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Wing Layout Tool

AE460 Aircraft Design

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Lecturer

Purpose

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- Wing/Stabilizer layout, during the Conceptual Design phase, can be a tedious process.
- Creating a spreadsheet is a convenient way to save time on the layout process as the design team decides on the best configuration
- Inputs Required:
  - Wing area-from initial weight estimate and takeoff wing loading analysis
  - Baseline airfoil choice
  - Leading edge sweep angle-from determining speed requirement and airfoil t/c choice
  - Baseline CG location
  - Baseline Tail Volume Coefficients
- Output:
  - Baseline Planform and side view of the aircraft
- Advantages to early wing layout
  - Design team can begin layout, including landing gear, engines, control surfaces, cockpit, fuselage sizing, etc.
  - Mass Properties can rapidly determine detailed aircraft weights and MOI
  - Drag and Performance teams can begin their efforts in the design
  - S&C teams can ensure the control sizing is sufficient

Spreadsheet Example

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CG	X (in)	Y (in)	Z (in)
	339.322	0	120

Wing

Taper Ratio	0.33
ct estimate (in)	74.25

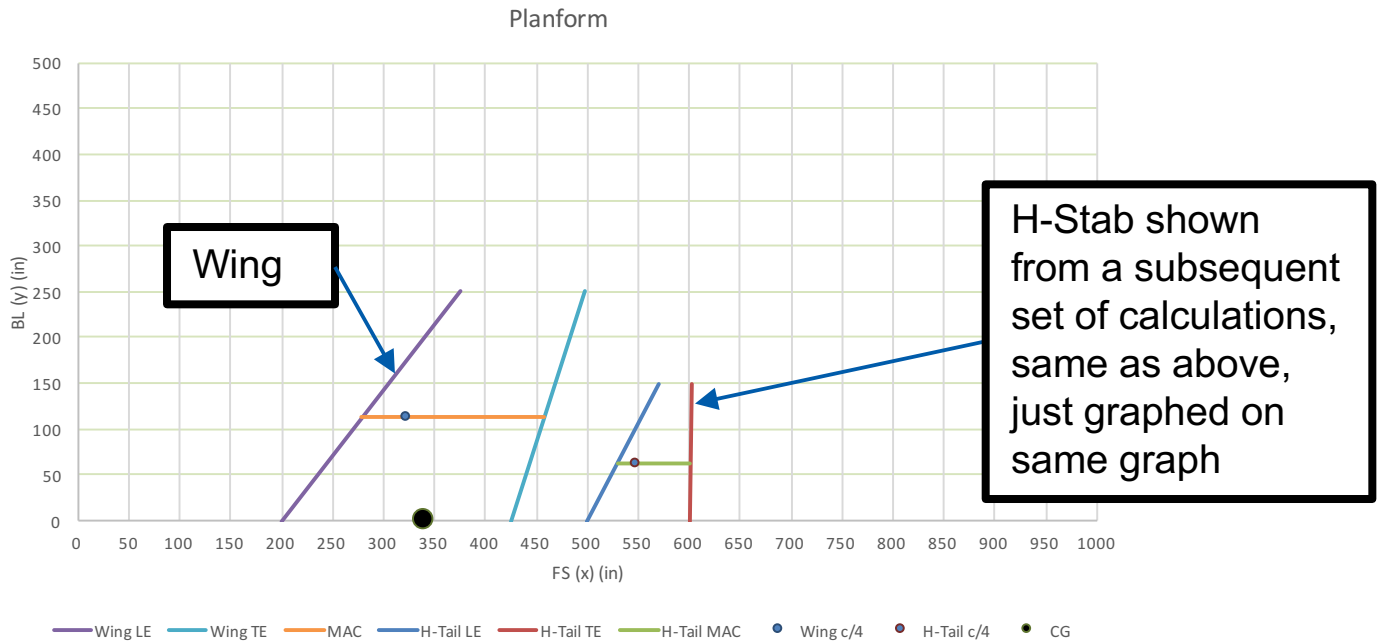
t/cmax= 0.399 Chord NACA62A410

	LE Δ	y	XLE	XTE	c	c/4	c/4 Δ	c/(t/c)max	c/(t/c)max Δ	c/2	c/2 Δ	TE Δ	slope m	intercept b	S	cbar	y^{cbar}	XLE mLE	bLE	XLEcbar
	deg	in	in	in	in	in	deg	in	deg	in	in	deg		in	ft^2	in	in			in
b0/2	35	0.000	200.000	425.000	225.000	256.250	30.9	289.775	28.2	312.500	26.4	16.2								
b1/2		250.000	375.052	497.773	122.721	405.732	0.0	424.017	0.0	436.412	0.0	0.0	-0.40912	225.000	603.7	178.874	112.744	0.70021	200.000	278.944
