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********************************************************************************************
"Test of Vallado's Example 3-15. Performing IAU-76/FK5 Reduction."
  (See p. 235, Vallado, "Fundamentals of Astrodynamics and Applications", 3rd Ed., 2007.)


Given:
        r_itrf = -1033.4793830 Ihat + u.y =  7901.2952754 Jhat + 6380.3565958 Khat
Find:
        r_gcrf  on April 6, 2004, 07:51:28.386009UTC


********************************************************************************************


    Setting Date and Time.
   ------------------------
    Date: 20040406
     UTC:  7.857885002500   (  07h 51m 28s.386 )


    Setting Earth Orientation Parameters.
   --------------------------------------
    DUT1:  -0.439961900000   ( -00h 00m 00s.440 )
      xp:  -0.000039078333   ( -00° 00′ 00″.141 )
      yp:   0.000092585833   (  00° 00′ 00″.333 )
   ddPsi:   0.000000000000   (  00° 00′ 00″.000 )
   ddEps:   0.000000000000   (  00° 00′ 00″.000 )


    Computing Coordinate Transformations.
   --------------------------------------
Time Quantitites:
    fYear             = 2004.265922
    Date              = 20040406
    UTC               = 7.857885 (  07h 51m 28s.386 )
    UT1               = 7.857763 (  07h 51m 27s.946 )
    TAI               = 7.866774 (  07h 52m 00s.386 )
    TT = TAI+32.184s  = 7.875714 (  07h 52m 32s.570 )
    DUT1 = UT1-UTC    = -0.4399619 seconds
    DAT  = TAI-UTC    = 32.0000000 seconds
    JD_UTC            = 2453101.827411875 days
    JD_UT1            = 2453101.827406783 days
    JD_TT             = 2453101.828154746 days
    T_UT1             =    0.0426236114 Julian Centuries
    T_TT              =    0.0426236319 Julian Centuries
    year              = 2004
    month             = 4
    day               = 6
    doy               = 97
    dow               = 2
    dowstr            = Tue
    gmst (hours)      = 20.8539930 (  20h 51m 14s.375 )
    gmst (degrees)    = 312.8098943 (  312° 48′ 35″.619 )
    gast (hours)      = 20.8537844 (  20h 51m 13s.624 )
    gast (degrees)    = 312.8067654 (  312° 48′ 24″.355 )

Eccentricity and Obliquity:
    eccentricity                    = 0.01670732
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    epsilon mean (obliq. of ecliptic) = 23.43873683 (  23° 26′ 19″.453 )
    epsilon true (obliq. of ecliptic) = 23.44076846 (  23° 26′ 26″.766 )

Precession Quantities:
    Zeta              = 0.0273055 (  00° 01′ 38″.300 )
    Zee               = 0.0273059 (  00° 01′ 38″.301 )
    Theta             = 0.0237306 (  00° 01′ 25″.430 )

Nutation Quantities:
    dPsi (w.o. corrections)          = -0.00341084 ( -00° 00′ 12″.279 )
    dEps (w.o. corrections)          = 0.00203163 (  00° 00′ 07″.314 )
    ddPsi (EOP correction)           = 0.00000000 (  00° 00′ 00″.000 )
    ddEps (EOP correction)           = 0.00000000 (  00° 00′ 00″.000 )
    dPsi (w. corrections)            = -0.00341084 ( -00° 00′ 12″.279 )
    dEps (w. corrections)            = 0.00203163 (  00° 00′ 07″.314 )
    epsilon true (obliq. of ecliptic) = 23.44076846 (  23° 26′ 26″.766 )
    Equation of the Equinox          = -0.00312888 ( -00° 00′ 11″.264 )

Low Accuracy Position of Sun:
    lambda_sun        =       16.860732  (  16° 51′ 38″.635 )
    earth_sun_dist    =    23476.333349 Re
    beta_sun          =              0   (  00° 00′ 00″.000 )
    RA_sun            =       15.539485  (  01h 02m 09s.476 )
    DEC_sun           =        6.625038  (  06° 37′ 30″.138 )

