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Memo

To:	AAA Users
Company:	DARcorporation
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Title:	**Y-Tail Modeling in AAA**
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Memo Change History:

0959:	2/08/2012	Original
0959B:	3/14/2021	Added V-Tail with Inverted Vertical Tail

For all symbols, please refer to Advanced Aircraft Analysis 4.0

To use a Y-Tail, the vertical tail must be inverted. The Z-location of the aerodynamic center of the inverted vertical tail is calculated as follows:

$$Z_{ac_V} = Z_{apex_V} - z_{mgc_V} \tag{1}$$

For this combination, each vertical tail is treated a separate component and the corresponding S&C derivatives are calculated for each tail and summed up together as shown below:

$$C_{y_{\beta_V}} = C_{y_{\beta_{vee}}} + C_{y_{\beta_{V_{inverted\ tail}}}} \tag{2}$$

$$C_{l_{\beta_V}} = C_{y_{\beta_{vee}}} \left(\frac{\left(Z_{ac_{vee}} - Z_{cg}\right)\cos\alpha - \left(X_{ac_{vee}} - X_{cg}\right)\sin\alpha}{b_w} \right) + C_{y_{\beta_{V_{inverted\ tail}}}} \left(\frac{\left(Z_{ac_{V_{inverted\ tail}}} - Z_{cg}\right)\cos\alpha - \left(X_{ac_{V_{inverted\ tail}}} - X_{cg}\right)\sin\alpha}{b_w} \right) \tag{3}$$

$$C_{n_{\beta_V}} = -C_{y_{\beta_{V_{regular\ tail}}}} \left(\frac{\left(X_{ac_{V_{regular\ tail}}} - X_{cg}\right)\cos\alpha + \left(Z_{ac_{V_{regular\ tail}}} - Z_{cg}\right)\sin\alpha}{b_w} \right) - C_{y_{\beta_{V_{inverted\ tail}}}} \left(\frac{\left(X_{ac_{V_{inverted\ tail}}} - X_{cg}\right)\cos\alpha + \left(Z_{ac_{V_{inverted\ tail}}} - Z_{cg}\right)\sin\alpha}{b_w} \right) \tag{4}$$

$$C_{y_{\dot{\beta}}} = C_{y_{\dot{\beta}_{vee}}} + C_{y_{\dot{\beta}_{v_{inverted\ tail}}}} \tag{5}$$

$$C_{l_{\dot{\beta}}} = C_{y_{\dot{\beta}_{vee}}} \left(\frac{\left(Z_{ac_{v_i}} - Z_{ac_w}\right)_{vee} \cos\alpha - \left(X_{ac_{v_i}} - X_{ac_w}\right)_{vee} \sin\alpha}{b_w} \right) + C_{y_{\dot{\beta}_{v_{inverted\ tail}}}} \left(\frac{\left(Z_{ac_{v_i}} - Z_{ac_w}\right)_{inverted\ tail} \cos\alpha - \left(X_{ac_{v_i}} - X_{ac_w}\right)_{inverted\ tail} \sin\alpha}{b_w} \right) \tag{6}$$

$$C_{n_{\dot{\beta}}} = C_{y_{\dot{\beta}_{v_{regular\ tail}}}} \left(\frac{\left(X_{ac_{vee}} - X_{ac_w}\right)\cos\alpha + \left(Z_{ac_{vee}} - Z_{ac_w}\right)\sin\alpha}{b_w} \right) + C_{y_{\dot{\beta}_{v_{inverted\ tail}}}} \left(\frac{\left(X_{ac_{v_{inverted\ tail}}} - X_{ac_w}\right)\cos\alpha + \left(Z_{ac_{v_{inverted\ tail}}} - Z_{ac_w}\right)\sin\alpha}{b_w} \right) \tag{7}$$

$$C_{y_p} = \left(2C_{y_{\beta_{vee}}} \frac{\left(Z_{ac_{vee}} - Z_{cg}\right)\cos\alpha - \left(X_{ac_{vee}} - X_{cg}\right)\sin\alpha - \left(Z_{ac_{vee}} - Z_{cg}\right)}{b_w} \right) +$$

$$\left(2C_{y_{\beta_{v_{inverted}}}} \frac{\left(Z_{ac_{v_{inverted}}} - Z_{cg}\right)\cos\alpha - \left(X_{ac_{v_{inverted}}} - X_{cg}\right)\sin\alpha - \left(Z_{ac_{v_{inverted}}} - Z_{cg}\right)}{b_w} \right) +$$

$$3\sin\Gamma_w \left[1 - 4\frac{\left(Z_{cg} - Z_{c_{r/4_w}}\right)}{b_w}\sin\Gamma_w \right] C_{l_{p@\Gamma_w=0,C_L=0}} \quad (8)$$