b2/2			0.000	74.250	74.250	18.563	0.0	29.626	0.0	37.125	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b3/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b4/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b5/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
															603.7	178.874	112.744			278.944

Summary

S	603.7	ft^2
mac	178.874	in
y^{cbar}	112.744	in
b	41.7	ft
AR	2.9	

		y^{cbar}
mac LE	278.944	112.744
mac TE	457.819	112.744
Wing c/4	323.663	112.744
CG	339.322	0.000



CG Location

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Enter Estimated CG location – only used for graphing, for "Design Awareness
Update as required throughout the design, to see if you may need to move the wing

CG	X (in)	Y (in)	Z (in)
	339.322	0	120

Wing

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	LE Λ	y	XLE	XTE	c	c/4	c/4 Λ	c/(t/c)max	c/(t/c)max Λ	c/2	c/2 Λ	TE Λ	slope m	intercept b	S	cbar	y^{cbar}	mLE	bLE	XLEcbar
	deg	in	in	in	in	in	deg	in	deg	in	in	deg		in	ft^2	in	in			in
b0/2	35	0.000	200.000	425.000	225.000	256.250	30.9	289.775	28.2	312.500	26.4	16.2								
b1/2		250.000	375.052	497.773	122.721	405.732	0.0	424.017	0.0	436.412	0.0	0.0	-0.40912	225.000	603.7	178.874	112.744	0.70021	200.000	278.944
b2/2			0.000	74.250	74.250	18.563	0.0	29.626	0.0	37.125	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b3/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b4/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b5/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
															603.7	178.874	112.744			278.944

Summary

S	603.7	ft^2
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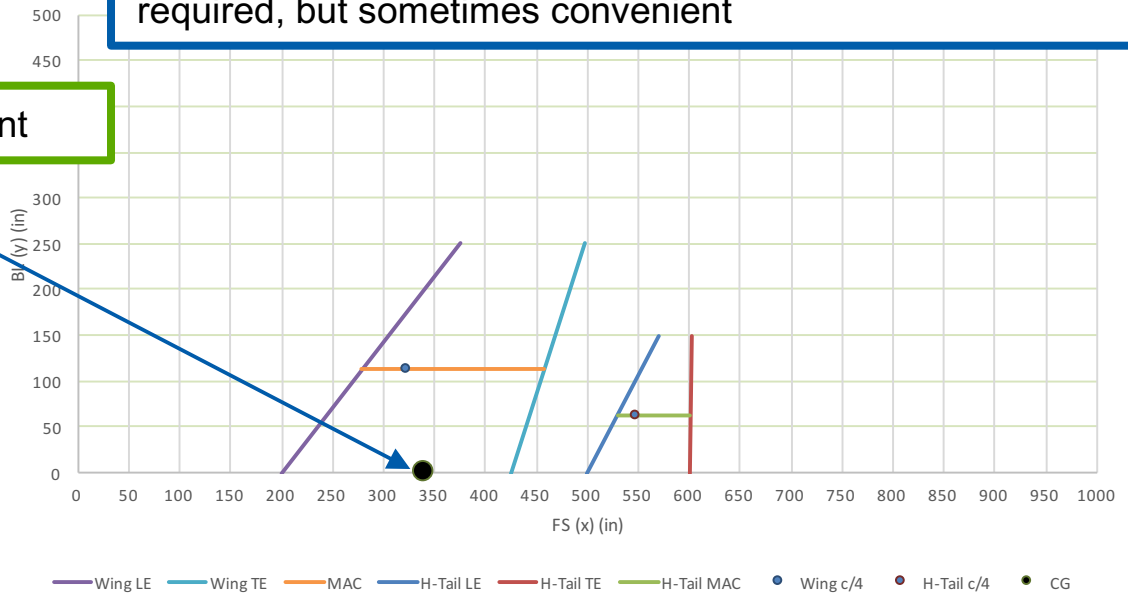
AR	2.9	

