NASA/GSFC	MISSION OPERATIONS & DATA SYSTEMS DIRECTORATE (MO&DSD) CONFIGURATION CHANGE REQUEST (CCR)			
1. CCR NO.	CCR-530-WSC-05	2. DATE 8 November 1996	3. PRIORITY ☐ EMERGENCY ☐ URGENT ■ ROUTINE	4. CHANGE LEVEL ☐ A ☐ B ☐ C ■ D ☐ E ☐ F

5. TITLE OF CHANGE

WSC Algorithm Update for FDF Consistency

6.

DOCUMENT TITLE Requirements Specification for the White Sands Complex (WSC)
1 September 1996

DOCUMENT NO. 530-RSD-WSC

LIST ALL AFFECTED DOCUMENTS INCLUDING PROCEDURES
NONE

Approved
4/2/97

(CONT ON ATTACHMENT)

7. REASON FOR CHANGE

To update WSC Requirements Specification to be consistent with FDF algorithms.

(CONT ON ATTACHMENT)

8. DESCRIPTION OF CHANGE

Pages A-9, A-10, and A-11.

(CONT ON ATTACHMENT)

9. IMPACT

YES	NO		YES	NO		YES	NO		YES	NO		YES	NO		YES	NO	
		SYSTEM							**ORGANIZATIONAL**								
☐	■	SCHEDULE	☐	■	RELIABILITY/MAINTAIN-ABILITY/SAFETY	■	☐	GROUND SEGMENT	☐	■	501	■	☐	530	☐	■	MSFC
☐	■	BUDGET				☐	■	SPACE SEGMENT	☐	■	502	☐	■	540	☐	■	JSC
☐	■	FACILITIES	☐	■	USER SERVICES/MANUALS	☐	■	LOGISTICS	☐	■	503	☐	■	550	☐	■	LERC
☐	■	TESTING	☐	■	RISK MANAGEMENT	■	☐	DOCUMENTATION	☐	■	510	☐	■	560	☐	■	KSC
☐	■	TRAINING	☐	■	SECURITY	☐	■	HARDWARE	☐	■	520	☐	■	OTHER	☐	■	JPL
■	☐	SPECIFICATIONS	☐	■	USAF FUNDING REQ'D	☐	■	SOFTWARE									
☐	■	CONTRACTOR SUPPORT	☐	■	POWER	☐	■	OTHER									
☐	■	INTERFACES	☐	■	WEIGHT												

YES	NO	
☐	■	CODE E
☐	■	CODE S
☐	■	CODE T
☐	■	OTHER

10. COMMENTS

	SIGNATURE	DATE
STel ANALYST		
HARDWARE ENGINEER		
OPERATIONS REPRESENTIVE		
SYSTEM ENGINEER		
I AND T MANAGER		

CONCURRENCE:

CODE 215

DATE

11. BOARD ACTION

☐ APPROVED ☐ WITHDRAWN
☐ DISAPPROVED ☐ DEFERRED UNTIL _____

12. DIRECTION/ACTION REQUIRED

☐ ECP ☐ TECH DIRECTION ☐ CONTRACT MOD
☐ WAIVER ☐ PUBLISH DOCUMENT ☐ PUBLISH DCN
☐ DEVIATION ☐ C.O. LETTER ☐ OTHER _____

13. ORIGINATOR D. Littmann X7643 CODE 530.4

SIGNATURE _____ DATE _____

14. SEGMENT MANAGER'S APPROVAL CODE _____

SIGNATURE _____ DATE _____

15. CCB APPROVAL

SIGNATURE _____ DATE _____

16. CCR IMPLEMENTED

ATR SIGNATURE _____ DATE _____
CCB SIGNATURE _____ DATE _____

The z-axis of the IIRV and the MOD systems shall be the Earth's spin axis. The y-axis completes the right-handed orthogonal coordinate system. Transforming from the GCR system to the MOD system shall be accomplished by a rotation of the position and velocity vectors about the z-axis. The velocity vector in addition shall be adjusted for the time dependence of the rotation matrix. The rotation angle is known as the Greenwich hour angle, a_G. a_G shall be computed in two steps. In the first step, a_{G0}, the Greenwich hour angle at midnight (X-582-76-77, Section 3.4.3), shall be computed from

$$a_{G0} = c_0 + c_1 T_u + c_2 T_u^2$$

where c_0 = 1.7533686~~399360~~
c_1 = 628.3319707~~510~~
c_2 = 0.0000068
T_u = (JD - 2451545.0~~15020.0~~)/36525 = (MJD - 21545.0~~+ 14980.0~~)/36525

c_0 is the ~~observational~~ value of a_{G0} at JD = 2451545.0~~15020.0~~ = 12:00:00 UT on January 1~~0~~, 2000~~1900~~. c_1 includes the orbital rate of the Earth about the Sun and the precession of the Earth's spin axis. c_2 is an empirically determined correction factor.

