Includi << ..\Default_Functions.mcdx

VERTICAL TAIL PARAMETERS INITIALIZATION

Hidden Area --> Import of Excel INPUT V-Tail Data

Hidden Area --> Preliminary Mapping of imported Data

Hidden Area --> Import and preliminary mapping of OTHER Excel Data

INPUT V-TAIL PARAMETERS LIST

Input parameters

$b_V = 4.831\ m$ $\quad$ $\Lambda_{V\_LE} = 47\ deg$ $\quad$ $\Gamma_V = 0\ deg$

$\xi_{tmax\_V} = 0.4$ $\quad$ $\varepsilon_V = 0\ deg$ $\quad$ $\eta_V = 0.97$

$c_{V\_r} = 5.273\ m$ $\quad$ $t\_over\_c_{V\_r} = 0.11$ $\quad$ $C_{l\alpha\_V\_r} = 0.105\ \dfrac{1}{deg}$

$\xi_{ac\_V\_r} = 0.25$ $\quad$ $C_{m\_ac\_V\_r} = -0.07$ $\quad$ $M_{cr\_V\_2D\_r} = 0.68$

$c_{V\_t} = 3.231\ m$ $\quad$ $t\_over\_c_{V\_t} = 0.11$ $\quad$ $C_{l\alpha\_V\_t} = 0.105\ \dfrac{1}{deg}$

$\xi_{ac\_V\_t} = 0.25$ $\quad$ $C_{m\_ac\_V\_t} = -0.07$ $\quad$ $M_{cr\_V\_2D\_t} = 0.68$

$\eta_{rd\_in} = 0$ $\quad$ $\eta_{rd\_out} = 0.656$ $\quad$ $c_{rd} = 1.89\ m$

Imported parameters

$\Delta X\_W_{LE}\_Nose = 11.13\ m$ $\quad$ $\Delta X\_VT_{LE}\_Nose = 22.3\ m$ $\quad$ $\Delta Z\_W_{LE}\_Nose = -0.94\ m$

$\Delta Z\_HT_{ac}\_W_{ac} = 6.83\ m$

$M_1 = 0.696$ $\quad$ $c_{W\_r} = 5.243\ m$ $\quad$ $i_W = 2\ deg$

$S_W = 87.62\ m^2$ $\quad$ $MAC_W = 3.642\ m$ $\quad$ $\Lambda_{W\_c4\_eqv} = 2\ deg$

$AR_W = 8.474$ $\quad$ $r_1 = 1.52\ m$ $\quad$ $h_1 = 2.35\ m$

$b_H = 11.217\ m$ $\quad$ $S_H = 25.47\ m^2$ $\quad$ $MAC_H = 2.433\ m$

$X_{MAC\_LE\_H} = 1.66\ m$ $\quad$ $X_{ac\_WB} = 3.265\ m$

VTAIL PARAMETERS CALCULATIONS

V-Tail basic parameters

$b_{2V} := 2 \cdot b_V = 9.662\ m$

- Considering Vertical Tail like other wings

$b_{2V} = 9.662\ m$

$\lambda_V := \dfrac{c_{V\_t}}{c_{V\_r}} = 0.613$ $\qquad \lambda_V = 0.613$

$S_V := \dfrac{b_V}{2} \cdot c_{V\_r} \cdot (1 + \lambda_V) = 20.542\ m^2$ $\qquad S_V = 20.542\ m^2$

$S_{2V} := \dfrac{b_{2V}}{2} \cdot c_{V\_r} \cdot (1 + \lambda_V) = 41.083\ m^2$ $\qquad S_{2V} = 41.083\ m^2$

$AR_{2V} := \dfrac{b_{2V}^{\ 2}}{S_{2V}} = 2.272$ $\qquad AR_{2V} = 2.272$

$AR_V := AR_{2V}$ $\qquad AR_V = 2.272$

$MAC_V := \dfrac{2}{3} \cdot c_{V\_r} \cdot \left(\dfrac{1 + \lambda_V^{\ 2} + \lambda_V}{1 + \lambda_V} \right) = 4.334\ m$ $\qquad MAC_V = 4.334\ m$