	X	y^{cbar}
mac LE	278.944	112.744
mac TE	457.819	112.744
Wing c/4	323.663	112.744
CG	339.322	0.000

Note: I sometimes have separate cells for graphing functions. Not required, but sometimes convenient

Graph the baseline CG point



Wing Planform

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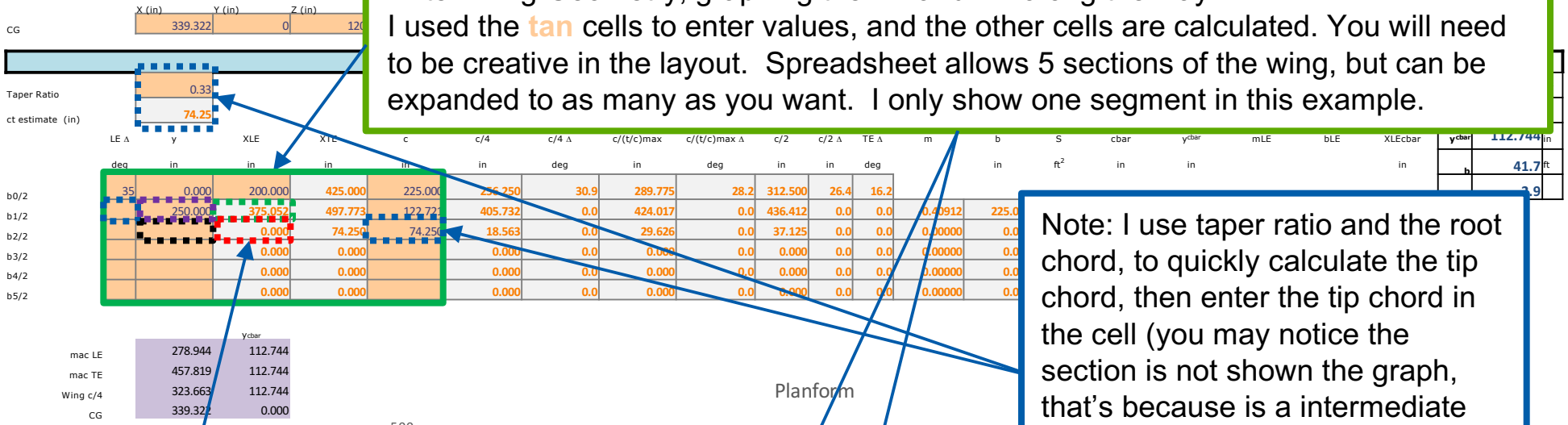
Enter Wing Geometry, graphing the LE and TE along the way
I used the tan cells to enter values, and the other cells are calculated. You will need to be creative in the layout. Spreadsheet allows 5 sections of the wing, but can be expanded to as many as you want. I only show one segment in this example.



Note: I use taper ratio and the root chord, to quickly calculate the tip chord, then enter the tip chord in the cell (you may notice the section is not shown the graph, that's because is a intermediate tool and I had deleted the outboard wing segment, so the tip chord here is not used… woops

Note: I use an If-Then Statement to "zero out" some cells, since the math WILL cause an "undefined" condition.

EXAMPLE:
=IF(C12>0, TAN(B11*PI()/180)*(C12-C11)+D11, 0)

Wing Planform

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All these are calculated values, using some simple math and trigonometry

