Annex C: Load, Gage Output, and Coordinate Transformations

Force and Moment Sign Convention: The sign convention of the loads in the body (balance) axis system (North American convention) is taken from the following two references: 1. Pope, A., and Goin, K. L., *High-Speed Wind Tunnel Testing,* R. E. Krieger Publishing Co., reprint edition 1978, p.242, Fig.7:1.; 2. AIAA Balance Technology Working Group, *Calibration and Use of Internal Strain-Gage Balances*, AIAA R-091-2003, p.3, Fig.1.

Load Transformations: The load transformations were derived assuming that related "forward" and "aft" gages are equidistant about the balance moment center (Reference: Ulbrich, N., and Bader, J., "Analysis of Sting Balance Calibration Data Using Optimized Regression Models," AIAA 2009-5372, 45th Joint Propulsion Conference, Denver, Colorado, Aug. 2009, pp.18-21).

Gage Output Transformations: The gage output transformations were derived from the load transformations assuming that (i) the primary gage load is approximately proportional to the primary gage output, (ii) the gage sensitivity is the constant of proportionality, and (iii) the sensitivity of a "forward" gage is more or less identical with the sensitivity of the corresponding "aft" gage.

FROM Force Balance Format TO Direct-Read Format

Loads:	**Gage Outputs:**
NF = N1 + N2	rNF = rN1 + rN2
PM = [N1 – N2] * (a/2)	rPM = rN1 – rN2
SF = S1 + S2	rSF = rS1 + rS2
YM = [S1 – S2] * (b/2)	rYM = rS1 – rS2

FROM Direct-Read Format TO Force Balance Format

Loads:	**Gage Outputs:**
N1 = NF / 2 + PM / a	rN1 = [rNF + rPM] / 2
N2 = NF / 2 – PM / a	rN2 = [rNF – rPM] / 2
S1 = SF / 2 + YM / b	rS1 = [rSF + rYM] / 2
S2 = SF / 2 – YM / b	rS2 = [rSF – rYM] / 2

FROM Moment Balance Format TO Direct-Read Format

Loads:	**Gage Outputs:**
NF = [(–PM1) + PM2] / g	rNF = (–rPM1) + rPM2
PM = [PM1 + PM2] / 2	rPM = rPM1 + rPM2
SF = [(–YM1) + YM2] / h	rSF = (–rYM1) + rYM2
YM = [YM1 + YM2] / 2	rYM = rYM1 + rYM2

FROM Direct-Read Format TO Moment Balance Format

Loads:	**Gage Outputs**
PM1 = PM – NF * (g/2)	rPM1 = [rPM – rNF] / 2
PM2 = PM + NF * (g/2)	rPM2 = [rPM + rNF] / 2
YM1 = YM – SF * (h/2)	rYM1 = [rYM – rSF] / 2
YM2 = YM + SF * (h/2)	rYM2 = [rYM + rSF] / 2

FROM Alternate Balance Axis System (Fig. 2) TO North American Balance Axis System (Fig. 1)

Coordinates:	**Forces:**	**Moments:**
$X_{BAL} = -X$	$AF = +F_X$	$RM = -M_X$
$Y_{BAL} = +Y$	$SF = +F_Y$	$PM = +M_Y$
$Z_{BAL} = -Z$	$NF = +F_Z$	$YM = -M_Z$

