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

$b_V = 10.68\ m$ $\Lambda_{V\_LE} = 44.5\ deg$ $\Gamma_V = 0\ deg$

$\xi_{tmax\_V} = 0.35$ $\varepsilon_V = 0\ deg$ $\eta_V = 1$

$c_{V\_r} = 8.1\ m$ $t\_over\_c_{V\_r} = 0.12$ $C_{l\alpha\_V\_r} = 0.12\ \frac{1}{deg}$

$\xi_{ac\_V\_r} = 0.25$ $C_{m\_ac\_V\_r} = 0$ $M_{cr\_V\_2D\_r} = 0.7$

$c_{V\_t} = 2.51\ m$ $t\_over\_c_{V\_t} = 0.09$ $C_{l\alpha\_V\_t} = 0.12\ \frac{1}{deg}$

$\xi_{ac\_V\_t} = 0.25$ $C_{m\_ac\_V\_t} = 0$ $M_{cr\_V\_2D\_t} = 0.7$

$\eta_{rd\_in} = 0$ $\eta_{rd\_out} = 0.95$ $c_{rd} = 1.83\ m$

## Imported parameters

$\Delta X\_W_{LE}\_Nose = 25.05\ m$ $\Delta X\_VT_{LE}\_Nose = 61.96\ m$ $\Delta Z\_W_{LE}\_Nose = -0.75\ m$

$\Delta Z\_HT_{ac}\_W_{ac} = 1.65\ m$

$M_1 = 0.65$ $c_{W\_r} = 15.57\ m$ $i_W = 2\ deg$

$S_W = 468.83\ m^2$ $MAC_W = 9.505\ m$ $\Lambda_{W\_c4\_eqv} = 2\ deg$

$AR_W = 7.916$ $r_1 = 3.9\ m$ $h_1 = 6.33\ m$

$b_H = 21.96\ m$ $S_H = 105.41\ m^2$ $MAC_H = 5.2\ m$

$X_{MAC\_LE\_H} = 3.705\ m$ $X_{ac\_WB} = 8.057\ m$

# VTAIL PARAMETERS CALCULATIONS

## V-Tail basic parameters

$b_{2V} := 2 \cdot b_V = 21.36\ m$ 

- Considering Vertical Tail like other wings

$b_{2V} = 21.36\ m$

$\lambda_V := \frac{c_{V\_t}}{c_{V\_r}} = 0.31$ $\lambda_V = 0.31$

$S_V := \frac{b_V}{2} \cdot c_{V\_r} \cdot (1 + \lambda_V) = 56.657\ m^2$ $S_V = 56.657\ m^2$

$S_{2V} := \frac{b_{2V}}{2} \cdot c_{V\_r} \cdot (1 + \lambda_V) = 113.315\ m^2$ $S_{2V} = 113.315\ m^2$

$AR_{2V} := \frac{{b_{2V}}^2}{S_{2V}} = 4.026$ $AR_{2V} = 4.026$

$AR_V := AR_{2V}$ $AR_V = 4.026$

$MAC_V := \frac{2}{3} \cdot c_{V\_r} \cdot \left( \frac{1 + {\lambda_V}^2 + \lambda_V}{1 + \lambda_V} \right) = 5.796\ m$ $MAC_V = 5.796\ m$

$X_{MAC\_LE\_V} := \frac{b_{2V}}{6} \cdot \frac{(1 + 2 \cdot \lambda_V)}{(1 + \lambda_V)} \cdot \tan(\Lambda_{V\_LE}) = 4.326\ m$ $X_{MAC\_LE\_V} = 4.326\ m$

$Y_{MAC\_V} := \frac{b_{2V}}{6} \cdot \frac{1 + 2 \cdot \lambda_V}{1 + \lambda_V} = 4.402\ m$ $Y_{MAC\_V} = 4.402\ m$

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

## V-Tail, sweep angles

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

- **Sweep angle function**

$\Lambda_{V\_LE} := {_f\Lambda}(0, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.777$ $\Lambda_{V\_LE} = 44.5\ deg$

$\Lambda_{V\_TE} := {_f\Lambda}(1, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.431$ $\Lambda_{V\_TE} = 24.669\ deg$

$\Lambda_{V\_c4} := {_f\Lambda}(0.25, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.706$ $\Lambda_{V\_c4} = 40.426\ deg$

$\Lambda_{V\_c2} := {_f\Lambda}(0.5, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.625$ $\Lambda_{V\_c2} = 35.791\ deg$

$\Lambda_{V\_tmax} := {_f\Lambda}(\xi_{tmax\_V}, \Lambda_{V\_LE}, AR_V, \lambda_V) = 0.674$ $\Lambda_{V\_tmax} = 38.642\ deg$

