Project

Empennage Sizing: The Tail Lever Arm as a Percentage of Fuselage Length Determined from Statistics

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Abstract

This project gives an overview of a selection of geometrical parameters with respect to the tail volume coefficient. A statistic on the basis of 30 aircraft, which differ in their dimensions, was made. One target was to create a graphical method for finding the tail levers arms, both for the horizontal, and the vertical tail. The average tail lever arm for the horizontal tail of all 30 aircraft altogether is 46.2% of their fuselages. The average tail lever arm for the vertical tail of all 30 aircraft altogether is 41.8% of their fuselages. When considering two different configurations, the first configuration (A) is one in which the aircraft have their engines attached to the wing and the second configuration (B) is the one in which aircraft have their engines attached to the fuselage. The percentages alter to 47% and 44.7% for configuration A and 44.6% and 36.1% for configuration B. With these values and some other geometrical data, it is, among other things, possible, to calculate the corresponding tail volume coefficients. In order to find the length of an aircraft's tail lever arm, three-view drawings with proper scale were analyzed graphically. The literature work of this project includes the finding of exact data for a small selection of aircraft, which also were investigated, in order to validate the values found with the graphical procedure. The deviation of the two is about 1% on average. Overall, a relation between the fuselage length of an aircraft and its tail lever arms could be noticed. The longer the aircraft's fuselage gets, the smaller the percentage increase of the tail lever arms are. Furthermore, tail volume coefficients were calculated and discussed with the help of the graphically determined values.

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Task for a project

Background

The area of the horizontal and vertical tail on an aircraft can be estimated quite easily with the tail volume coefficient. However, acceptable results can only be expected if the underlying statistics have been carefully compiled. Values of the tail volume coefficient have already been researched. However, the tail lever arm should also get systematically examined.

Task

Research should be carried out on the following topics:

- Review of the literature on the tail volume coefficient. Supplement given methods where necessary. See also: http://www.fzt.haw-hamburg.de/pers/Scholz/Aero/AERO_TN_TailSizing_13-04-15.pdf
- Review of the literature on the tail lever arm as a percentage value of the fuselage length (or in another meaningful relationship).
- Creation of your own statistics for the tail lever arm as a percentage value of the fuselage length (different types of aircraft; horizontal stabilizer and vertical stabilizer separately).
- Sample calculation. Discussion of the sample calculation.

The results are documented in a report. The relevant standards for report writing must be observed when creating the report.

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List of Symbols

b	Wing span
S_W	Wing area
S_{HT}	Horizontal tail area
S_{VT}	Vertical tail area
C_{HT}	Tail volume coefficient - horizontal tail
C_{VT}	Tail volume coefficient - vertical tail
L_{HT}	Tail lever arm - horizontal tail
L_{VT}	Tail lever arm - vertical tail

List of Abbreviations

AC	Aerodynamic center
CG	Center of gravity
MAC	Mean aerodynamic chord

1 Introduction

1.1 Motivation

Empennage sizing is part of the process of aircraft design. The area of the horizontal and the vertical tail of an aircraft can be estimated relatively easy with the tail volume coefficient. In order to calculate tail volume coefficients, certain geometrical values are required. The tail lever arms and the tail areas are related to each other, so for achieving longitudinal trim requirements of an aircraft, both need to be known. **Hall 2002** states that small tails for example tend, among others, to limit the permissible travel of the aircraft's center of gravity, which leads to low static stability and therefore to a harder ability to fly on instruments than higher-stability aircraft. On the other hand, low stick/pedal forces and low drag are going along with small tails.

This projects aim is to determine the lever arms of the horizontal and vertical tails, stated as the percentage of the length of their fuselage. A selection of different kinds of aircraft is used to get a basic statistic. Data is gathered from 30 aircraft (See: Appendix A and B).

The project continues work done by Barua, Sousa, and Scholz (**Barua 2015**).

1.2 Definitions

Aerodynamic center
A point on a cross section of a wing or rotor blade through which the forces of drag and lift are acting and about which the pitching moment coefficient is practically constant (**Encyclopedia 2017**).

Empennage
An arrangement of stabilizing surfaces at the tail of an aircraft (**Oxford 2017**).

Fuselage
The central body portion of an aircraft designed to accommodate the crew and the passengers or cargo (**Merriam 2017a**).

Mean aerodynamic chord
The mean aerodynamic chord is the average chord length of a tapered, swept wing (**Skybrary 2017**).