CG	X (in)	Y (in)	Z (in)
	339.322	0	120

Wing

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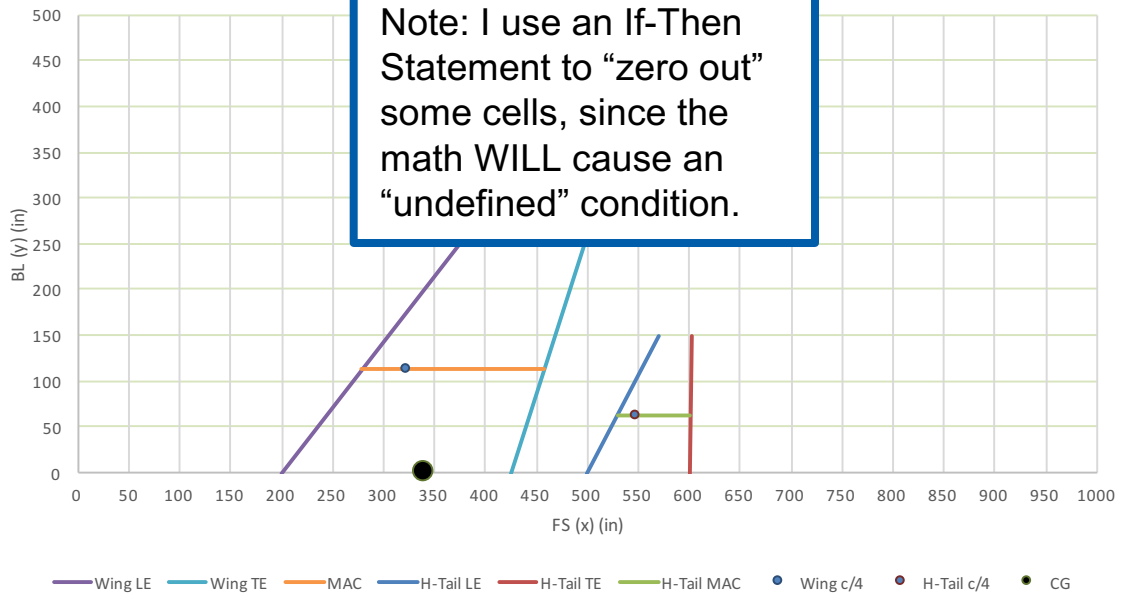
	deg	in	in	in	in	in	deg	in	deg	in	in	deg	m	in	ft^2	in	in			in
b0/2	35	0.000	200.000	425.000	225.000	256.250	30.9	289.775	28.2	312.500	26.4	16.4								
b1/2		250.000	375.052	497.773	122.721	405.732	0.0	424.017	0.0	436.412	0.0	0.0	-0.40912	225.000	603.7	178.874	112.744	0.70021	200.000	278.944
b2/2			0.000	74.250	74.250	18.563	0.0	29.626	0.0	37.125	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b3/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b4/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
b5/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	0.00000	0.000	0.0	0.000	0.000	0.00000	0.000	0.000
															603.7	178.874	112.744			278.944

Summary		
S	603.7	ft^2
mac	178.874	in
y^{cbar}	112.744	in
b	41.7	ft
AR	2.9	

		y^{cbar}
mac LE	278.944	112.744
mac TE	457.819	112.744
Wing c/4	323.663	112.744
CG	339.322	0.000

Planform

Note: I use an If-Then Statement to "zero out" some cells, since the math WILL cause an "undefined" condition.



Now for the Calculus

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- Roskam, Part VI, Figure 2.7, shows how to use some basic calculus to calculate the planform area and mac of an arbitrary wing.