## 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

$$t\_over\_c_{V\_mean} := \frac{1}{S_V} \cdot \int_0^{b_V} {_{f}c_V}(y) \cdot {_{f}t\_over\_c_V}(y)\, dy = 0.053$$

$t\_over\_c_{V\_mean} = 0.053$

$$C_{m\_ac\_V\_mean} := \frac{1}{S_V \cdot MAC_V} \cdot \int_0^{b_V} {_{f}c_V}(y)^2 \cdot {_{f}C_{m\_ac\_2D\_V}}(y)\, dy = 0$$

$C_{m\_ac\_V\_mean} = 0$

$$C_{l\alpha\_V\_mean} := \frac{1}{S_V} \cdot \int_0^{b_V} {_{f}c_V}(y) \cdot {_{f}C_{l\alpha\_V}}(y)\, dy = 3.253$$

$C_{l\alpha\_V\_mean} = 0.057\ \mathbf{deg}^{-1}$

# MISCELLANEOUS DATA CALCULATIONS

$$\Delta X\_VT_{LE}\_W_{LE} := \Delta X\_VT_{LE}\_Nose - \Delta X\_W_{LE}\_Nose = 36.91\ \mathbf{m}$$

$$\Delta X\_VT_{c4\_r}\_W_{c4\_r} := \Delta X\_VT_{LE}\_W_{LE} + \frac{c_{V\_r}}{4} - \frac{c_{W\_r}}{4} = 35.043\ \mathbf{m}$$

$$\Delta Z\_W_{c4\_r}\_B_{CL} := \Delta Z\_W_{LE}\_Nose + \sin(i_W) \cdot \frac{c_{W\_r}}{4} = -0.614\ \mathbf{m}$$

$$\Delta Z\_HT_{c4\_r}\_B_{CL} := \Delta Z\_W_{c4\_r}\_B_{CL} - \Delta Z\_HT_{ac}\_W_{ac} = -2.264\ \mathbf{m}$$

$$x_{AC\_HV} := X_{MAC\_LE\_H} + 0.25 \cdot MAC_H = 5.005\ \mathbf{m}$$

## Rudder inner and outer stations and area

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

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

$y_{rd\_out} := \eta_{rd\_out} \cdot b_V = 10.146\ \mathbf{m}$

$y_{rd\_out} = 10.146\ \mathbf{m}$

$$c_{V\_mean\_@rd} := {_{f}c_V}\left(\frac{y_{rd\_in} + y_{rd\_out}}{2}\right) = 2.79\ \mathbf{m}$$

$c_{V\_mean\_@rd} = 2.79\ \mathbf{m}$

$$S_{rd} := 2 \cdot c_{rd} \cdot (y_{rd\_out} - y_{rd\_in}) = 37.134\ \mathbf{m}^2$$

$S_{rd} = 37.134\ \mathbf{m}^2$

@Aerodynamic Database ---> (control_surface)_tau_e_vs_c_control_surface_over_c_horizontal_tail

$\tau_{rd} = 0.793$

Induced drag factors, only due to geometric effects

$$e_{V\_alt} := \frac{2}{2 - AR_V + \sqrt{4 + AR_V^{\,2}\left(1 + \tan\left(\Lambda_{V\_tmax}\right)^2\right)}} = 0.571$$

$e_{V\_alt} = 0.571$

$$e_{V\_alt\_\Lambda 0} := 1.78 \cdot \left(1 - 0.045 \cdot AR_V^{\,0.68}\right) - 0.64 = 0.933$$

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

$$e_{V\_alt\_\Lambda} := 4.61 \cdot \left(1 - 0.045 \cdot AR_V^{\,0.68}\right) \cdot \cos\left(\Lambda_{V\_LE}\right)^{0.15} - 3.1 = 0.774$$

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

3d critical Mach number at mean aerodynamic chord

$$M_{cr\_V\_3D\_@MAC\_V} := \frac{{}_{\mathrm{f}}\mathrm{M}_{\mathrm{cr\_V\_2D}}\left(Y_{MAC\_V}\right)}{\cos\left(\Lambda_{V\_LE}\right)} = 0.981$$

$M_{cr\_V\_3D\_@MAC\_V} = 0.981$

# VERTICAL TAIL EFFECTIVE ASPETC RATIO

@Aerodynamic Database ---> (control_surface)_tau_e_vs_c_control_surface_over_c_horizontal_tail