High Accuracy Position of Sun:
    lambda_sun_ha     =       16.856520  (  16° 51′ 23″.473 )
    r_sun_ha          =    23474.069058 Re
    beta_sun_ha       =    2.08851e-05   (  00° 00′ 00″.075 )
    RA_sun  (MOD)   =       15.535560  (  01h 02m 08s.535 )
    DEC_sun (MOD)   =        6.623444  (  06° 37′ 24″.397 )
    RA_sun  (TOD)   =       15.532162  (  01h 02m 07s.719 )
    DEC_sun (TOD)   =        6.622680  (  06° 37′ 21″.650 )

Sun vector and Ecliptic Pole in GEI2000:
    Sun               = (0.957013, 0.266113, 0.115371)
    EcPole            = (0.000000, -0.397768, 0.917486)

Geo-dipole tilt angle:
    psi                      = -0.616385  ( -00° 36′ 58″.986 )
    sin_psi                  = -0.010758
    cos_psi                  = 0.999942
    tan_psi                  = -0.010758

Position of Moon:
   RA_moon                     = 206.871584  (  13h 47m 29s.180 )
   DEC_moon                    = -9.751673  ( -09° 45′ 06″.024 )
   EarthMoonDistance           = 57.990581
   MoonPhase                   = 0.989924

IGRF-derived quantities:
    M_cd              = 30048.883892
    M_cd_McIllwain    = 31165.300000
    CD_gcolat         = 10.285656 (deg.)  (  10° 17′ 08″.363 )
    CD_glon           = -71.751916 (deg.)  ( -71° 45′ 06″.897 )
    ED_x0             = 0.032572  Re  (207.748374 km)
    ED_y0             = -0.062921  Re  (-401.318256 km)
    ED_z0             = 0.049404  Re  (315.107727 km)

Transformation Matrices:
```

```
                    [      0.95701259       0.26611345       0.11537124 ]
Amod_to_gse       = [     -0.29004636       0.87804557       0.38066925 ]
                    [      0.00000000      -0.39776828       0.91748591 ]

                    [      0.95701259       0.26611345       0.11537124 ]
Amod_to_gsm       = [     -0.27988060       0.95165720       0.12655210 ]
                    [     -0.07611666      -0.15340212       0.98522791 ]

                    [      0.67886841      -0.73425991      -0.00023989 ]
Agei_to_wgs84     = [      0.73425985       0.67886845      -0.00031232 ]
                    [      0.00039218       0.00003588       0.99999992 ]

                    [      0.95701259      -0.29004636       0.00000000 ]
Agse_to_mod       = [      0.26611345       0.87804557      -0.39776828 ]
                    [      0.11537124       0.38066925       0.91748591 ]

                    [      1.00000000       0.00000000      -0.00000000 ]
Agse_to_gsm       = [     -0.00000000       0.96495123      -0.26242928 ]
                    [      0.00000000       0.26242928       0.96495123 ]

                    [      0.67886841       0.73425985       0.00039218 ]
Awgs84_to_gei     = [     -0.73425991       0.67886845       0.00003588 ]
                    [     -0.00023989      -0.00031232       0.99999992 ]

                    [      0.95701259      -0.27988060      -0.07611666 ]
Agsm_to_mod       = [      0.26611345       0.95165720      -0.15340212 ]
                    [      0.11537124       0.12655210       0.98522791 ]

                    [      0.99994213       0.00000000       0.01075774 ]
Agsm_to_sm        = [      0.00000000       1.00000000       0.00000000 ]
                    [     -0.01075774       0.00000000       0.99994213 ]

                    [      1.00000000      -0.00000000       0.00000000 ]
Agsm_to_gse       = [      0.00000000       0.96495123       0.26242928 ]
                    [     -0.00000000      -0.26242928       0.96495123 ]

                    [      0.99994213       0.00000000      -0.01075774 ]
Asm_to_gsm        = [      0.00000000       1.00000000       0.00000000 ]
                    [      0.01075774       0.00000000       0.99994213 ]

