUSES SECULAR (LINEAR IN TIME) CHANGE IN PERIAPSIS LOCATION ("APSIDAL ROTATION")
- CAN "FREEZE" PERIAPSIS USING OTHER PERTURBATIONS
  - J_3 DESCRIBES HOW "PEAR-SHAPED" A BODY IS
  - FREEZE PERIAPSIS BY PUTTING J_3 TO WORK AGAINST J_2
  - LONG-PERIOD PERTURBATION ON ECCENTRICITY e DUE TO J_3 IS MINIMIZED WITH ARGUMENT OF PERIAPSIS ω OF $\pm 90°$
  - a, e, AND i CHOSEN SO SECULAR CHANGE IN ω DUE TO J_2 IS OFFSET BY LONG-PERIOD PERTURBATION IN ω DUE TO J_3
    - SIGN OF J_3 DETERMINES IF ω IS 90° or -90°
      - AT MARS, ω IS -90° (NEAR THE SOUTH POLE) - EARTH IS NORTH POLE
- HIGHER DEGREE ZONAL FIELDS CAN BE ACCOMODATED
  - ODD J's VS. EVEN J's. VARIATION IN ω IS GREATER (LESS FROZEN)
- DETAILED FIELD, INCLUDING TERMS DEPENDENT ON BOTH LATITUDE AND LONGITUDE
  - GENERAL ZONAL BEHAVIOR, WITH MANY PERIODIC FLUCTUATIONS OVERLAID

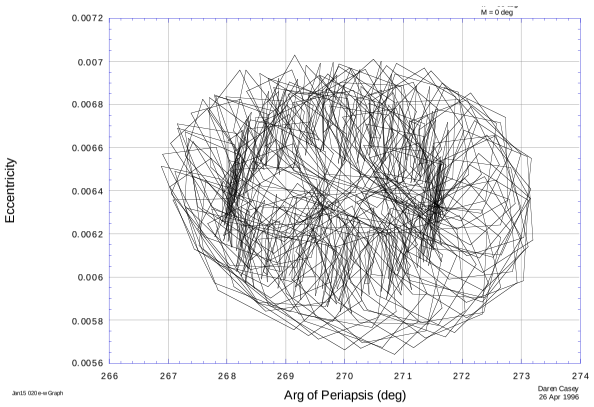
DESIGN PROCEDURE

- DIFFERENTIAL CORRECTION METHOD OF CESARONE AND BASS
  - 3 TARGET QUANTITIES
    - DESCENDING NODE TIME AT A SPECIFIED REV (USE IDEAL P_n)
    - DESCENDING NODE LONGITUDE AT SAME REV (USE IDEAL $S = 360° / Q$)
    - VARIATION IN ARGUMENT OF PERIAPSIS: MAX OF $| \omega - \omega_{mean} |$
  - 3 CONTROLS
    - a, SEMIMAJOR AXIS
    - e, ECCENTRICITY
    - i, INCLINATION
  - GENERATE 4 TRAJECTORIES AND EXTRACT NODE/PERIAPSIS DATA
    - REFERENCE INITIAL STATE (a_o, e_o, i_o, Ω_o, ω_o, M_o)
    - 3 NEW STATES: $a = a_o + \delta a$, $e = e_o + \delta e$, $i = i_o + \delta i$
  - FORM 3x3 MATRIX OF PARTIAL DERIVATIVES, THE CHANGE IN 3 TARGET QUANTITIES FOR SMALL CHANGES IN THE 3 CONTROLS
  - SOLVE MATRIX EQUATION TO GIVE NEW STATE FOR NEXT ITERATION
    - EXAMPLE: ACTUAL NODE TIME VS. IDEAL NODE TIME, t_{err}

      $t_{err} + (\Delta t / \delta a)\, \Delta a_o + (\Delta t / \delta e)\, \Delta e_o + (\Delta t / \delta i)\, \Delta i_o = 0$ —> new a_o = old $a_o + \Delta a_o$...

DESIGN PROCEDURE

- FROZEN CONDITION CHECKED BY EXAMINING ECCENTRICITY VS. ARGUMENT OF PERIAPSIS (e-ω PLOT)



- AFTER SEVERAL ITERATIONS, PROCESS WAFFLES BETWEEN TWO "GOOD" ECCENTRICITIES
  - DUE TO CYCLIC BEHAVIOR IN e-ω PLOT, TWO ECCENTRICITIES EXIST FOR A GIVEN ω
- LARGE Δe CAUSES UNDESIRABLE CHANGES IN a AND i
  - ONCE ORBIT IS AS FROZEN AS POSSIBLE, KEEP e FIXED AND VARY a AND i, USE ONLY NODE TIME AND LONGITUDE AS TARGETS (2x2)