Pitching moment
A moment about a lateral axis of an aircraft, rocket, or airfoil (**Encyclopedia 2017**).

Statistics
A branch of mathematics dealing with the collection, analysis, interpretation and presentation of masses of numerical data (**Merriam 2017b**).

2 Sizing of Horizontal and Vertical Tails

A tail's main purpose is to counter moments produced by the wing (**Gate 2017)**. Therefore it is nearby that the tail size is in some way related to the wing size. The force, the tail produces, is proportional to the tail area multiplied by the tail lever arm. Since this product has the unit of a volume, the method for estimating the initial tail size is called "tail volume coefficient".

2.1 Classification of the Tail Volume Coefficient

In order to determine the empennage reference areas S_V and S_H, the tail volume coefficients C_V and C_H are used (**Kundu 2010**). The equations for the tail volume coefficients come from the aircraft stability equations. The position of the CG is shown in Figure 2.1. L_{HT} and L_{VT} are the distances between the CG and the aerodynamic center at the MAC of the horizontal tail and the vertical tail. The aerodynamic center is located at the quarter-chord of the MAC.

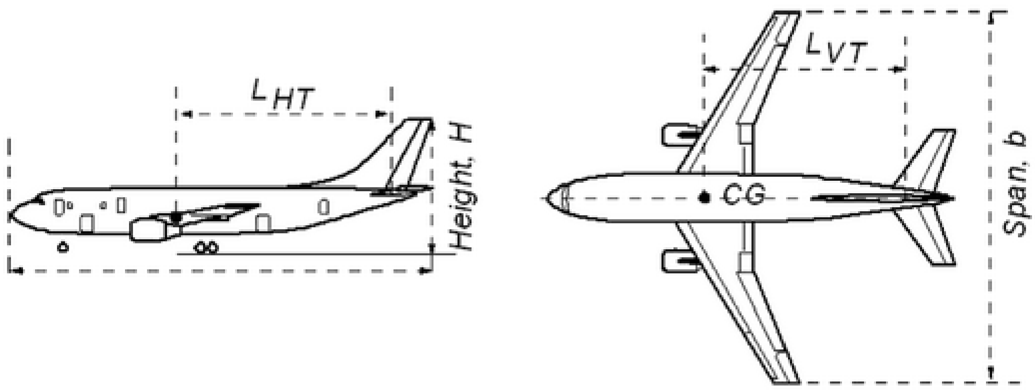

Figure 2.1 Geometric parameters for the tail volume coefficients

2.2 Horizontal Tail Volume Coefficient C_{HT}

The tail volume coefficient for horizontal tails C_{HT} is defined as

$$C_{HT} = \frac{S_{HT} L_{HT}}{S_W MAC} \quad . \tag{2.1}$$

L_{HT} is the lever arm between the aircraft's CG and the aerodynamic center of MAC_{HT}. This equation is originating from the pitching-moment equation for steady-state level flight. C_{HT} lies in between 0.5 and 1.2. 0.8 is considered as a good value for C_{HT}. Generally, the area ratio $\frac{S_{HT}}{S_W}$ is about 0.25 to 0.35 (**Kundu 2010**).

2.3 Vertical Tail Volume Coefficient C_{VT}

The tail volume coefficient for vertical tails C_{VT} is defined as

$$C_{VT} = \frac{S_{VT} L_{VT}}{S_W b} \quad . \tag{2.2}$$

L_{VT} is the lever arm between the aircraft's CG and the aerodynamic center of MAC_{VT}. b is the wing span. C_{VT} often located somewhere between 0.05 and 0.1. A value of 0.07 is considered as "good" referring to **Kundu 2010**.

Note: Due to several other sources referring to the lever arm as being the distance between the aerodynamic center of wing and tailplane, from now on, that will be applied (**Scholz 2017a**). As a good approximation, the 25%-points on both the MAC of the wing and of the tailplane can also be used to indicate the distance and therefore the lever arm length. Table 2.1 shows a list of typical values for tail volume coefficients of different types of aircraft.

Table 2.1 Typical tail volume coefficients of horizontal and vertical tails (**Gate 2017**)

Type	C_{HT}	C_{VT}
Sailplane	0.50	0.02
Homebuilt	0.50	0.04
General aviation - single engine	0.70	0.04
General aviation - twin Engine	0.80	0.07
Agricultural	0.50	0.04
Twin turboprop	0.90	0.08
Flying boat	0.70	0.06
Jet - trainer	0.70	0.06
Jet - fighter	0.40	0.07
Military cargo/bomber	1.00	0.08
Jet transport	1.00	0.09

In order to determine the size of a tail, the lever arm must be estimated.