$c_1 = 1.607$

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

$c_2 = 1.105$

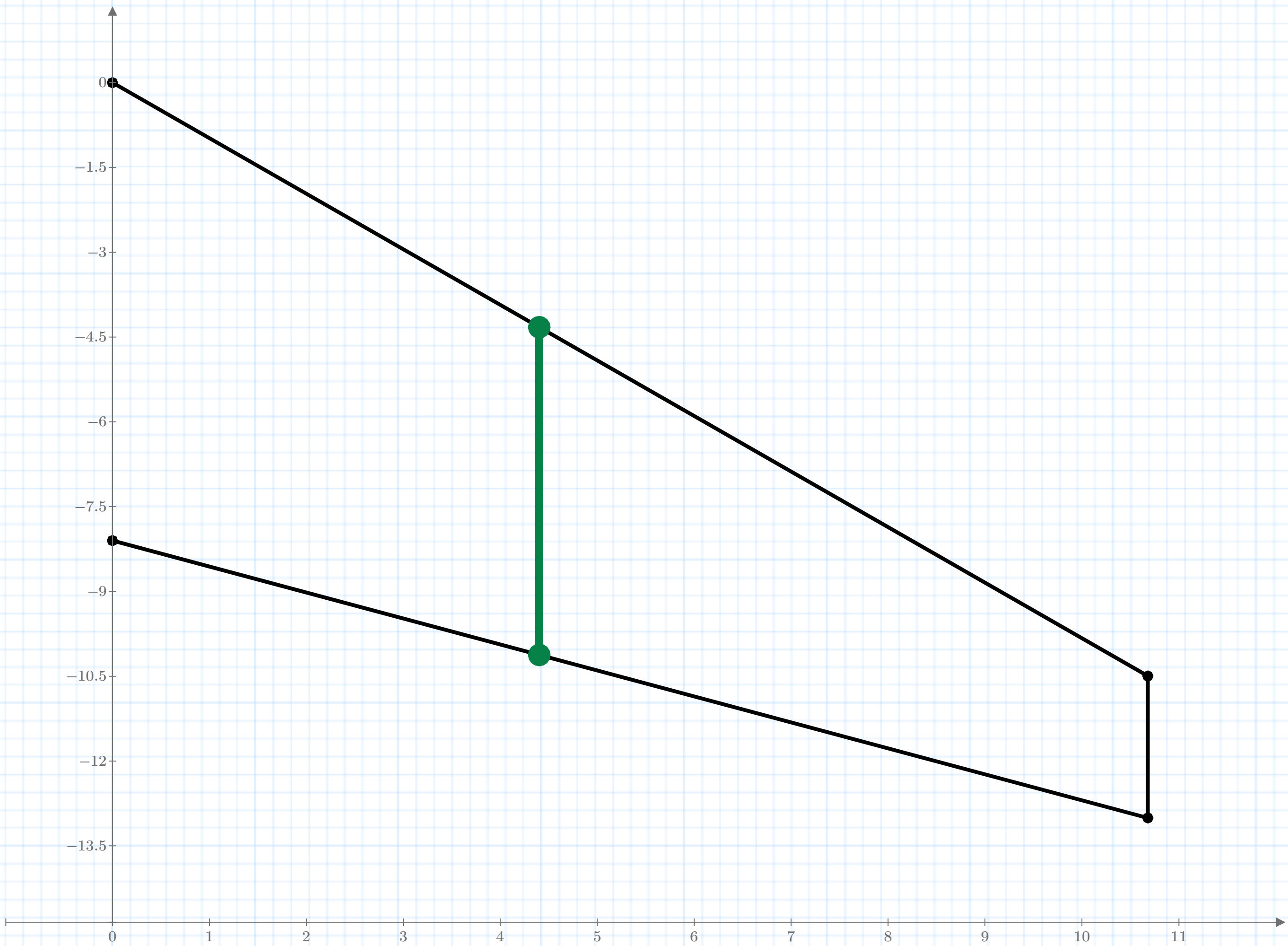
@Aerodynamic Database ---> (AR_v_eff)_k_h_v_vs_S_h_over_S_v

$K_{HV} = 1.118$

$$AR_{V\_eff} := c_1 \cdot AR_V \cdot \left(1 + K_{HV} \cdot \left(c_2 - 1\right)\right) = 7.225$$

$AR_{V\_eff} = 7.225$

## V-Tail planform with Mean Aerodynamic Chord



# VERTICAL TAIL LIFT-CURVE SLOPE

## V-Tail Lift Curve Slope, function definitions

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

( ---> Polhamus Formula is not valid)

- **Polhamus Formula Coefficient**

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

( ---> use Polhamus Formula)