$$C_{l_{p_v}} = \frac{2}{b_w^2} C_{y_{\beta_{vee}}} \left| \left(z_{vee}\cos\alpha - l_v\sin\alpha\right)\left[\left(z_{vee}\cos\alpha - l_v\sin\alpha\right) - \left(Z_{ac_{vee}} - Z_{cg}\right)\right] \right|$$
$$+ \frac{2}{b_w^2} C_{y_{\beta_{v_{inverted\ tail}}}} \left| \left(z_{v_{inverted\ tail}}\cos\alpha - l_v\sin\alpha\right)\left[\left(z_{v_{inverted\ tail}}\cos\alpha - l_v\sin\alpha\right) - \left(Z_{ac_{v_{inverted\ tail}}} - Z_{cg}\right)\right] \right| \quad (9)$$

$$C_{n_{p_v}} = -\frac{2}{b_w^2} C_{y_{\beta_{vee}}} \left| \left(l_v\cos\alpha + z_{vee}\sin\alpha\right)\left[\left(z_{vee}\cos\alpha - l_v\sin\alpha\right) - \left(Z_{ac_{vee}} - Z_{cg}\right)\right] \right|$$
$$- \frac{2}{b_w^2} C_{y_{\beta_{v_{inverted\ tail}}}} \left| \left(l_v\cos\alpha + z_{v_{inverted\ tail}}\sin\alpha\right)\left[\left(z_{v_{inverted\ tail}}\cos\alpha - l_v\sin\alpha\right) - \left(Z_{ac_{v_{inverted\ tail}}} - Z_{cg}\right)\right] \right| \quad (10)$$

$$C_{y_r} = -2C_{y_{\beta_{vee}}}\left(\frac{l_v\cos\alpha + z_{vee}\sin\alpha}{b_w}\right) - 2C_{y_{\beta_{v_{inverted\ tail}}}}\left(\frac{l_v\cos\alpha + z_{v_{inverted\ tail}}\sin\alpha}{b_w}\right) \quad (11)$$

$$\begin{aligned} C_{l_{r_v}} = &-\frac{2}{b_w^2}C_{y_{\beta_{vee}}}\left(l_v\cos\alpha + z_{vee}\sin\alpha\right)\left(z_{vee}\cos\alpha - l_v\sin\alpha\right) \\ &-\frac{2}{b_w^2}C_{y_{\beta_{v_{inverted\ tail}}}}\left(l_v\cos\alpha + z_{v_{inverted\ tail}}\sin\alpha\right)\left(z_{v_{inverted\ tail}}\cos\alpha - l_v\sin\alpha\right) \end{aligned} \quad (12)$$

$$\begin{aligned} C_{n_{r_v}} = &-\frac{2}{b_w^2}C_{y_{\beta_{vee}}}\left[\left(X_{ac_v} - X_{cg}\right)\cos\alpha + \left(Z_{ac_{vee}} - Z_{cg}\right)\sin\alpha\right]^2 \\ &-\frac{2}{b_w^2}C_{y_{\beta_{v_{inverted\ tail}}}}\left[\left(X_{ac_v} - X_{cg}\right)\cos\alpha + \left(Z_{ac_{v_{inverted\ tail}}} - Z_{cg}\right)\sin\alpha\right]^2 \end{aligned} \quad (13)$$

$$C_{y_{i_v}} = C_{y_{i_{vee}}} + C_{y_{i_{v_{inverted\ tail}}}} \quad (14)$$

$$C_{l_{i_v}} = C_{y_{i_{vee}}}\left(\frac{z_{vee}\cos\alpha - l_v\sin\alpha}{b_w}\right) + C_{y_{i_{v_{inverted\ tail}}}}\left(\frac{z_{v_{inverted\ tail}}\cos\alpha - l_v\sin\alpha}{b_w}\right) \quad (15)$$

$$C_{n_{i_v}} = -C_{y_{i_{vee}}}\left(\frac{l_v\cos\alpha + z_{vee}\sin\alpha}{b_w}\right) - C_{y_{i_{v_{inverted\ tail}}}}\left(\frac{l_v\cos\alpha + z_{v_{inverted\ tail}}\sin\alpha}{b_w}\right) \quad (16)$$

$$C_{y_{\delta_r}} = C_{y_{\delta_{r_{vee}}}} + C_{y_{\delta_{r_{inverted\ tail}}}} \tag{17}$$

$$C_{l_{\delta_r}} = C_{y_{\delta_{r_{vee}}}} \left(\frac{z_{r_{vee}} \cos\alpha - l_{r_{vee}} \sin\alpha}{b_w} \right) + C_{y_{\delta_{r_{inverted\ tail}}}} \left(\frac{z_{r_{inverted\ tail}} \cos\alpha - l_{r_{inverted\ tail}} \sin\alpha}{b_w} \right) \tag{18}$$

$$C_{n_{\delta_r}} = -C_{y_{\delta_{r_{vee}}}} \left(\frac{l_{r_{vee}} \cos\alpha + z_{r_{vee}} \sin\alpha}{b_w} \right) - C_{y_{\delta_{r_{inverted\ tail}}}} \left(\frac{l_{r_{inverted\ tail}} \cos\alpha + z_{r_{inverted\ tail}} \sin\alpha}{b_w} \right) \tag{19}$$