The value of a_G shall then be determined from

$$a_G = a_{G0} + c_3 f_d$$

where c_3 = 6.3003881 radians/day

c_3 accounts for the rotation rate of the Earth corrected for orbital motion and precession of the spin axis.

The rotation matrix R_M is then computed

$$R_M = \begin{bmatrix} \cos(a_G) & -\sin(a_G) & 0 \\ \sin(a_G) & \cos(a_G) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

and the position vector in MOD coordinates $\vec{r}$ shall be computed from the position vector in GCR coordinates $\vec{r}_{GCR}$ by

$$\vec{r} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} = R_M \vec{r}_{GCR}$$

$$\vec{r}_{GCR} = \begin{pmatrix} x_{GCR} \\ y_{GCR} \\ z_{GCR} \end{pmatrix}$$

using the usual rules of matrix multiplication. The velocity vector in MOD coordinates $\dot{\vec{r}}$ shall be computed from the velocity $\dot{\vec{r}}_{GCR}$ and position vectors by

$$\dot{\vec{r}} = R_M \dot{\vec{r}}_{GCR} + \dot{R}_M \vec{r}_{GCR}$$

where

$$\dot{R} = \omega_e \begin{bmatrix} -\sin(a_G) & -\cos(a_G) & 0 \\ \cos(a_G) & -\sin(a_G) & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

and

$$\omega_e = c_3/(86400 \text{ seconds}) = 7.29211598 \times 10^{-5} \text{ radian/seconds}^{-1}$$

For stationary customers,

$$\dot{\vec{r}}_{GCR} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

and therefore the MOD velocity vector shall be

$$\dot{\vec{r}} = \dot{R}_M \vec{r}_{GCR}$$

As defined in Reference 1, the origin of the inertial coordinate system used in the WSC shall be the center of mass of the Earth. Because the Earth is accelerating to maintain its orbital motion about the Sun, this coordinate system is not truly inertial. However, all artificial Earth satellites are also accelerating to maintain orbital motion about the Sun. Ignoring the influence of the Sun on both the Earth and the satellite results in a coordinate system that is a good approximation to a true inertial system. This approach is generally used in ephemeris computations for near-Earth satellites (X-582-76-77).

A.3.3 Stationary and Ground Terminal Vector Propagation

Stationary customers of the TDRSS shall be those that are stationary with respect to the Earth's surface. Because the Earth rotates approximately once per day about the z-axis, stationary customers shall not be stationary in an inertial reference frame. Therefore, a customer ephemeris shall be generated that includes the position and velocity of the customer.

The stationary customer state vector shall be propagated forward in h = 1 hour steps by successive applications of the rotation matrix:

$$\begin{bmatrix} \cos(h\omega_e) & -\sin(h\omega_e) & 0 \\ \sin(h\omega_e) & \cos(h\omega_e) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where $\sin(h\omega_e) = 0.25951134$

$$\cos(h\omega_e) = 0.96574006$$

The rotation matrix shall be applied to both the position and velocity vectors. Vectors at other times shall be generated by interpolating between the vectors from one hour propagation.

Ground Terminal vectors shall be propagated by the same procedures used for propagating the customer stationary vectors.

A.3.4 Free-Flight Vector Propagation

The propagation of a free-flight state vector from its assigned epoch time to some other time in the future shall be accomplished by integration of the equation of motion:

$$\ddot{\vec{r}} = \frac{-\mu \vec{r}}{r^3} + \vec{a}_{20}$$

where $\vec{r}$ = position vector of the spacecraft

r = magnitude of $\vec{r}$

$\ddot{\vec{r}}$ = acceleration vector of the spacecraft

$\vec{a}_{20}$ = perturbing acceleration due to the quadrupole gravitational harmonic portion of the gravitational field

μ = Earth's gravitational constant
= GM_e = 398600.441564 kilometers^3/second^2

G = universal gravitational constant

M_e = mass of the Earth

The contribution of the quadrupole gravitational harmonic to the gravitational potential is given by

$$V_{20} = C_{20} \frac{\mu R_e^2}{r^3} \left[P_{20} (\sin \varphi) \right]$$

where[1]

C_{20} = -1.0826266671 x 10^{-3}

R_e = Earth's equatorial radius
= 6378.13639 kilometers

P_{20} (sin φ) = associated Legendre polynomial of degree 2 and
= and order 0
= $(3 \sin^2\varphi - 1)/2$

φ = north latitude of the subspacecraft point

[1]The values of C_{20}, R_e, and μ are a correlated set of parameters.

Note 1, SEABROOK, 04/04/97 04:48:06 PM
4/2/97