2.4 Optimal Tail Lever Arm

The tail lever arm acts as the lever arm for the pitching moment around the lateral axis. The pitching direction can be seen in Figure 2.2.

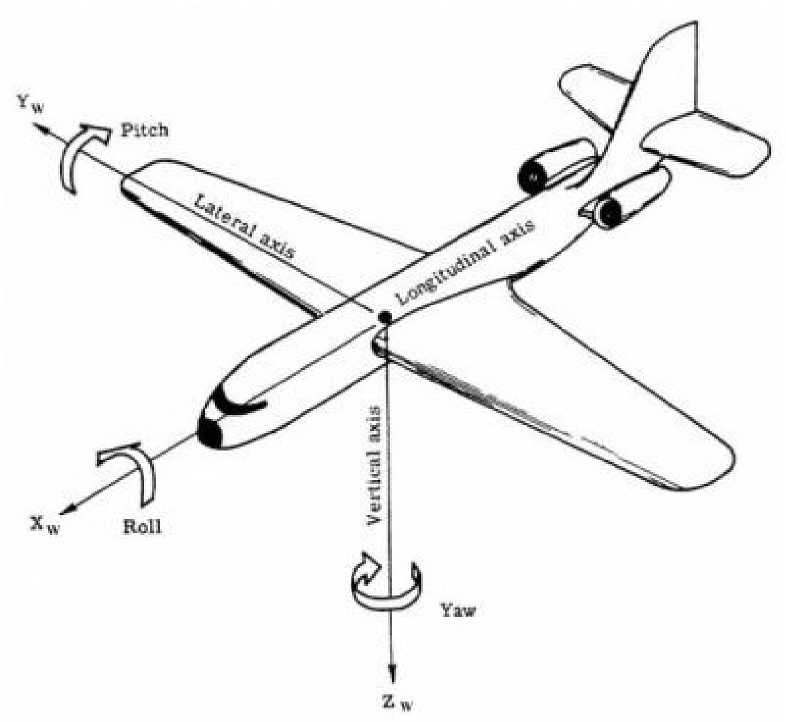

Figure 2.2 Notation of the three rotational degrees of freedom of an airplane (**Tkjelectronis 2012**)

The longer the tail lever arm, the smaller the tail area has to be and the shorter the tail lever arm, the bigger the tail area has to be (**Sadraey 2013**). Both configurations are capable of achieving longitudinal trim requirements of an aircraft. Short tail lever arms can be found for example on fighters, long tail lever arms on most transport aircraft.

3 Graphical Determination of the Tail Lever Arm

In this project, tail lever arms of different types of aircraft are determined graphically on the basis of three-view drawings. Figure 3.1 shows such a drawing with which these determinations are being done. First, the mean aerodynamic chord of the wing has to be found.