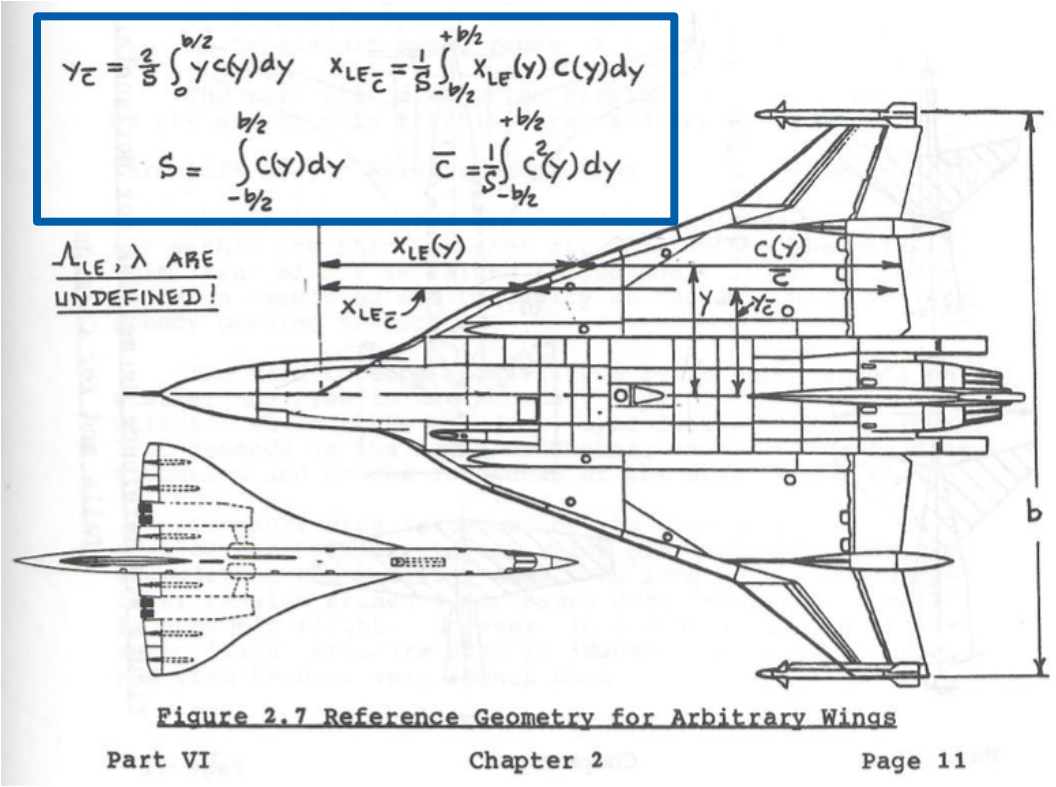
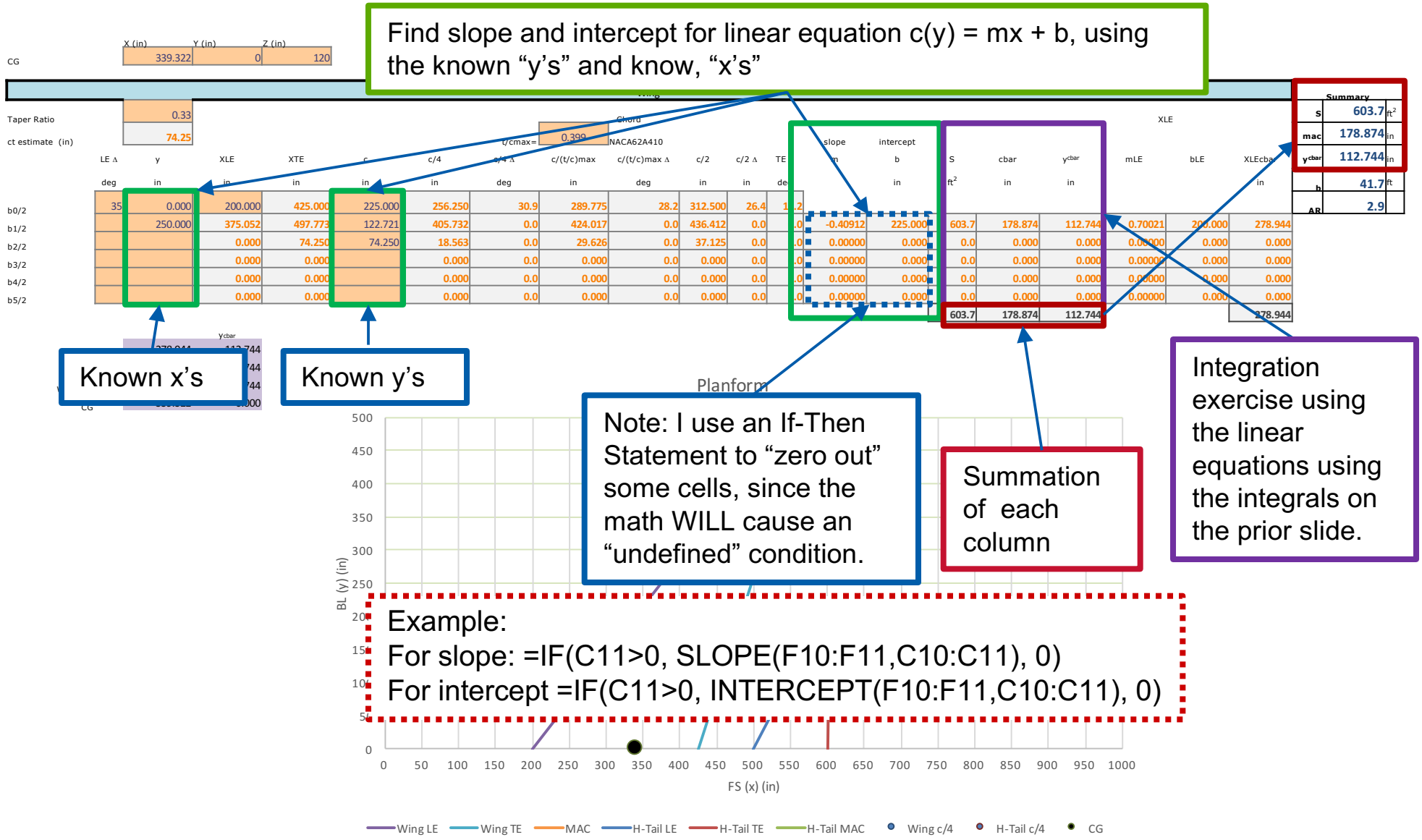