$X_{MAC\_LE\_V} := \dfrac{b_{2V}}{6} \cdot \dfrac{(1 + 2 \cdot \lambda_V)}{(1 + \lambda_V)} \cdot \tan(\Lambda_{V\_LE}) = 2.383\ m$ $\qquad X_{MAC\_LE\_V} = 2.383\ m$

$Y_{MAC\_V} := \dfrac{b_{2V}}{6} \cdot \dfrac{1 + 2 \cdot \lambda_V}{1 + \lambda_V} = 2.222\ m$ $\qquad Y_{MAC\_V} = 2.222\ m$

$Z_{MAC\_V} := Y_{MAC\_V} \cdot \tan(\Gamma_V) = 0\ m$ $\qquad Z_{MAC\_V} = 0\ m$

V-Tail, sweep angles

$_{f}\Lambda(x, \Lambda_{le}, AR, \lambda) := \text{if}\left(AR = 0, \Lambda_{le}, \text{atan}\left(\tan(\Lambda_{le}) - \dfrac{4 \cdot x \cdot (1 - \lambda)}{AR \cdot (1 + \lambda)} \right) \right)$

- **Sweep angle function**

$\Lambda_{V\_LE} := {_f}\Lambda(0, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.82$ $\qquad \Lambda_{V\_LE} = 47\ deg$

$\Lambda_{V\_TE} := {_f}\Lambda(1, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.576$ $\qquad \Lambda_{V\_TE} = 33.01\ deg$

$\Lambda_{V\_c4} := {_f}\Lambda(0.25, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.768$ $\qquad \Lambda_{V\_c4} = 44.03\ deg$

$\Lambda_{V\_c2} := {_f}\Lambda(0.5, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.711$ $\qquad \Lambda_{V\_c2} = 40.729\ deg$

$\Lambda_{V\_tmax} := {_f}\Lambda(\xi_{tmax\_V}, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.735$ $\qquad \Lambda_{V\_tmax} = 42.091\ deg$

Hidden Area --> V-Tail, linear laws coefficients

V-Tail, linear laws defined over the whole semi-span

$_f c_V(y) := A_{c\_V} \cdot y + B_{c\_V}$

$_f t\_over\_c_V(y) := A_{tc\_V} \cdot y + B_{tc\_V}$

$_f C_{l\alpha\_V}(y) := A_{Cl\alpha\_V} \cdot y + B_{Cl\alpha\_V}$

$_f C_{m\_ac\_2D\_V}(y) := A_{Cm0\_V} \cdot y + B_{Cm0\_V}$

$_f \varepsilon_{g\_V}(y) := A_{\varepsilon\_V} \cdot y + B_{\varepsilon\_V}$

$_f \xi_{ac\_2D\_V}(y) := A_{\xi ac\_V} \cdot y + B_{\xi ac\_V}$

$_f M_{cr\_V\_2D}(y) := A_{Mcr\_V} \cdot y + B_{Mcr\_V}$

V-Tail, 2D mean quantities

$$t\_over\_c_{V\_mean} := \frac{1}{S_V} \cdot \int_0^{b_V} {_f c_V}(y) \cdot {_f t\_over\_c_V}(y)\, dy = 0.084$$

$t\_over\_c_{V\_mean} = 0.084$

$$C_{m\_ac\_V\_mean} := \frac{1}{S_V \cdot MAC_V} \cdot \int_0^{b_V} {_f c_V}(y)^2 \cdot {_f C_{m\_ac\_2D\_V}}(y)\, dy = -0.045$$

$C_{m\_ac\_V\_mean} = -0.045$

$$C_{l\alpha\_V\_mean} := \frac{1}{S_V} \cdot \int_0^{b_V} {_f c_V}(y) \cdot {_f C_{l\alpha\_V}}(y)\, dy = 4.571$$

