

# Correction to: Fundamentals of Spacecraft Attitude Determination and Control



## Correction to:

**F.L. Markley and J.L. Crassidis,**

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An error in the production process unfortunately led to publication of this book prematurely, before incorporation of the final corrections. The version supplied here has been corrected and approved by the author [F. Landis Markley and John L. Crassidis].

## Chapter 1

On page 2 there should be a closed parenthesis after “1630” in Table 1.1.

## Chapter 2

On the sixth line of page 17 “conceptionally” should be “conceptually”.

On page 23, the sentence below Eq. (2.28) should read “In particular, if we have a scalar  $f(\mathbf{x})$  in place of the vector function  $\mathbf{y}(\mathbf{x})$ , this reduces to the  $1 \times n$  row vector . . .”

Also, the next sentence should read “The transpose of this, an  $n \times 1$  column vector . . .”

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The updated version of this book can be found at  
<https://doi.org/10.1007/978-1-4939-0802-8>

### Chapter 3

In the first paragraph of page 67 the translational momentum should be defined as “ $\mathbf{p} \equiv m\mathbf{v}$ ” not “ $\mathbf{p} \equiv m\dot{\mathbf{v}}$ ”.

In the second paragraph on page 89 (fourth line), the word “away” should read “a way”.

The inertia matrix in Exercise 3.6 on page 119 does not satisfy the triangle inequality. We recommend using the following inertia matrix:

$$J_B^c = \begin{bmatrix} 100 & 0 & 0 \\ 0 & 75 & 0 \\ 0 & 0 & 50 \end{bmatrix} \text{ kg-m}^2$$

### Chapter 4

On page 126, in Eq. (4.3b) “ $u_0$ ” should be “ $v_0$ ”

On page 129, above Eq. (4.9) “finding  $N$  stars” should be changed to “finding exactly  $N$  stars”. Also, below Eq. (4.9) and in the next paragraph “finding 4 stars” should be changed to “finding 4 or more stars” (3 places). Finally, below Eq. (4.9) and in the next paragraph “finding 5 stars” should be changed to “finding 5 or more stars” (3 places).

On page 143, in the first sentence of Section 4.7.1, “rate-integrating gyro” should be replaced by “rate gyro”.

On page 159 the label “newpoly.eps” should be removed from Figure 4.10.

On page 176 the subscript “min” in Eq. (4.127) should be text, not italic.

### Chapter 5

On page 200 the reference to Eq. (5.3) in the second line of the second (new) paragraph should be to Eq. (5.6).

The matrix  $A^{\text{true}}$  in Problem 5.3 on page 225 should read

$$A^{\text{true}} = \begin{bmatrix} 0.352 & 0.864 & 0.360 \\ -0.864 & 0.152 & 0.480 \\ 0.360 & -0.480 & 0.800 \end{bmatrix}$$

That is, the (2,3) element is changed from 0.460 to 0.480 to ensure that  $A$  is orthogonal.

**Chapter 6**

On page 243 in the last sentence of the paragraph below Eq. (6.25),  $\delta \hat{\boldsymbol{\nu}}_k^-$  and  $\Delta \hat{\boldsymbol{\xi}}^-$  should be  $\delta \hat{\boldsymbol{\nu}}$  and  $\Delta \hat{\boldsymbol{\xi}}$ .

The asterisk used for the unnormalized reset quaternion in Eqs. (6.27) and (6.28) and in Tables 6.1 and 6.3 conflicts with the notation for the conjugate quaternion, which is used throughout the book. To better differentiate between the two, replace Eqs. (6.27) and (6.28) with

$$\hat{\mathbf{q}}^{\text{unnorm}} = \begin{bmatrix} \delta \hat{\boldsymbol{\nu}}^+ / 2 \\ 1 \end{bmatrix} \otimes \hat{\mathbf{q}}^- = \hat{\mathbf{q}}^- + \frac{1}{2} \mathcal{E}(\hat{\mathbf{q}}^-) \delta \hat{\boldsymbol{\nu}}^+$$

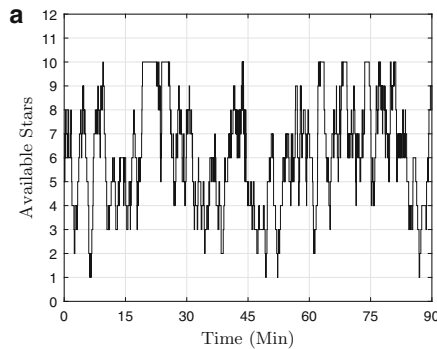
and

$$\hat{\mathbf{q}}^+ = \frac{\hat{\mathbf{q}}^{\text{unnorm}}}{\|\hat{\mathbf{q}}^{\text{unnorm}}\|}$$

respectively. Also, replace both  $\mathbf{q}^*$  and  $\hat{\mathbf{q}}^*$  by  $\hat{\mathbf{q}}^{\text{unnorm}}$  in Tables 6.1 and 6.3.

