MARS GLOBAL SURVEYOR

Mapping Orbit and Loose Longitude Control Status

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INTRODUCTION

- MAPPING ORBIT REQUIREMENTS
  - LOW-ALTITUDE - MOC,RS RESOLUTION, MAG SENSITIVITY
  - NEAR-CIRCULAR - MINIMIZE ALTITUDE VARIATIONS
  - NEAR-POLAR - GLOBAL COVERAGE
  - SUN-SYNCHRONOUS - UNIFORM ILLUMINATION, MINIMIZE IONOSPHERIC CURRENTS IMPACT
  - "SHORT" NEAR REPEAT CYCLE - FREQUENT REVISITS, HIGH RESOLUTION
- 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 1,2, AND MARINER 9 DOPPLER TRACKING DATA
    - SIMILAR TO GMM-1 (Goddard Mars Model 1, Smith *et al*)
      - BETTER PEAK VALUES FOR THARSIS VOLCANOES
      - INCLUDES ATTITUDE MANEUVER INFORMATION NOT AVAILABLE FOR GMM-1
  - INITIAL 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
  - $Q \approx 742 / 59 = 12.576$ —> 59 DAY NEAR REPEAT, 9.2 KM WALK EAST

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 $a_o + \Delta a_o$...

RESULTS

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

ELEMENTS AT PERIAPSIS

- 50 x 50

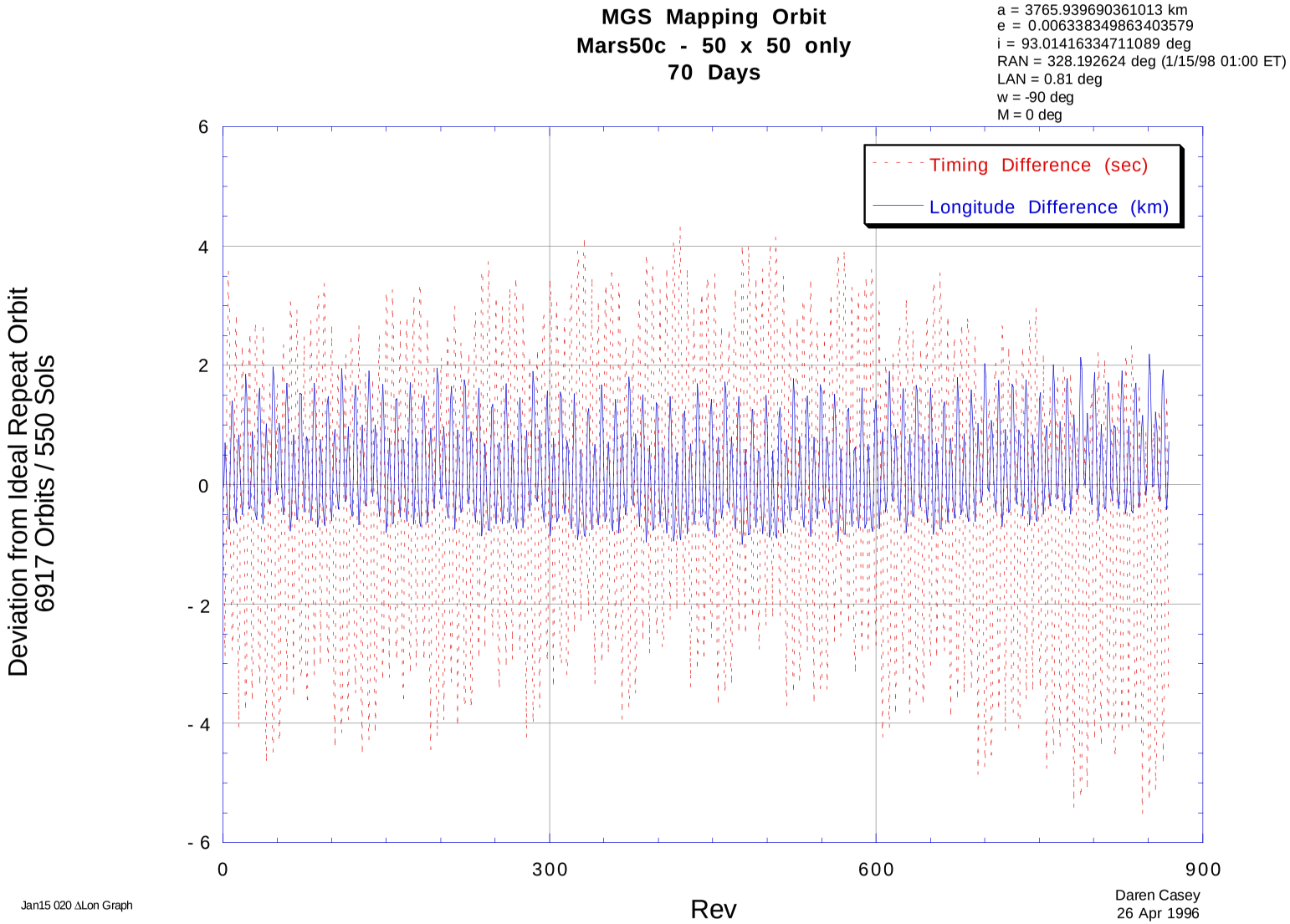
OSCULATING	MEAN*	VS. MO
a = 3765.939690361013 km	3774.998 km	-34 m
e = 0.006338349863403579	0.009526	+0.0016
i = 93.0141634711089°	93.0106°	+0.036°
$\Delta\omega \approx \pm 3.2°$		