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

- **General Formula for Lift Curve Slope**

else

( ---> use alternative formula)

$$a_0 \leftarrow \frac{C_{l\alpha@MAC}}{\sqrt{1 - M^2 \cdot \cos(\Lambda_{LE})^2}}$$

$$\text{return } \frac{a_0 \cdot \cos(\Lambda_{LE})}{\sqrt{1 - (M \cdot \cos(\Lambda_{LE}))^2 + \left(\frac{a_0 \cdot \cos(\Lambda_{LE})}{\pi \cdot AR}\right)^2} + \frac{a_0 \cdot \cos(\Lambda_{LE})}{\pi \cdot AR}}$$

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

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

$C_{l\alpha\_V\_@MAC\_V} := {}_f C_{l\alpha\_V}(Y_{MAC\_V}) = 6.875$ $\quad C_{l\alpha\_V\_@MAC\_V} = 0.12\ deg^{-1}$

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

$C_{L\alpha\_V\_@M0} = 3.358\ rad^{-1}$ $\quad C_{L\alpha\_V\_@M0} = 0.059\ deg^{-1}$

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

$C_{L\alpha\_V} = 4.76\ rad^{-1}$ $\quad C_{L\alpha\_V} = 0.083\ deg^{-1}$

## Induced drag factor, due to both geometric and aerodynamic effects

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

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

$e_V := {}_f e(C_{L\alpha\_V}, AR_{V\_eff}, \lambda_V, \Lambda_{V\_LE}) = 0.941$ $\quad e_V = 0.941$

## V-Tail Lift Curve Slope, classic formula

$$C_{L\alpha\_V\_classic} := \frac{C_{l\alpha\_V\_mean}}{\sqrt[2]{1 - M_1^{\,2}} + \frac{C_{l\alpha\_V\_mean}}{\pi \cdot AR_V \cdot e_V}} = 3.148$$

$C_{L\alpha\_V\_classic} = 3.148$

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

@Aerodynamic Database ---> (x_bar_ac_w)_k1_vs_lambda

$K1_{ac\_V\_Datcom} = 1.393$

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

$K2_{ac\_V\_Datcom} = 0.537$

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

$X_{ac\_over\_c_{r\_V\_Datcom}} = 0.762$

Aerodynamic center positions

$\xi_{ac\_V} := K1_{ac\_V\_Datcom} \cdot \left(X_{ac\_over\_c_{r\_V\_Datcom}} - K2_{ac\_V\_Datcom}\right) = 0.312$

$X_{ac\_V} := \xi_{ac\_V} \cdot MAC_V + X_{MAC\_LE\_V} = 6.137\ m$ $\qquad X_{ac\_V} = 6.137\ m$

$x_{ac\_V} := X_{ac\_V} - X_{MAC\_LE\_V} = 1.811\ m$ $\qquad x_{ac\_V} = 1.811\ m$

## V-Tail Volume Ratio based on aerodynamic centers distance

$$\Delta X\_VT_{ac}\_W_{TE} := \Delta X\_VT_{LE}\_Nose - \Delta X\_W_{LE}\_Nose - c_{W\_r} + X_{ac\_V} = 27.477\ m$$

$$\Delta X\_VT_{ac}\_W_{ac} := \Delta X\_VT_{LE}\_Nose - \Delta X\_W_{LE}\_Nose - X_{ac\_WB} + X_{ac\_V} = 34.99\ m$$

$$VolumeRatio_{V\_ac} := \frac{S_V}{S_W} \cdot \frac{\Delta X\_VT_{ac}\_W_{ac}}{MAC_W} = 0.445$$

# 3D PITCHING MOMENT COEFFICIENT ABOUT V-TAIL AERODYNAMIC CENTER

## Approximated formulation (Roskam)

$$C_{Mac\_V} := \frac{2}{S_V \cdot MAC_V} \cdot \int_0^{b_V} {}_{\mathrm{f}}\mathrm{C_{m\_ac\_2D\_V}}(y) \cdot {}_{\mathrm{f}}\mathrm{c_V}(y)^2 \, \mathrm{d}y = 0$$

$$C_{Mac\_V} = 0$$

# SIDEWASH EFFECT

$$\eta_V\_times\_1\_plus\_d\sigma\_over\_d\beta := 0.724 + 3.06 \cdot \frac{\frac{S_V}{S_W}}{1 + \cos\left(\Lambda_{W\_c4\_eqv}\right)} + 0.4 \cdot \frac{\Delta Z\_W_{c4\_r}\_B_{CL}}{h_1} + 0.009 \cdot AR_W = 0.941$$

# MAPPING AND OUTPUT CREATION

Includi << ..\Default_Map_VTail.mcdx

## Excel Writing

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## TeX Macro writing on .tex

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

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