Nomenclature:

a = distance between forward and aft normal force gages

b = distance between forward and aft side force gages

g = distance between forward and aft pitching moment gages

h = distance between forward and aft yawing moment gages

NF = normal force at the balance moment center

PM = pitching moment at the balance moment center

SF = side force at the balance moment center

YM = yawing moment at the balance moment center

rNF = electrical output of the normal force gage

rPM = electrical output of the pitching moment gage

rSF = electrical output of the side force gage

rYM = electrical output of the yawing moment gage

N1 = normal force at the forward normal force gage

N2 = normal force at the aft normal force gage

S1 = side force at the forward side force gage

S2 = side force at the aft side force gage

rN1 = electrical output of the forward normal force gage

rN2 = electrical output of the aft normal force gage

rS1 = electrical output of the forward side force gage

rS2 = electrical output of the aft side force gage

PM1 = pitching moment at the forward pitching moment gage

PM2 = pitching moment at the aft pitching moment gage

YM1 = yawing moment at the forward yawing moment gage

YM2 = yawing moment at the aft yawing moment gage

rPM1 = electrical output of the forward pitching moment gage

rPM2 = electrical output of the aft pitching moment gage

rYM1 = electrical output of the forward yawing moment gage

rYM2 = electrical output of the aft yawing moment gage

X_{BAL}, Y_{BAL}, Z_{BAL} = balance axis system (used in North America)

X, Y, Z = alternate balance axis system (used outside of North America)

F_X = force vector in x-axis direction of alternate balance axis system

F_Y = force vector in y-axis direction of alternate balance axis system

F_Z = force vector in z-axis direction of alternate balance axis system

M_X = moment vector in x-axis direction of alternate balance axis system

M_Y = moment vector in y-axis direction of alternate balance axis system

M_Z = moment vector in z-axis direction of alternate balance axis system

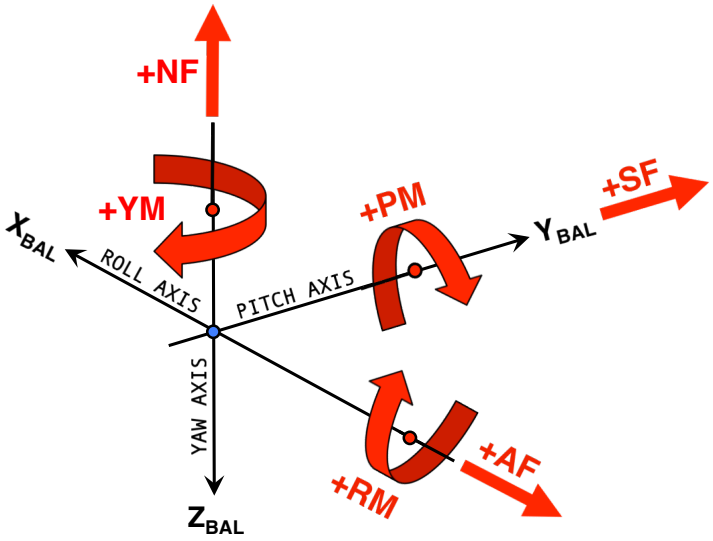

Figure 1 - Definition of Forces and Moments in North American Balance Axis System.

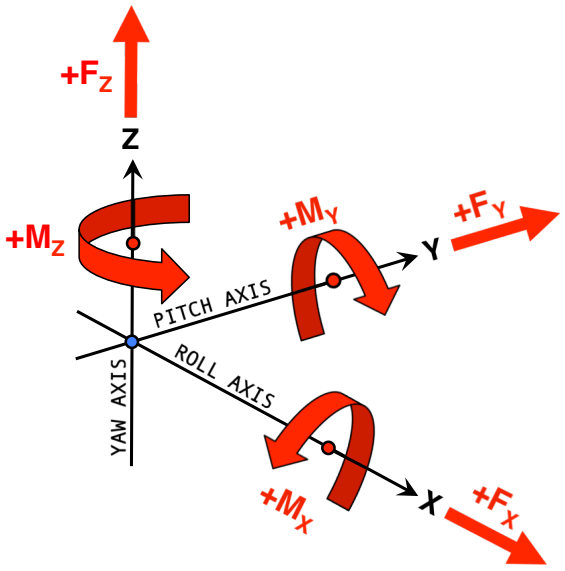

Figure 2 - Definition of Forces and Moments in Alternate Balance Axis System.