                    [      0.99999946      -0.00095315      -0.00041418 ]
Agei_to_mod       = [      0.00095315       0.99999955      -0.00000020 ]
                    [      0.00041418      -0.00000020       0.99999991 ]

                    [      0.99999946       0.00095315       0.00041418 ]
Amod_to_gei       = [     -0.00095315       0.99999955      -0.00000020 ]
                    [     -0.00041418      -0.00000020       0.99999991 ]

                    [      1.00000000       0.00005462       0.00002368 ]
Amod_to_tod       = [     -0.00005462       1.00000000      -0.00003546 ]
                    [     -0.00002368      -0.00000020       1.00000000 ]

                    [      1.00000000      -0.00005462      -0.00002368 ]
Atod_to_mod       = [      0.00005462       1.00000000       0.00003546 ]
                    [      0.00002368      -0.00003546       1.00000000 ]

                    [      0.67952794      -0.73364963       0.00000000 ]
Atod_to_pef       = [      0.73364963       0.67952794       0.00000000 ]
                    [      0.00000000       0.00000000       1.00000000 ]
```

```
                      [      0.67952794       0.73364963       0.00000000 ]
 Apef_to_tod       = [     -0.73364963       0.67952794       0.00000000 ]
                      [      0.00000000       0.00000000       1.00000000 ]

                      [  6.79568000e-01  -7.33612523e-01   0.00000000e+00 ]
 Ateme_to_pef      = [  7.33612523e-01   6.79568000e-01   0.00000000e+00 ]
                      [  0.00000000e+00   0.00000000e+00   1.00000000e+00 ]

                      [  6.79568000e-01   7.33612523e-01   0.00000000e+00 ]
 Apef_to_teme      = [ -7.33612523e-01   6.79568000e-01   0.00000000e+00 ]
                      [  0.00000000e+00   0.00000000e+00   1.00000000e+00 ]

                      [  1.00000000e+00   0.00000000e+00   6.82045583e-07 ]
 Awgs84_to_pef     = [ -1.10213630e-12   1.00000000e+00   1.61592763e-06 ]
                      [ -6.82045583e-07  -1.61592763e-06   1.00000000e+00 ]

                      [  1.00000000e+00  -1.10213630e-12  -6.82045583e-07 ]
 Apef_to_wgs84     = [  0.00000000e+00   1.00000000e+00  -1.61592763e-06 ]
                      [  6.82045583e-07   1.61592763e-06   1.00000000e+00 ]



 Setting ITRF Coordinates (km).
--------------------------------
 u_itrf: -1033.479383000  7901.295275400  6380.356595800


 Transforming to PEF Coordinates (km).
---------------------------------------
  u_pef: -1033.475031306   7901.305585585   6380.344532749
  u_pef: -1033.475031300   7901.305585600   6380.344532800  (Vallado's result)
   DIFF:    -0.000000006     -0.000000015     -0.000000051  (LGM - Vallado's result)


 Transforming to TOD Coordinates (km).
---------------------------------------
  u_tod:  5094.514781057   6127.366460619   6380.344532749
  u_tod:  5094.514780400   6127.366461200   6380.344532800  (Vallado's result)
   DIFF:     0.000000657     -0.000000581     -0.000000051  (LGM - Vallado's result)


 Transforming to MOD Coordinates (km).
---------------------------------------
  u_mod: 5094.02901646  6127.87093603  6380.24788896
  u_mod:  5094.028374500   6127.870816400   6380.248516400  (Vallado's result)
   DIFF:     0.000641964      0.000119627     -0.000627444  (LGM - Vallado's result)


 Transforming to GCRF Coordinates (km).
---------------------------------------
  u_gcrf:  5102.509599273   6123.011520001   6378.136300595
  u_gcrf:  5102.508953000   6123.011396000   6378.136937000  (Vallado's result)
    DIFF:     0.000646273      0.000124001     -0.000636405  (LGM - Vallado's result)
```