Fundamentals of Astrodynamics and Applications 3rd Ed

Errata

June 20, 2011

This listing is an on-going document of corrections and clarifications encountered in the book. I appreciate any comments and questions you find. I use RHS for right hand side when referring to equations. You may reach me at: dvallado@agi.com. Changes in equations are sometimes indicated by circles.

Page front eqtns, equations for conic sections**:** The parabolic semi-parameter should be $p = -\frac{h^2}{\mu}$. The period equation should also apply for ellipses. There should be a negative on the semi-major axis in the hyperbolic mean motion equation.

Page 41, First equation**:** The first and third "+" signs should be "-" and the sentence should say "for the satellite, and performing the cross product, we have"

Page 43, Last equation**:** The last line should read "In reality, three quintics are required to find the distance **(ξ)** from each Lagrange point to the nearest primary (Szebehely, 1967:135–138)"

The symbol **(ξ) replaces (*x*)** in the formula as follows:

$$\xi^5 + (3-\mu^*)\xi^4 + (3-2\mu^*)\xi^3 - \mu^*\xi^2 - 2\mu^*\xi - \mu^* = 0$$
$$\xi^5 - (3-\mu^*)\xi^4 + (3-2\mu^*)\xi^3 - \mu^*\xi^2 + 2\mu^*\xi - \mu^* = 0 \quad .$$
$$\xi^5 + (2+\mu^*)\xi^4 + (1+2\mu^*)\xi^3 - (1-\mu^*)\xi^2 - 2(1-\mu^*)\xi - (1-\mu^*) = 0$$

Page 64, 2nd equation**:** The second term should not have an "*e*" in the denominator.

Page 96, Equation2-69**:** Change the denominators as follows:

$$\frac{dc_2}{d\psi} = \frac{1}{2\psi}\{1 - \psi c_3 - 2c_2\}$$
$$\frac{dc_3}{d\psi} = \frac{1}{2\psi}\{c_2 - 3c_3\}$$

Page 119, Eq 2-100**:** Change as follows:

$$h_p = \sqrt{2\sqrt{\mu a(1-e^2)}(1-\cos(i))}\cos(\Omega)$$
$$G_p = -\sqrt{2(\sqrt{\mu a}(1-\sqrt{1-e^2}))}\sin(\omega+\Omega)$$
$$H_p = -\sqrt{2\sqrt{\mu a(1-e^2)}(1-\cos(i))}\sin(\Omega)$$

Page 158, Fig 3-10**:** Change the perihelion date to "~1 Jan":

Page 194-195, Footnote and Ex 3-5**:** Change the numbers to read "taking the time derivative of Eq. (3-45) (with respect to T_{UT1}) and dividing by 36,525. The result gives the number of sidereal seconds in one solar day (86,636.555 367 908 73^s + 5.098 097 × 10^{-6} T_{UT1} – 5.0924 × 10^{-10} T_{UT1}^2 " in the footnote. The Ex 3-5 had too many decimal places. Correct as follows:

θ_{GMST} = –232,984,181.090 925 5^s

Reduce this quantity to a result within the range of 86400^s (–49,781.090 925 5^s). Then convert to degrees by dividing by 240 (1^s = 1/240° using Eq. (3-35)).

θ_{GMST} = –207.421 212 189 5°

Add this answer to 360° to get the final answer.

θ_{GMST}= 152.578 787 810°

Find LST given $\theta_{GMST} + \lambda$ = 152.578 787 810° + (–104.0°) = 48.578 787 810°

θ_{LST} = 48.578 787 810°

Page 204, Ex 3-8**:** Delete "TRUNC" from the last line in the example.

Page 202-203, Ex 3-7**:** The *JD* should be 2,453,140 instead of 2,453,102 in several places. This changes the values of T_{TT} and T_{TDB} to 0.043 674 121 031 and T_{UT1} to 0.043 674 100 545.

Page 217, Eq 3-56**:** The final term in $D_{\odot}$ should be raised to the 4th power.

Page 218, 1st, 2nd and Last equation**:** The first equation should have a $\vec{r}_{ITRF}$ at the end. The s' equation should be a negative. The velocity equation should be $\vec{v}_{CIRS} = \text{ROT3}(-\theta_{ERA})\{\vec{v}_{TIRS} + \omega_{\oplus} \times \vec{r}_{TIRS}\}$.

Page 221, End of last para**:** Insert the following addition "Note that although Kaplan (2005:48) shows the true obliquity in $Eq_{equinox2000}$, the narrative suggests it's more appropriately the mean value, shown below."

Page 222, Para before Eq 3-61**:** Add the following note "The A_{p1c_i} and A_{e1s_i} terms represent out of phase contributions (McCarthy and Petit 2003:43), but they are not used in the equinox approaches (Kaplan 2005:45-46)."

Page 225, Last Eq before the Example**:** The ***R*** matrix should be outside the large left bracket.