$C_{l\alpha\_V\_mean} = 0.08\ deg^{-1}$

MISCELLANEOUS DATA CALCULATIONS

$$\Delta X\_VT_{LE}\_W_{LE} := \Delta X\_VT_{LE}\_Nose - \Delta X\_W_{LE}\_Nose = 11.17\ m$$

$$\Delta X\_VT_{c4\_r}\_W_{c4\_r} := \Delta X\_VT_{LE}\_W_{LE} + \frac{c_{V\_r}}{4} - \frac{c_{W\_r}}{4} = 11.178\ m$$

$$\Delta Z\_W_{c4\_r}\_B_{CL} := \Delta Z\_W_{LE}\_Nose + \sin(i_W) \cdot \frac{c_{W\_r}}{4} = -0.894\ m$$

$$\Delta Z\_HT_{c4\_r}\_B_{CL} := \Delta Z\_W_{c4\_r}\_B_{CL} - \Delta Z\_HT_{ac}\_W_{ac} = -7.724\ m$$

$$x_{AC\_HV} := X_{MAC\_LE\_H} + 0.25 \cdot MAC_H = 2.268\ m$$

Rudder inner and outer stations and area

$y_{rd\_in} := \eta_{rd\_in} \cdot b_V = 0\ m$

$y_{rd\_in} = 0\ m$

$y_{rd\_out} := \eta_{rd\_out} \cdot b_V = 3.169\ m$

$y_{rd\_out} = 3.169\ m$

$$c_{V\_mean\_@rd} := {_f c_V}\left(\frac{y_{rd\_in} + y_{rd\_out}}{2}\right) = 3.933\ m$$

$c_{V\_mean\_@rd} = 3.933\ m$

$$S_{rd} := 2 \cdot c_{rd} \cdot (y_{rd\_out} - y_{rd\_in}) = 11.978\ m^2$$

$S_{rd} = 11.978\ m^2$

@Aerodynamic Database ---> (control_surface)_tau_e_vs_c_control_surface_over_c_horizontal_tail

$\tau_{rd} = 0.68$

Induced drag factors, only due to geometric effects

$$e_{V\_alt} := \frac{2}{2 - AR_V + \sqrt{4 + AR_V^{\,2} \left(1 + \tan\left(\Lambda_{V\_tmax}\right)^2\right)}} = 0.591$$

$e_{V\_alt} = 0.591$

$$e_{V\_alt\_\Lambda 0} := 1.78 \cdot \left(1 - 0.045 \cdot AR_V^{\,0.68}\right) - 0.64 = 1$$

- **Alternative formula: valid for unswept wings**

$$e_{V\_alt\_\Lambda} := 4.61 \cdot \left(1 - 0.045 \cdot AR_V^{\,0.68}\right) \cdot \cos\left(\Lambda_{V\_LE}\right)^{0.15} - 3.1 = 0.911$$

- **Alternative formula: valid for swept wings**

3d critical Mach number at mean aerodynamic chord

$$M_{cr\_V\_3D\_@MAC\_V} := \frac{{}_{\mathrm{f}}\mathrm{M}_{\mathrm{cr\_V\_2D}}\left(Y_{MAC\_V}\right)}{\cos\left(\Lambda_{V\_LE}\right)} = 0.997$$

$M_{cr\_V\_3D\_@MAC\_V} = 0.997$

VERTICAL TAIL EFFECTIVE ASPETC RATIO

@Aerodynamic Database ---> (control_surface)_tau_e_vs_c_control_surface_over_c_horizontal_tail

$c_1 = 1.606$

@Aerodynamic Database ---> (AR_v_eff)_c2_vs_Z_h_over_b_v_(x_ac_h--v_over_c_bar_v)