RESULTS

15-Jan-1998 01:00 ET, RAN 328.193°, LAN 0.81° - TARGET NODE IS #655

- J2 + J3
  - a = 3766.170577180714 km (mean*: 3775.148)
  - e = 0.004086631297563429 (mean: 0.00727)
  - i = 92.87209423418787° (mean: 92.869)
  - $\Delta w \approx \pm 0.00002°$
- 8 x 8
  - a = 3765.888412078945 km (mean: 3774.898)
  - e = 0.004993582036164781 (mean: 0.00818)
  - i = 92.96686308080749° (mean: 92.963)
  - $\Delta w \approx \pm 2°$
- 50 x 50
  - a = 3765.939690361013 km (mean: 3774.998, 11x11: 3774.740)
  - e = 0.006338349863403579 (mean: 0.00953)
  - i = 93.0141634711089° (mean: 93.011, 11x11: 93.021)
  - $\Delta w \approx \pm 3.2°$

*removing averaged effects due to gravity perturbations - $J_2+J_3+J_2^2$

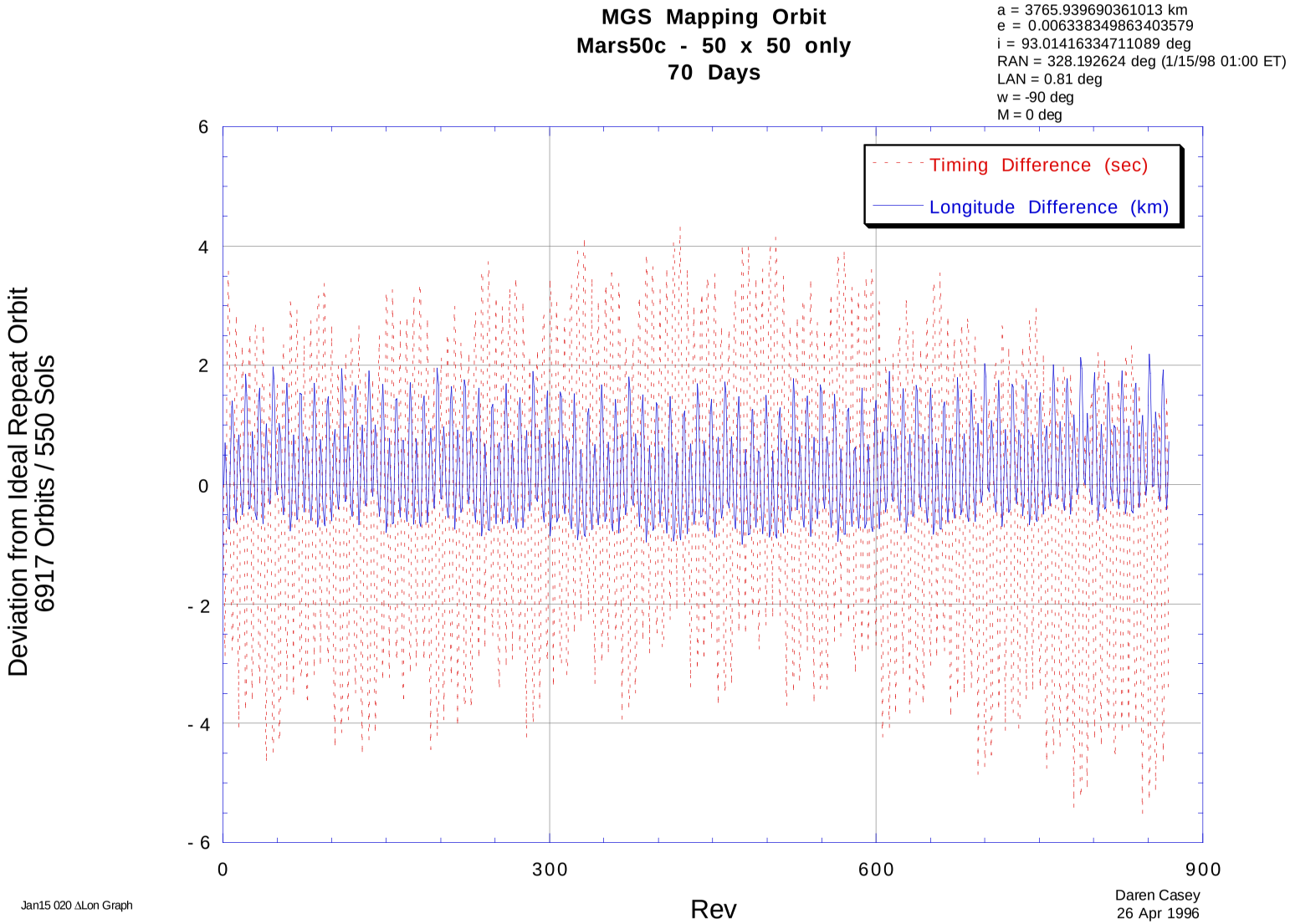
RESULTS

- AGREEMENT WITH MO RESULTS?