Page 227, Sec 3.7.2 and eq 3-65**:** Insert "acceleration" into the section heading. Add the following to Eq 3-65. $\vec{a}_{GCRF} = [\boldsymbol{B}][\boldsymbol{P}][\boldsymbol{N}][\boldsymbol{R}]\left\{[\boldsymbol{W}]\vec{a}_{ITRF} + \vec{\omega}_{\oplus} \times \vec{\omega}_{\oplus} \times \vec{r}_{TIRS} + 2\vec{\omega}_{\oplus} \times \vec{v}_{TIRS}\right\}$

Page 234, Alg 24**:** The four frame bias terms [**B**] are not needed and should be removed.

Page 281, 2nd equation**:** The Mean anomaly values should have a solar subscript on each.

Page 282-283, Ex 5-1**:** The ecliptic longitude value should be reduced to 360 deg, and be = 12.114 404 deg. The Sun position vector at the bottom of page 282 should have 146,186,212 as the first component.The last sentence in the first para on page 283 should say "is about 28873 km, or 0.0002 AU". The final declination value should be 4.788 417 deg. The final digit should be a 7.

Page 290-291, Alg 31 and Ex 5-3**:** The ecliptic longitude second term should have the fractional part "8813" instead of the "883". This changes the value slightly in the example, and the final position to -134,240.626, -311,571.590, and -126,693.785 km.

Page 292-295, Alg 32 and Ex 5-4**:** The constant term "0.0233" should be "0.00233" in both the text, algorithm, and the example problem. In the algorithm, UT_{temp} should be t_{n-1}. All 2pi values should be 360 deg for consistency.

Page 301, 2nd para**:** The umbra and penumbra equations should both use Sine instead of Tangent. The values change slightly to 0.264 121 687 and 0.269 007 205 respectively. The distances and times should be corrected as follows 13098 km and 71 min, and 12412 km and 67 min.

Page 371, Alg 46**:** The top two lines are not needed for the algorithm and should be deleted. The "Find" line should include pi at the end. $\lambda_{true_{int1}} = \Omega + \pi$

Page 477, 478, 481, First para, Eq 7-43, 7-45 and Eq 7-50**:** Change "tme" to "Δt_{min}".Change the equations as follows

$$\Delta t_p = \frac{1}{3}\sqrt{\frac{2s^3}{\mu}}\left\{1 \mp \left(\frac{s-c}{s}\right)^{\frac{3}{2}}\right\},\ T = \left(\frac{\Delta t}{\Delta t_p} - 1\right) = \sum_{n=1}^{\infty} A_n\left(\frac{s}{2}\right)^n a^{-n},\ a = \frac{s}{2}\sum_{n=1}^{\infty} B_n\left(\frac{\Delta t}{\Delta t_p} - 1\right)^{n-2}$$

Page 478, 2nd para**:** Change the pochhammer index from "*n*" to "*i*".

Page 540, Eq 8-15**:** There should be a "2" before the summation.

Page 548, Eq 8-27**:** Add $-\frac{\mu r}{r^3}$ to each component for the two-body terms.

Page 558, Eq 8-31**:** Remove the "/" in the denominator.

Page 631-632, Equations for dM_o/dt: The last equation on pg 631 should replace "*t*" with $(t-t_o)$. The dM_o/dt equation on pg 632 should have the following term added: $-\frac{dn}{dt}(t - t_o)$ .the next equation should be $\frac{d\nu}{dt} = \frac{h}{r^2} + \frac{1}{eh}\{p\cos(\nu)\}F_R - ((p+r)\sin(\nu))F_S$ instead of $\frac{d\sigma}{dt}$.

Page 671, 2nd Eq**:** Change the 3rd term in the brackets to be $J_1 - J_3$.

Page 683, 2nd Eq for $\dot{\omega}$**:** The final term in the square brackets should be "+a" instead of the "-a".

Page 705, Several Equations**:** Update and add as follows.

$$\Delta r_{SP} = -\frac{J_2 R_\oplus^2}{4p}\left((3\cos^2(i) - 1)\left\{\frac{2\sqrt{1-e^2}}{1+e\cos(\nu)} + \frac{e\cos(\nu)}{1+\sqrt{1-e^2}} + 1\right\} - \sin^2(i)\cos(2u)\right)$$

$$\Delta\dot{r}_{SP} = \frac{J_2\sqrt{\mu}R_\oplus^2}{4p^{5/2}}\left((3\cos^2(i) - 1)e\sin(\nu)\left\{\sqrt{1-e^2} + \frac{(1+e\cos(\nu))^2}{1+\sqrt{1-e^2}}\right\}\right.$$

$$r = \frac{p}{1+e\cos(\nu)} \qquad \dot{r} = \sqrt{\frac{\mu}{p}}e\sin(\nu)$$

$$\dot{r}_{osc} = \dot{r} + \Delta\dot{r}_{SP}$$

$$B = \sqrt{\frac{p_{osc}}{\mu}}\dot{r}_{osc}$$

Page 696, Last 2 equations**:** Change as follows:

$$f_{i1} = \sum_{j=1}^{6}\frac{\partial F_i}{\partial a_j}\eta_{j1} \qquad f_{i2} = \sum_{j=1}^{6}\frac{\partial F_i}{\partial a_j}\eta_{j2} + \frac{1}{2}\sum_{j=1}^{6}\sum_{k=1}^{6}\frac{\partial^2 F_i}{\partial a_j \partial a_k}\eta_{j1}\eta_{k1}$$