$c_2 = -7.943$

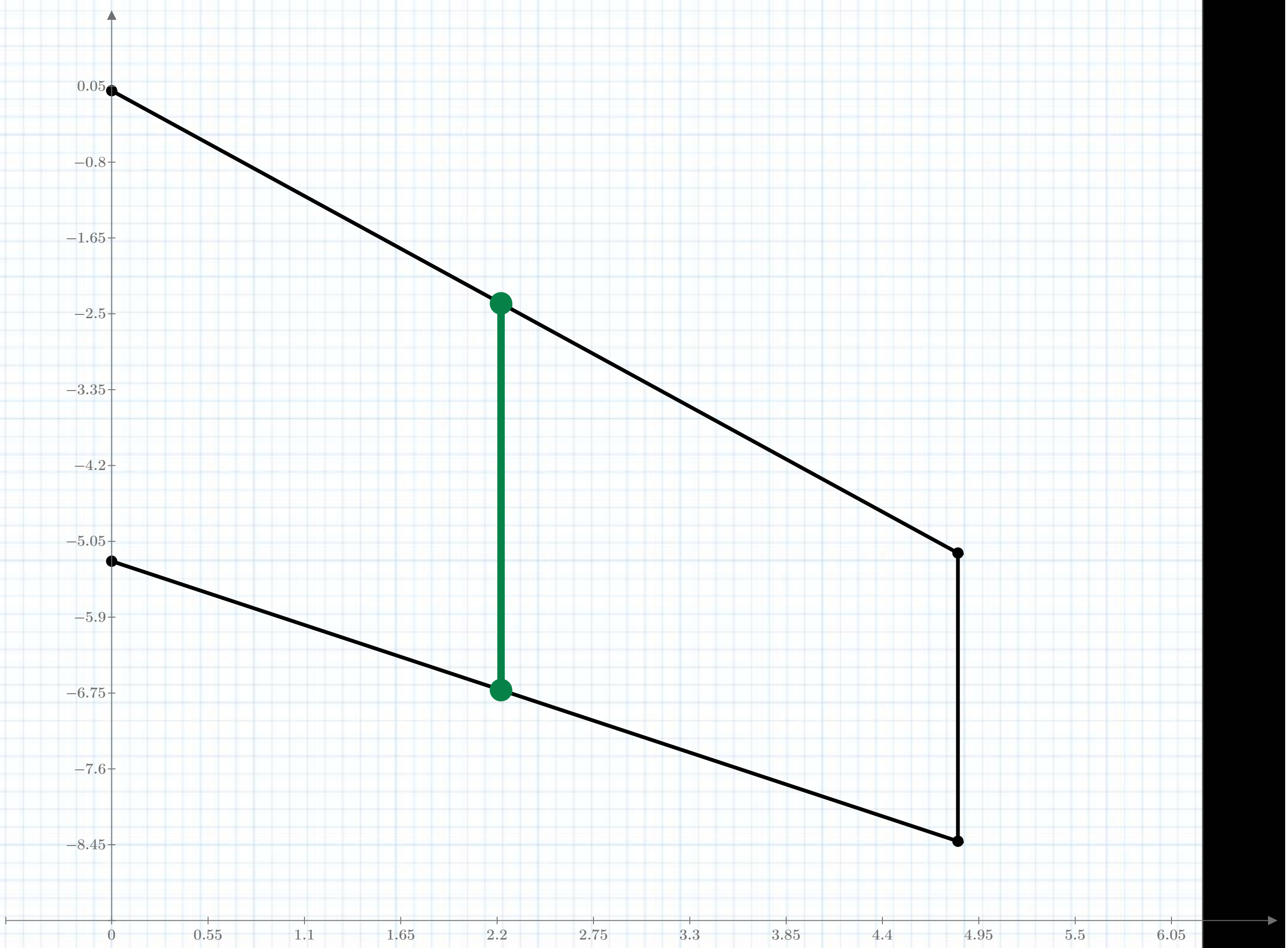
@Aerodynamic Database ---> (AR_v_eff)_k_h_v_vs_S_h_over_S_v

$K_{HV} = 0.988$

$$AR_{V\_eff} := c_1 \cdot AR_V \cdot \left(1 + K_{HV} \cdot \left(c_2 - 1\right)\right) = -28.583$$