Figure 2.7 Reference Geometry for Arbitrary Wings

Part VI Chapter 2 Page 11

Finding c(y) (Chord length as a function of y)



Finding XLE(y) (Leading location as a function of y)

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Find slope and intercept for linear equation XLE(y) = mx + b, using the known “y’s” and know, “x’s”

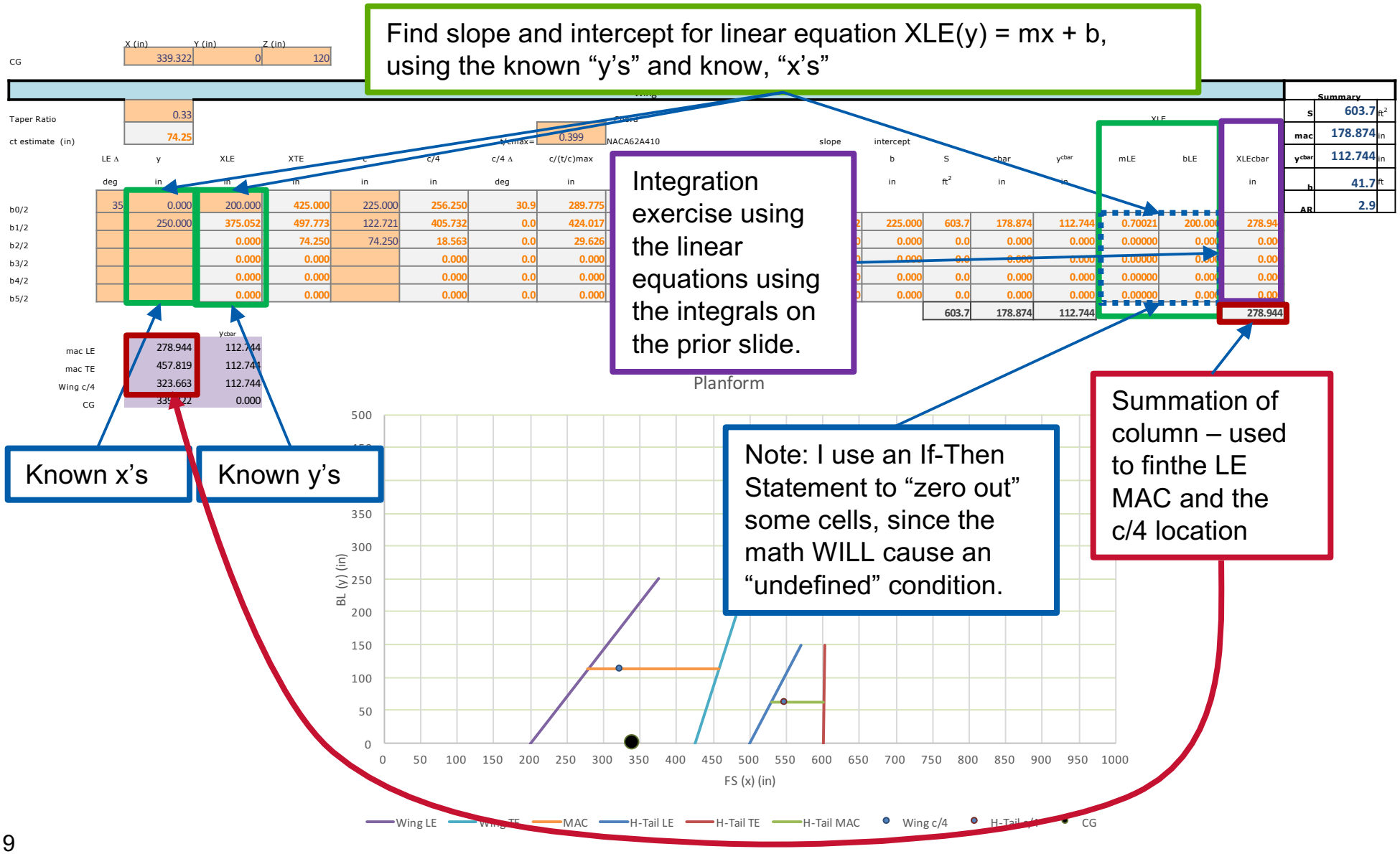
Integration exercise using the linear equations using the integrals on the prior slide.