…

$$N_1 = -\frac{3\eta_{11}}{2a_1}n(a_1) \qquad N_2 = \left\{-\frac{3\eta_{12}}{2a_1} + \frac{15}{8}\left(\frac{\eta_{11}}{a_1}\right)^2\right\}n(a_1)$$

…

$$\frac{d\hat{a}_i}{dt} = \delta_{i6}\left(n + \sum_{j=1}^{m} \epsilon^j N_j\right) + \epsilon F_i(a, \lambda_M) + \sum_{j=1}^{m} \epsilon^{(j+1)} f_j(a_1, a_2, \ldots a_5, \lambda_M)$$

Page 733, Sentence after the data in Ex 10-1**:** Change the equation to $y = \alpha + \beta x$ for consistency.

Page 744, Bottom set of equations and pg 745 top set of equations**:** Change the four "b" symbols to "y" at the bottom of page 744. Change the "b" matrix equation on the top of pg 745 to a "r mean" (overbar). Add "Note that ***W*** contains the weights (as appropriate) for each measurement. In practice, we accumulate measurements so the correlation between terms in the ***W*** matrix is simpler."

Page 757, 1st equation**:** Change the equation as follows.

$$\frac{\partial \text{ observations}}{\partial \hat{\boldsymbol{X}}_o} \cong \frac{f(\ddot{\boldsymbol{X}} + \delta_i) - f(\ddot{\boldsymbol{X}})}{\delta_i}$$

Page 798, 2nd equation from the bottom**:** Change the equation as follows.

$$\frac{\partial^2 U}{\partial \phi_{gc}^2} = \frac{\mu}{r}\sum_{\ell=2}^{\infty}\left(\frac{R_\oplus}{r}\right)^{\ell}\sum_{m=0}^{\ell}\{C_{\ell m}\mathrm{COS}(m\lambda) + S_{\ell m}\mathrm{SIN}(m\lambda)\}\left[\mathrm{TAN}(\phi_{gc})P_{\ell,m+1}[\mathrm{SIN}(\phi_{gc})]\right.$$
$$\left.+\{-m^2\mathrm{SEC}^2(\phi_{gc}) + m\,\mathrm{TAN}^2(\phi_{gc}) - (\ell - m)(\ell + m + 1)\}P_{\ell m}[\mathrm{SIN}(\phi_{gc})]\right]$$

Page 852, Eq 11-15 and Eq 11-16**:** For Eq 11-15, the $a^{7/2}$ should be moved down with the numerator, and add a negative sign before the 2. For Eq 11-16, move the $a^{7/2}$ to the denominator.

Page 859, Eq 11-25**:** The denominator should be changed to

$$1 + \frac{3J_2}{4}\left(\frac{R_\oplus}{p}\right)^2\left\{\sqrt{1-e^2}(2 - 3\mathrm{SIN}^2(i)) + (4 - 5\mathrm{SIN}^2(i))\right\}.$$

Page 875, 1st equation**:** Change the equation as follows.

$$\frac{3n}{8e}J_3\left(\frac{R_\oplus}{p}\right)^3\mathrm{SIN}(\omega)\left[(4 - 5\mathrm{SIN}^2(i))\left(\frac{\mathrm{SIN}^2(i) - e^2\mathrm{COS}^2(i)}{e\,\mathrm{SIN}(i)}\right) + 2e^2\mathrm{SIN}(i)(15\mathrm{SIN}^2(i) - 13)\right]$$

For the equation in the middle of the page for e_o, the sin(w) term is not needed.

Page 930, Problem 13**:** The "*J*" component should have a decimal point — 28,026.945 431

Page 952, Intermediate equations**:** Change each r_i to x_{ri} in the $U(r_i)$ and $W(r_i)$ equations.

Page 958, Eq B-16**:** Delete the negative sign in front of k_1.

Page 967, Matrix inversion example**:** The 2,2 term should be 0.126 814.

Page 969, Para after Eq C-13**:** Add the following statement.

The second ± sign is not necessarily the same as the first one, but is determined as follows: For a given function *f*, a given value of *n*, and a given choice of the first (±) sign, the second side will be the same as the first function for all values of α. Thus, it is only necessary to check the sign for any one value of α, and the formula will be complete.

Page 985, Two IF statements**:** Both variables should be α_{qi0} instead of α_{qi6}.

Page 1030, 1034, References**:** Add the following:

O’Conner, John J. 1983. Methods of Trajectory Mechanics (Second Edition). RCA International Services Corporation. Report # ESMC-TRR-84-01.

Vallado, David A. and Scott S. Carter. 1997. Accurate Orbit Determination from Short-arc Dense Observational Data. Paper AAS 97-704 presented at the AAS/AIAA Astrodynamics Specialist Conference. Sun Valley, ID. [10]

Page Backcover, Numerical values**:** Tropical year value has an extra “2” in the fraction. It should be 365.2421897.