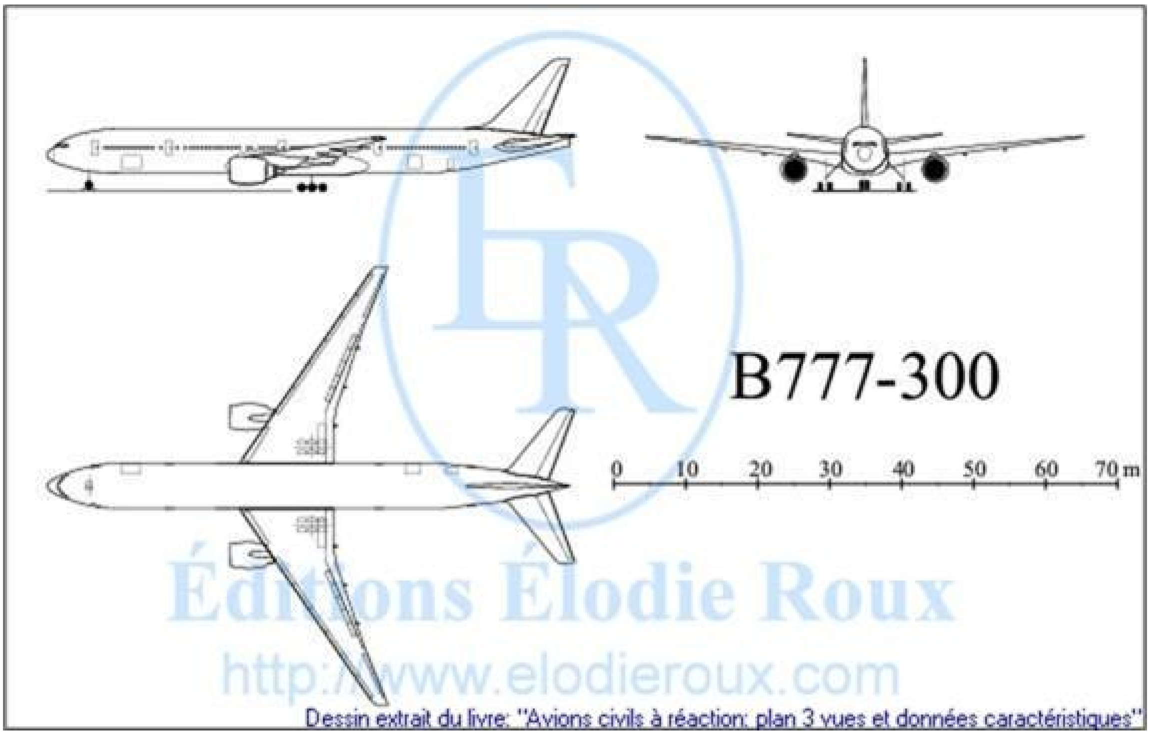

Figure 3.1 Three-view drawing of the Boeing B777-300 (**Roux 2012**)

3.1 Graphical Determination of the MAC of a Wing

In order to find the mean aerodynamic chord of a tapered wing like the one shown in Figure **3.2** graphically, the following steps have to be made (**Moleski 2017**):

1. Draw the half-wing chord as a straight line between the mid-point of the root chord to the mid-point of the tip chord.
2. Add the length of the root chord to the tip chord (At the leading edge of the wing).
3. Add the length of the tip chord to the root chord (At the trailing edge of the wing).
4. Draw a diagonal line from the endpoint of the line drawn in step 2 to the endpoint of the line drawn in step 3.
5. Draw a line parallel to the root chord that crosses the intersection of the lines drawn in step 1 and 4. That’s the mean aerodynamic chord.

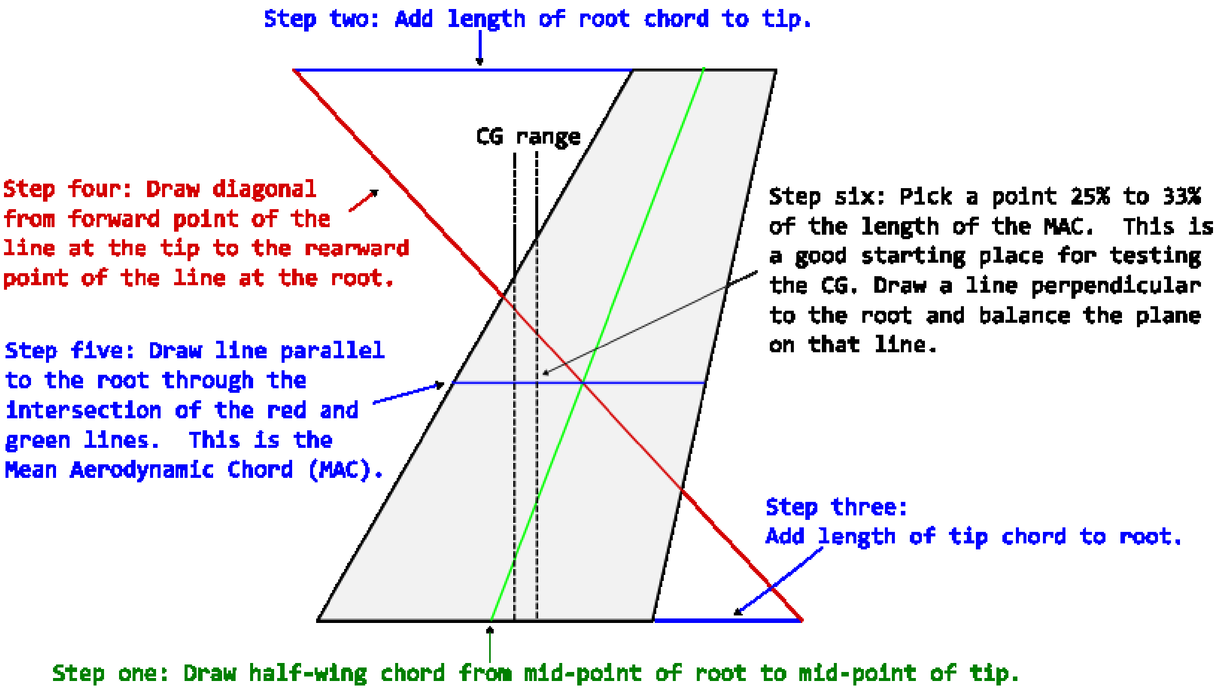

Figure 3.2 Graphical determination of the mean aerodynamic chord (**Moleski 2017**)