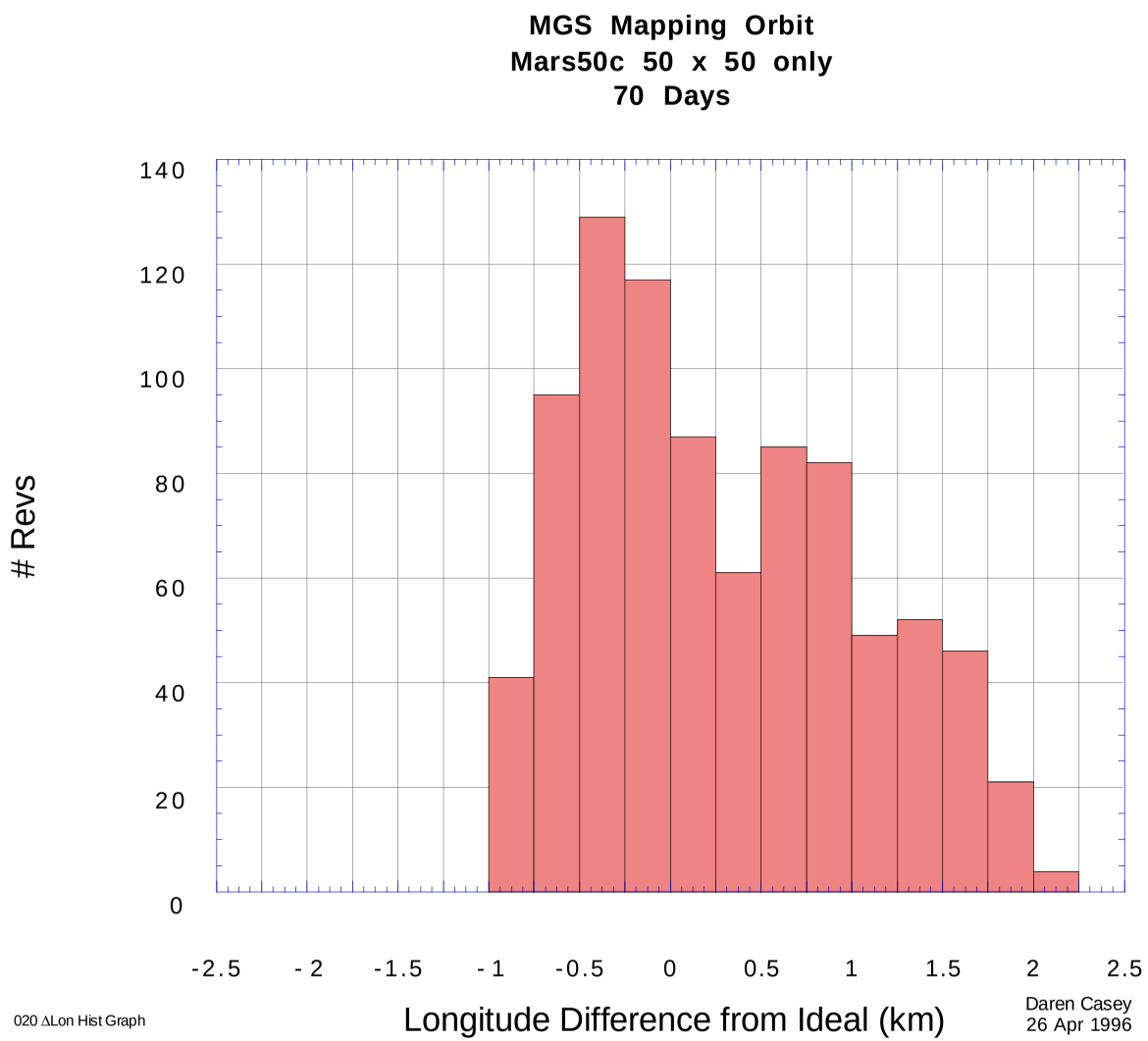
MEAN ELEMENTS

- J2 + J3
  - Δa 4 m
  - $\Delta e \approx 1\%$
  - Δi 0.003°
- 50 x 50 (vs. 18 x 18)
  - Δa 157 m
  - Δe 0.00166
  - Δi 0.036°