- J2 + J3 only

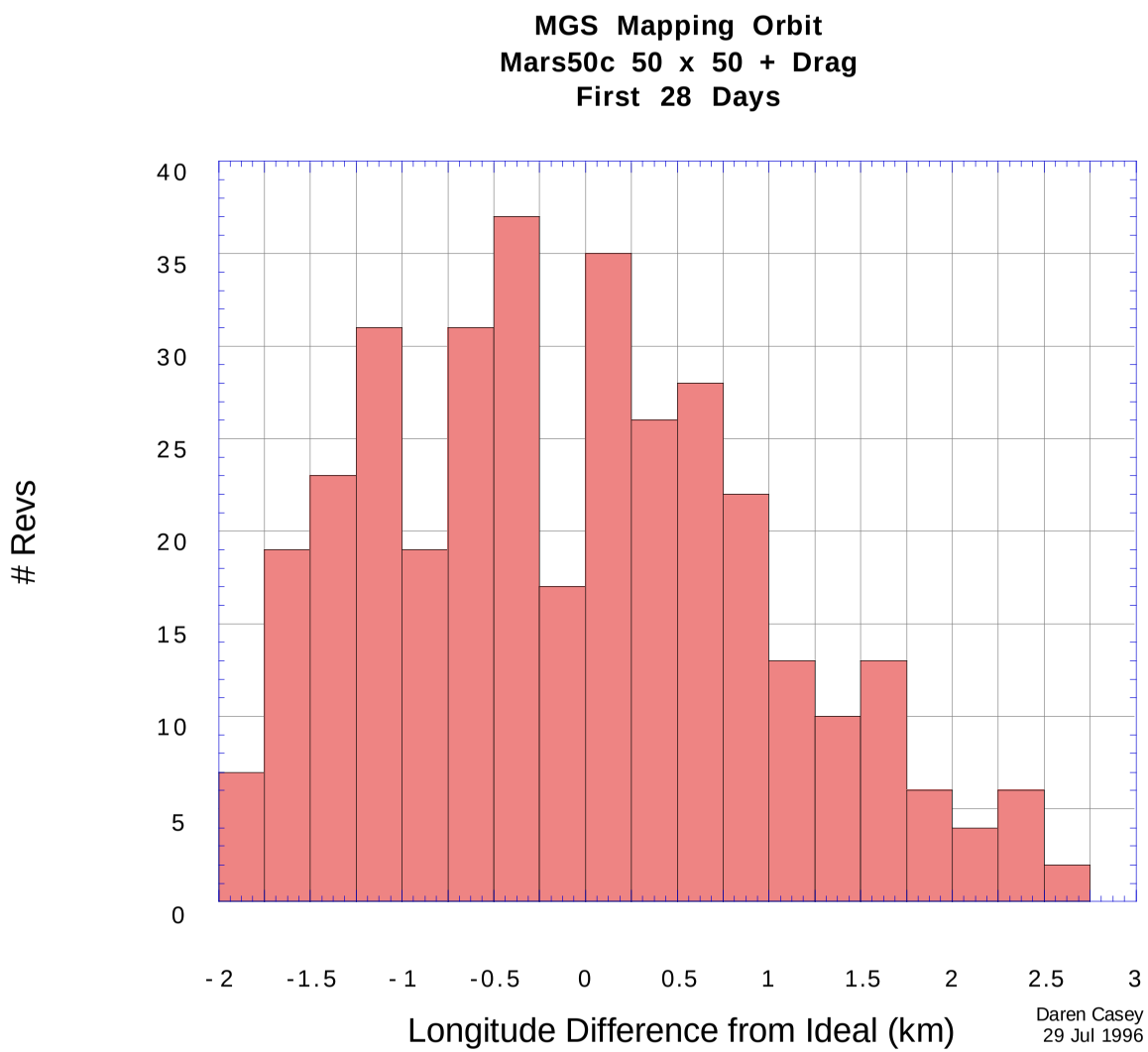
OSCULATING	MEAN*
a = 3766.170577180714 km	3775.148 km
e = 0.004086631297563429	0.00727
i = 92.87209423418787°	92.869°
$\Delta\omega \approx \pm 0.00002°$	

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

NODE HISTORY - 50 x 50



LOOSE LONGITUDE CONTROL

- FUEL CAPACITY AND OPERATIONS CONSTRAINTS DO NOT ALLOW TIGHT GROUNDTRACK CONTROL
- LOOSE LONGITUDE CONTROL STRATEGY WILL ATTEMPT TO CORRECT FOR GROUNDTRACK DRIFT DUE TO ATMOSPHERIC DRAG AND OTHER PERTURBATIONS, SUCH AS SUN AS THIRD BODY
- PLAN TO DO AN ALTITUDE RAISE UP TO EVERY 28 DAYS
  - DENSITY IS GENERALLY AT MAXIMUM AT START OF MAPPING
    - GROUNDTRACK DRIFT BY ~2.5 KM / MONTH
    - MONTHLY MANEUVERS NEEDED
  - MINIMUM DENSITY 9 MONTHS LATER
    - MANEUVER AS NEEDED
- AT START OF MAPPING, GROUNDTRACKS BETWEEN -2 AND +3 KM FROM NOMINAL LOCATION. ASSUMES DRIFT FROM SLIGHTLY HIGH INITIAL ALTITUDE THROUGH NOMINAL
  - GRAVITY FIELD FEATURES THAT "BUMP" GIVEN NODE OFF OF NOMINAL LOCATION *SHOULD* TEND TO BUMP NEIGHBORING NODE BY SIMILAR AMOUNT - MUST BE VERIFIED

NODE HISTORY WITH DRAG