When it comes to the determination of the MAC of a wing having a kink in the trailing edge, like for example the one on the aircraft that is shown in Figure 3.3, a slight adaption to the procedure by Moleski has to be made. In order to find a graphical method for determining the MAC of such wing shapes, reverse engineering was applied within the framework of this project. Three-view drawings of aircraft with researched values for the MACs have been investigated with the objective to create such a method.

At first, two lines are drawn as an extension of the leading and trailing edges of the wing starting at the wingtip and ending on the symmetry line of the aircraft (See: Figure 3.3). Next, the 50%-line of the wing with respect to these two lines is drawn. The next step is to put the distance ‘b’ from the wingtip to the end of the extended trailing edge line, directly on the symmetry line of the aircraft. This step is contrary to the method shown above. In contrast to the method from above, distance ‘a’ measures from the end of the extended leading edge line to the point in horizontal direction, where the trailing edge of the wing is connected to the fuselage. Note that this distance is longer than the distance between the endpoints of the extended leading edge and trailing edge line. This takes into account that the wing has a larger area due to the kinked trailing edge than it would have without it. The line of distance ‘a’ needs to be connected to the wingtip as the figure shows. In the second to last step, point 1 and 2 are connected. The intersection of this line with the 50%-line marks the point on the wing, where the MAC is located. The distance between the extended leading edge line and the extended trailing edge line at this point is the MAC of the wing.

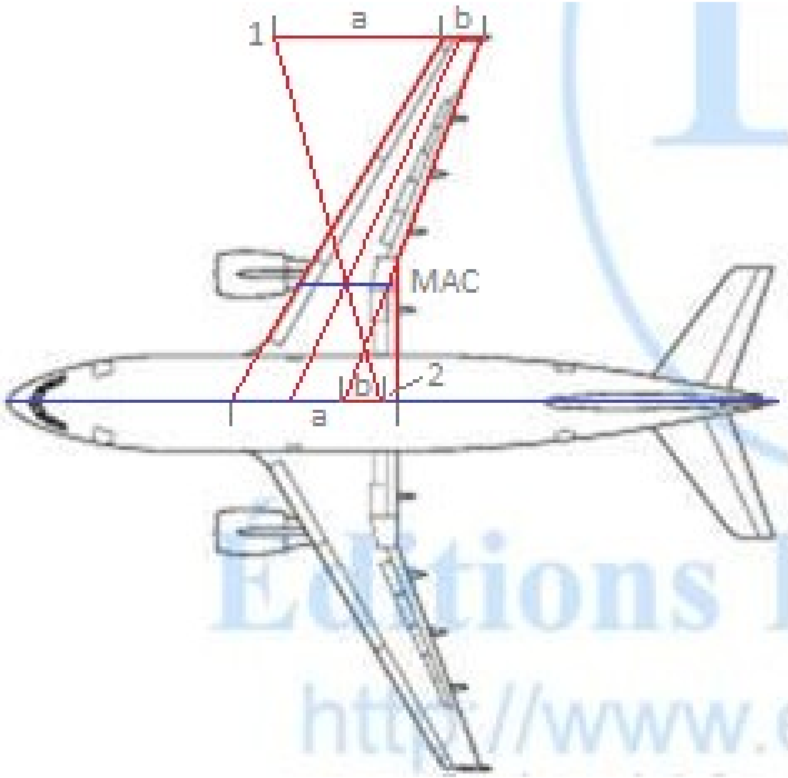

Figure 3.3 MAC determination of a real aircraft wing, the Airbus A310 (based on **Roux 2012**)

In order to validate the values for the mean aerodynamic chord determined with the graphical method, a few MAC values of different, arbitrarily chosen types of aircraft are compared to exact values taken from data sheets. Table 3.1 lists these. Out of the five listed aircraft and their MACs, the mean deviation from the exact values is 0.9%.