Known x’s

Known y’s

Note: I use an If-Then Statement to “zero out” some cells, since the math WILL cause an “undefined” condition.

Summation of column – used to finthe LE MAC and the c/4 location



What next?

- Use the same methodology on the Horizontal and Vertical Stabilizer (the extra columns are hidden, but they are the same method as the wing)

Horizontal Stab

Taper Ratio		0.33						Chord					
ct estimate (in)		33					t/cmax=	0.28					
	LE Δ	y	XLE	XTE	c	c/4	c/4 Δ	c/(t/c)max	c/(t/c)max Δ	c/2	c/2 Δ	TE Δ	
	deg	in	in	in	in	in	deg	in	deg	in	in	deg	
b0/2	25	0.000	500.000	600.000	100.000	525.000	19.5	528.000	18.8	550.000	13.7	1.1	
b1/2		150.000	569.946	602.946	33.000	578.196	0.0	579.186	0.0	586.446	0.0	0.0	
b2/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	
b3/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	
b4/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	
b5/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	

		y_{cbar}
HT mac LE	529.100	62.406
HT mac TE	601.226	62.406
HT c/4	547.132	62.406
CG	339.322	0.000

Summary

S	138.5	ft^2
mac	72.125	in
y_{cbar}	62.406	in
C_{HT}	0.267	

Note: I sometimes have separate cells for graphing functions. Not required, but sometimes convenient

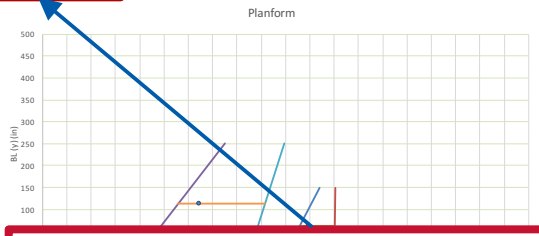
Vertical Stab

Taper Ratio		0.33						Chord					
ct estimate (in)		33					t/cmax=	0.28					
	LE Δ	y	XLE	XTE	c	c/4	c/4 Δ	c/(t/c)max	c/(t/c)max Δ	c/2	c/2 Δ	TE Δ	
	deg	in	in	in	in	in	deg	in	deg	in	in	deg	
b0/2	35	100.000	500.000	600.000	100.000	525.000	28.0	528.000	27.1	550.000	20.1	1.7	
b1/2		200.000	570.021	603.021	33.000	578.271	0.0	579.261	0.0	586.521	0.0	0.0	
b2/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	
b3/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	
b4/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	
b5/2			0.000	0.000		0.000	0.0	0.000	0.0	0.000	0.0	0.0	

		z_{cbar}	
VT mac LE	529.131	141.604	
VT mac TE	601.257	141.604	
VT c/4	547.163	141.604	
mac LE	278.944	100.000	enter wing WL
mac TE	457.819	100.000	
Wing c/4	323.663	100.000	
CG	339.322	120.000	

Summary

S		
mac	72.125	in
z_{cbar}	141.604	in
C_{VT}	0.064	



Add the Tail Volume Coefficients to allow quick adjustments of the planforms to obtain the desired coefficient values

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