$AR_{V\_eff} = -28.583$

V-Tail planform with Mean Aerodynamic Chord



VERTICAL TAIL LIFT-CURVE SLOPE

V-Tail Lift Curve Slope, function definitions

- **Polhamus Formula Coefficient**

$$
{}_f k_{\text{Polhamus}}\left(M, M_{cr\_3D}, \Lambda_{LE}, \lambda, AR\right) :=
\begin{array}{l}
\text{if } \left(M < M_{cr\_3D}\right) \wedge \left(\Lambda_{LE} < 32\ deg\right) \wedge (\lambda > 0.4) \wedge (\lambda < 1) \wedge (AR > 3) \wedge (AR < 8) \\
\quad \begin{array}{l}
\text{if } AR < 4 \\
\quad \text{return } 1 + \dfrac{AR \cdot \left(1.87 - 0.000233 \cdot \Lambda_{LE}\right)}{100} \\
\text{else} \\
\quad \text{return } 1 + \dfrac{\left(\left(8.2 - 2.3 \cdot \Lambda_{LE}\right) - AR \cdot \left(0.22 - 0.153 \cdot \Lambda_{LE}\right)\right)}{100}
\end{array} \\
\text{else} \\
\quad \text{return } 100
\end{array}
$$

(---> Polhamus Formula is not valid)

$$_f C_{L\alpha\_V}(M, k_P, AR, \Lambda_{c2}, C_{l\alpha@MAC}, \Lambda_{LE}) := \text{if } k_P \neq 100 \quad \text{(---> use Polhamus Formula)}$$

$$\left\| \text{return } \frac{2 \cdot \pi \cdot AR}{2 + \sqrt{\left(\left(\frac{AR^2 \cdot (1 - M^2)}{k_P^{\,2}}\right)\left(1 + \frac{\tan(\Lambda_{c2})^2}{(1 - M^2)}\right)\right) + 4}} \right.$$

$$\text{else} \quad \text{(---> use alternative formula)}$$

$$\left\| \begin{array}{l} a_0 \leftarrow \dfrac{C_{l\alpha@MAC}}{\sqrt{1 - M^2 \cdot \cos(\Lambda_{LE})^2}} \\ \text{return } \dfrac{a_0 \cdot \cos(\Lambda_{LE})}{\sqrt{1 - (M \cdot \cos(\Lambda_{LE}))^2 + \left(\dfrac{a_0 \cdot \cos(\Lambda_{LE})}{\pi \cdot AR}\right)^2} + \dfrac{a_0 \cdot \cos(\Lambda_{LE})}{\pi \cdot AR}} \end{array} \right.$$

- **General Formula for Lift Curve Slope**

V-Tail Lift Curve Slope, general formula for inner/outer panel and whole wing

$k_{Polhamus\_V} := {}_f k_{Polhamus}(M_1, M_{cr\_V\_3D\_@MAC\_V}, \Lambda_{V\_LE}, \lambda_V, AR_V) = 100$ $\quad k_{Polhamus\_V} = 100$

$C_{l\alpha\_V\_@MAC\_V} := {}_f C_{l\alpha\_V}(Y_{MAC\_V}) = 6.016$ $\quad C_{l\alpha\_V\_@MAC\_V} = 0.105\ deg^{-1}$

$C_{L\alpha\_V\_@M0} := {}_f C_{L\alpha\_V}(0, k_{Polhamus\_V}, AR_V, \Lambda_{V\_c2}, C_{l\alpha\_V\_@MAC\_V}, \Lambda_{V\_LE})$

$C_{L\alpha\_V\_@M0} = 2.374\ rad^{-1}$ $\quad C_{L\alpha\_V\_@M0} = 0.041\ deg^{-1}$

$C_{L\alpha\_V} := {}_f C_{L\alpha\_V}(M_1, k_{Polhamus\_V}, AR_{V\_eff}, \Lambda_{V\_c2}, C_{l\alpha\_V\_@MAC\_V}, \Lambda_{V\_LE})$