In the second line of Example 6.2 “a 90-min low-Earth orbit” should be changed to “a 91.5-min equatorial low-Earth orbit”.

On page 262, in Figure 6.3, the number of available stars changes slightly but the results are nearly identical. A plot of the available stars with a 91.5-min equatorial low-Earth orbit is shown in Figure 6.3a.



On page 264, just above Eq. (6.102a) the estimate should be defined as  $E\{x|\theta^{\text{out}}\}$ . Thus, the sentence should read “Because  $\eta_u$ ,  $\eta_v$ , and  $v_e$  have zero mean, the conditional expectation  $\hat{\mathbf{x}} \equiv E\{x|\theta^{\text{out}}\}$  and the state error vector  $\Delta \mathbf{x} \equiv \mathbf{x} - \hat{\mathbf{x}}$  obey”

On page 265 three lines from the bottom “Equation (6.107) are” should be “Equations (6.107) are”.

On page 266, in Eq. (6.108b) the 3-2 element of the matrix  $P^+$  should be changed from  $\zeta^{-1} S_e^2 S_u / (\Delta t)^{-1}$  to  $\zeta^{-1} S_e^2 S_u / \Delta t$  to make the notation consistent in the matrix.

In Problem 6.7 on page 280, the sentence “Use the discrete-time covariance propagation in Eq. (E.132) ...” should be replaced with “Use the discrete-time covariance propagation in Eq. (E.131)”

On page 284, the word “convergence” in Ref. 34 is misspelled.

**Chapter 7**

On page 293, in Example 7.2, the inertia matrix has now been changed to

$$J = \begin{bmatrix} 640 & -7.64 & -2.56 \\ -76.4 & 473 & -4 \\ -2.56 & -4 & 816 \end{bmatrix} \text{ kg-m}^2$$

On page 293, in Example 7.2:

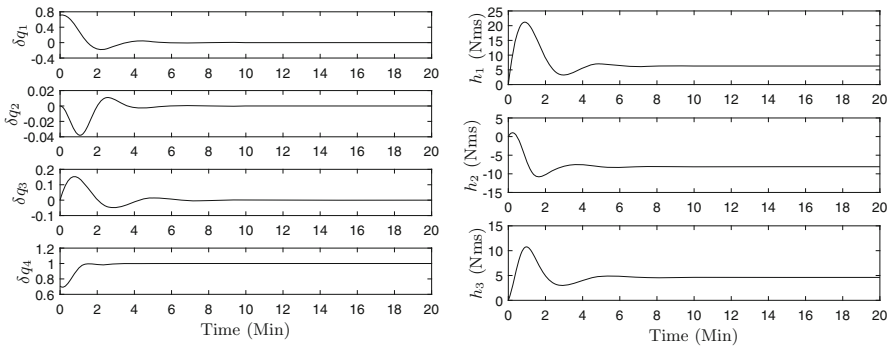
Change “The gains are set to  $k_p = 10$  and  $k_d = 150$ ” to “The gains are set to  $k_p = 1$  and  $k_d = 15$ ”.

Change “... the norm of the momentum is  $\|J\omega(t_0)\| = 112.4586 \text{ Nms}$ ” to “the norm of the momentum is  $\|J\omega(t_0)\| = 11.25 \text{ Nms}$ ”.

Change “... pyramid configuration at the final time is  $96.8044 \text{ Nms}$ ” to “... pyramid configuration at the final time is  $9.68 \text{ Nms}$ ”.

Change “... NASA standard configuration at the final time is  $111.8695 \text{ Nms}$ ” to “... NASA standard configuration at the final time is  $11.19 \text{ Nms}$ ”.

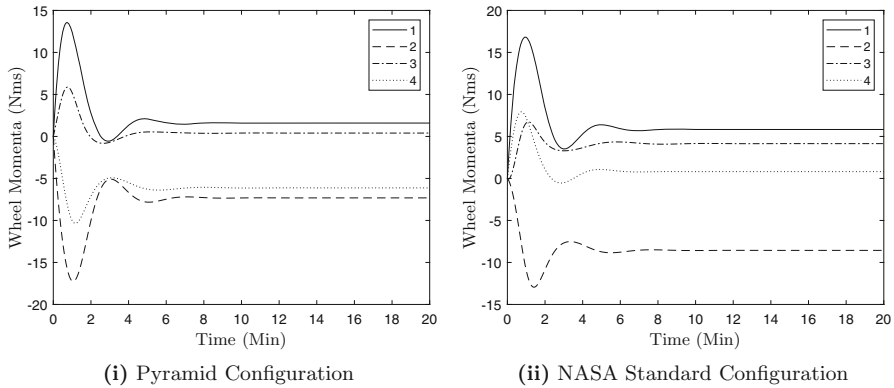
On page 293, Figure 7.2 has been revised as given below. Note that Figure 7.2(a) is the same as before, however Fig. 7.2(b) only changed.