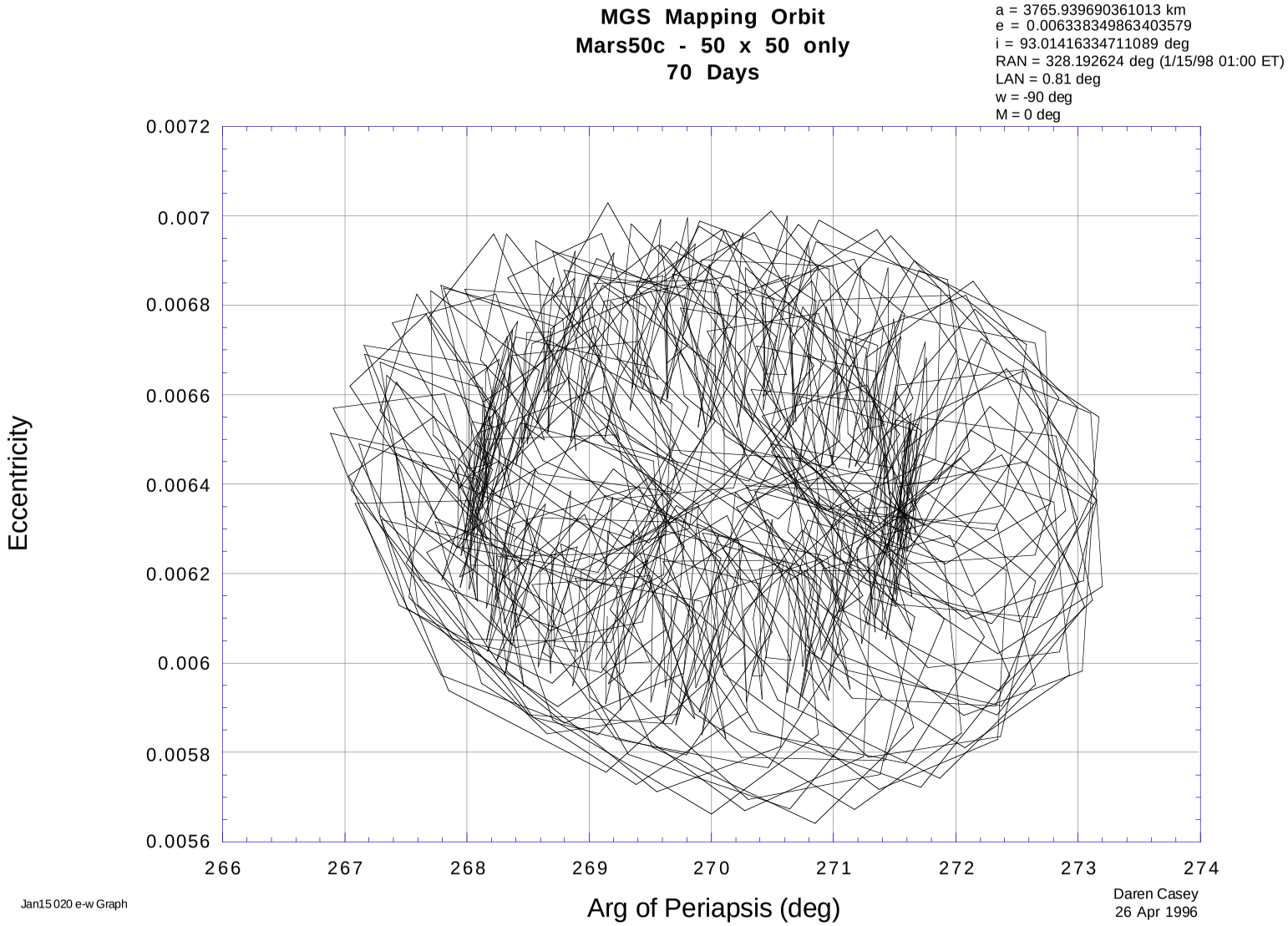
NODE HISTORY - 50 x 50



NODE HISTORY - 50 x 50



FROZENNESS - 50 x 50



SPECIAL STUDIES

- 8 x 8 ELEMENTS FLOWN IN 50 x 50 FIELD
  - "DO WE REALLY NEED ALL OF THOSE HARMONICS?"
  - ASSUME 50 x 50 IS REALITY, FLY ORBIT BASED ON SIMPLER MODEL
  - NODE ERRORS IN 70 DAYS OF 20 KM AND >240 SECONDS
- SUN AS THIRD BODY
  - TAKE ORBIT GENERATED WITHOUT THE SUN, FLY WITH SUN "ON"
  - NODE CHANGES OF 1 KM AND 0.05 SEC OVER 70 DAYS
- C_{21}, S_{21} GRAVITY HARMONICS
  - Mars50c LIKELY OVERESTIMATES C_{21} AND S_{21} TERMS IN FIELD
  - TAKE NOMINAL ORBIT, REDUCE C_{21} AND S_{21} BY 3σ
  - NODE TIMING DIFFERENCE OF 0.005 SECONDS AFTER 70 DAYS
- ATMOSPHERIC DRAG
  - NOT PERFORMED YET
  - PART OF LOOSE LONGITUDE CONTROL STUDY, BEGINNING NOW