$C_{L\alpha\_V} = 5.618\ rad^{-1}$ $\quad C_{L\alpha\_V} = 0.098\ deg^{-1}$

Induced drag factor, due to both geometric and aerodynamic effects

$$_f e(C_{L\alpha}, AR, \lambda, \Lambda_{LE}) := \left\| \begin{array}{l} \lambda_e \leftarrow \dfrac{AR \cdot \lambda}{\cos(\Lambda_{LE})} \\ R \leftarrow 0.0004 \cdot \lambda_e^{\,3} - 0.008 \cdot \lambda_e^{\,2} + 0.0501 \cdot \lambda_e + 0.8642 \\ \text{return if}\left(AR = 0, 0, \dfrac{1.1 \cdot C_{L\alpha}}{R \cdot C_{L\alpha} + (1 - R)\,\pi \cdot AR}\right) \end{array} \right.$$

- **Function for calculating wing induced drag factor, icluding aerodynamic and geometric effects**

$e_V := {}_f e(C_{L\alpha\_V}, AR_{V\_eff}, \lambda_V, \Lambda_{V\_LE}) = -0.005$ $\quad e_V = -0.005$

V-Tail Lift Curve Slope, classic formula

$$C_{L\alpha\_V\_classic} := \frac{C_{l\alpha\_V\_mean}}{\sqrt[2]{1 - M_1^{\,2}} + \dfrac{C_{l\alpha\_V\_mean}}{\pi \cdot AR_V \cdot e_V}} = -0.035$$

$C_{L\alpha\_V\_classic} = -0.035$

V-TAIL AERODYNAMIC CENTER - GRAPHICAL METHOD (DATCOM/NAPOLITANO)

@Aerodynamic Database ---> (x_bar_ac_w)_k1_vs_lambda

$K1_{ac\_V\_Datcom} = 1.213$

@Aerodynamic Database ---> (x_bar_ac_w)_k2_vs_L_LE_(AR)_(lambda)

$K2_{ac\_V\_Datcom} = 0.454$

@Aerodynamic Database ---> (x_bar_ac_w)_x'_ac_over_root_chord_vs_tan_(L_LE)_over_beta_(AR_times_tan_(L_LE))_(lambda)

$X_{ac\_over\_c_{r\_V\_Datcom}} = 0.664$

Aerodynamic center positions

$\xi_{ac\_V} := K1_{ac\_V\_Datcom} \cdot \left(X_{ac\_over\_c_{r\_V\_Datcom}} - K2_{ac\_V\_Datcom}\right) = 0.255$

$X_{ac\_V} := \xi_{ac\_V} \cdot MAC_V + X_{MAC\_LE\_V} = 3.487\ m$ $\qquad X_{ac\_V} = 3.487\ m$

$x_{ac\_V} := X_{ac\_V} - X_{MAC\_LE\_V} = 1.104\ m$ $\qquad x_{ac\_V} = 1.104\ m$

V-Tail Volume Ratio based on aerodynamic centers distance

$$\Delta X\_VT_{ac}\_W_{TE} := \Delta X\_VT_{LE}\_Nose - \Delta X\_W_{LE}\_Nose - c_{W\_r} + X_{ac\_V} = 9.414\ m$$

$$\Delta X\_VT_{ac}\_W_{ac} := \Delta X\_VT_{LE}\_Nose - \Delta X\_W_{LE}\_Nose - X_{ac\_WB} + X_{ac\_V} = 11.392\ m$$

$$VolumeRatio_{V\_ac} := \frac{S_V}{S_W} \cdot \frac{\Delta X\_VT_{ac}\_W_{ac}}{MAC_W} = 0.733$$