(i) Quaternion Errors

(ii) Wheel Momenta

On page 294, Figure 7.3 has been revised as given below:



On page 300  $\omega_c$  should be given by

$$\omega_c = \begin{bmatrix} \dot{\phi}_c \sin \theta_c \sin \psi_c \\ \dot{\phi}_c \sin \theta_c \cos \psi_c \\ \dot{\psi}_c + \dot{\phi}_c \cos \theta_c \end{bmatrix} \frac{\text{rad}}{\text{sec}}$$

On page 302 “Substituting Eqs. (7.1b) and (7.3.1) into Eq. (7.33), and after ...” should read “Substituting Eqs. (7.1b) and (7.32) into Eq. (7.33), and after ...”

On page 328 the fourth line of the last paragraph of Section 7.7.3.2 should read “the rotation of the z-axis ...”

On page 342 the last page of Ref. [30] is 2566 not 2565.

**Chapter 8**

On page 346 the sentence above Eq. (8.6) should read “... then from Eq. (8.3b) we have.”

The third sentence on page 358 should read “Equation (8.50a) can be used to prove ...”

The last sentence on page 358 should read “Equation (8.50d) can be used to prove ...”

**Chapter 10**

On page 390, in the ninth line of Section 10.3.4 “SRP only contributes as times ...” should be replaced with “SRP only contributes at times ...”

On page 397 two lines under Eq. (10.129), it should say “greater than 90°”, not 95.68°.

**Chapter 11**

On page 412, the  $\Delta T_c$  term in Eq. (11.18) should read

$$\Delta T_c = A + Bh_p + Ch_p^2 + Dh_p^3$$

Also, the  $B$  term in Eq. (11.20) should read

$$B = B_{13}y + B_{14}yT + B_{15}yT^2 + B_{16}yT^3 + B_{17}yT^4 + B_{18}yT^5$$

**Chapter 12**

Equation (12.69) on page 446 should read

$$s = \left( \frac{d}{dt} + \lambda \right)^{n-1} \Delta x$$

Also, the sliding surface for  $n = 3$  should be  $s = \Delta \ddot{x} + 2\lambda \Delta \dot{x} + \lambda^2 \Delta x$ . Note that Eq. (12.69) is a notational simplification for the weighted sum average used to generate  $s$ , which is discussed in [25].

Equations (12.70)–(12.72) and the associated wording should be changed as follows. As an example consider the following second-order system:

$$\ddot{x} = f(x, \dot{x}) + u$$

where an assumed model  $\bar{f}(x, \dot{x})$  will be used to develop the control law. Taking the derivative of  $s$  in Eq. (12.65) and substituting  $\ddot{x} = f(x, \dot{x}) + u$  gives

$$\begin{aligned} \dot{s} &= \ddot{x} - \ddot{x}_c + \lambda \Delta \dot{x} \\ &= f(x, \dot{x}) + u - \ddot{x}_c + \lambda \Delta \dot{x} \end{aligned}$$

Using the condition  $\dot{s} = 0$  from Eq. (12.67) with the assumed model  $\bar{f}(x, \dot{x})$  leads to the following control law:

$$u_e = -\bar{f}(x, \dot{x}) + \ddot{x}_c - \lambda \Delta \dot{x}$$

In Example 12.3 on page 448,  $\dot{x}_2$  should be

$$\dot{x}_2 = -(k_1/m)x_1 - (k_2/m)x_1^3 - (c/m)x_2|x_2| + u/m$$

On the first line of page 459 “Nonlinear Least squares implies that an fairly ...” should be replaced with “Nonlinear Least squares implies that a fairly ...”

Equation (12.113) should read

$$\hat{\mathbf{p}} = \frac{(1 - \|\mathbf{p}_c\|^2) \Delta \mathbf{x} + (1 - \|\Delta \mathbf{x}\|^2) \mathbf{p}_c - 2 \Delta \mathbf{x} \times \mathbf{p}_c}{1 + \|\mathbf{p}_c\|^2 \|\Delta \mathbf{x}\|^2 - 2 \Delta \mathbf{x} \cdot \mathbf{p}_c}$$

On line two of page 465 “This the preferred form ...” should be replaced with “This is the preferred form ...”

On page 467, in the paragraph just after Eq. (12.137), “then the simple covariance expression in Eq. (12.137) cannot be used, since a Gaussian input causes a non-Gaussian response. Fortunately, a Kalman filter can still be derived using nonlinear models. The extended Kalman filter,” should be replaced with “then the linear Kalman filter cannot be used. Fortunately, linearization leads to an extended Kalman filter (EKF) for nonlinear systems with the same covariance propagation and update equations as in the linear filter. The EKF,”