3D PITCHING MOMENT COEFFICIENT ABOUT V-TAIL AERODYNAMIC CENTER

Approximated formulation (Roskam)

$$C_{Mac\_V} := \frac{2}{S_V \cdot MAC_V} \cdot \int_0^{b_V} {}_{f}\mathrm{C_{m\_ac\_2D\_V}}(y) \cdot {}_{f}\mathrm{c_V}(y)^2 \,\mathrm{d}y = -0.09$$

$$C_{Mac\_V} = -0.09$$

SIDEWASH EFFECT

$$\eta_V\_times\_1\_plus\_d\sigma\_over\_d\beta := 0.724 + 3.06 \cdot \frac{\frac{S_V}{S_W}}{1 + \cos\left(\Lambda_{W\_c4\_eqv}\right)} + 0.4 \cdot \frac{\Delta Z\_W_{c4\_r}\_B_{CL}}{h_1} + 0.009 \cdot AR_W = 1.007$$

MAPPING AND OUTPUT CREATION

Includi << ..\Default_Map_VTail.mcdx

Excel Writing

$First\_Row_{V\_1} := 4$

$Block_{V\_1} := {}_{f}\mathrm{map\_matrix\_transform}\left({}_{m}VTail\_Data\_Map_{imported}\right)$

$Excel\_Output_{V\_1} := {}_{f}\mathrm{write\_full\_output}\left({}_{s}Output\_Excel\_File, Block_{V\_1}, n_{sheet}, First\_Row_{V\_1}\right)$

$First\_Row_{V\_2} := First\_Row_{V\_1} + \mathrm{rows}\left(Block_{V\_1}\right) + 2 = 40$

$Block_{V\_2} := {}_{f}\mathrm{map\_matrix\_transform}\left({}_{m}VTail\_Data\_Map_{input}\right)$

$Excel\_Output_{V\_2} := {}_{f}\mathrm{write\_full\_output}\left({}_{s}Output\_Excel\_File, Block_{V\_2}, n_{sheet}, First\_Row_{V\_2}\right)$

$First\_Row_{V\_3} := First\_Row_{V\_2} + \mathrm{rows}\left(Block_{V\_2}\right) + 2 = 72$

$Block_{V\_3} := {}_{f}\mathrm{map\_matrix\_transform}\left({}_{m}VTail\_Data\_Map\right)$

$Excel\_Output_{V\_3} := {}_{f}\mathrm{write\_full\_output}\left({}_{s}Output\_Excel\_File, Block_{V\_3}, n_{sheet}, First\_Row_{V\_3}\right)$

$First\_Row_{V\_4} := First\_Row_{V\_3} + \text{rows}\left(Block_{V\_3}\right) + 2 = 142$

$Block_{V\_4} := {}_{f}\text{map\_matrix\_transform}\left({}_{m}VTail\_Data\_Map_{LLCoeffs}\right)$

$Excel\_Output_{V\_4} := {}_{f}\text{write\_full\_output}\left({}_{s}Output\_Excel\_File, Block_{V\_4}, n_{sheet}, First\_Row_{V\_4}\right)$

$First\_Row_{V\_5} := First\_Row_{V\_4} + \text{rows}\left(Block_{V\_4}\right) + 2 = 171$

$Block_{V\_5} := {}_{f}\text{map\_matrix\_transform}\left({}_{m}VTail\_Data\_Map_{Misc}\right)$

$Excel\_Output_{V\_5} := {}_{f}\text{write\_full\_output}\left({}_{s}Output\_Excel\_File, Block_{V\_5}, n_{sheet}, First\_Row_{V\_5}\right)$

TeX Macro writing on .tex

${}_{v}complete\_macros_{V} := \text{stack}\left(Block_{V\_1}^{\langle 2\rangle}, Block_{V\_2}^{\langle 2\rangle}, Block_{V\_3}^{\langle 2\rangle}, Block_{V\_4}^{\langle 2\rangle}, Block_{V\_5}^{\langle 2\rangle}\right)$

${}_{v}tex_{V} := {}_{f}\text{write\_matrix}\left(\text{“.\textbackslash Output\textbackslash VTAIL\_TeX\_Macros.tex”}, {}_{v}complete\_macros_{V}, \text{“ ”}\right)$