Table 3.1 Values for the MAC of certain aircraft

Aircraft	MAC [m] (data sheets)	MAC [m] (graphical method)	Deviation [%]
Airbus A310	5.83 (**Scholz 2017b**)	5.80	0.5
Airbus A320	4.19 (**EASA 2013**)	4.18	0.2
Airbus A380-800	12.30 (**Flightglobal 2005**)	12.55	2.0
Boeing B737-100	3.80 (**B737 1999**)	3.76	1.1
Fokker100	3.80 (**Mattos 2013**)	3.83	0.8

3.2 Graphical Determination of L_{VT} and L_{HT}

After finding the position and length of the mean aerodynamic chords of the wing and the tails, the 25%-points on either of those are being marked. To get the length of the lever arm L_{VT} of the vertical tail, a line is drawn between the corresponding points like it is marked as the upper green line in Figure 3.4. The value for the length of the tail lever arm L_{HT} of the horizontal tail is found between the 25%-point of the wing's mean aerodynamic chord and the 25%-point of the horizontal tail's mean aerodynamic chord. This one is marked as the lower green line in Figure 3.4.

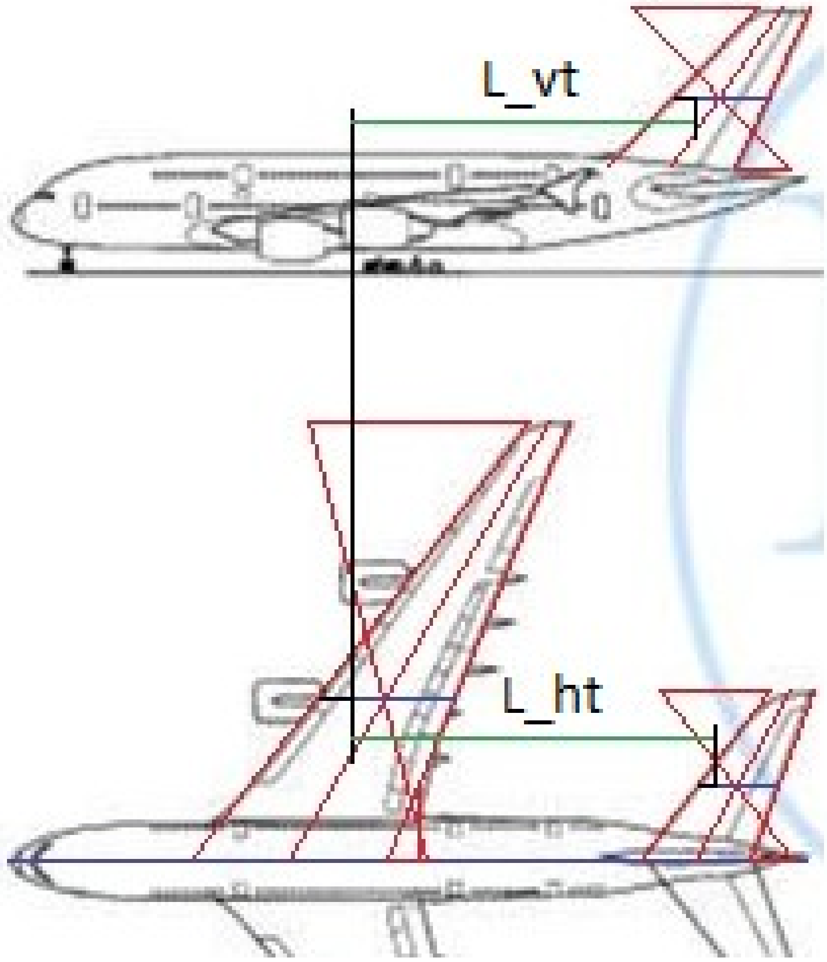

Figure 3.4 Graphical determination of L_{VT} and L_{HT} on the Airbus A380 (based on **Roux 2012**)

As described, the needed dimensions are taken from the drawings and filled into an Excel sheet (columns highlighted in green). The whole process is then repeated for various aircraft types of the manufacturers Airbus, Antonov, Comac, Boeing, Fokker, Sud Aviation, Bombardier, Cessna, de Havilland, Douglas, Tupolev and Yakovlev.

Finally, all needed graphical dimensions are known:

- Fuselage length
- MAC wing
- 25%-point MAC wing
- MAC horizontal tail
- 25%-point MAC on the horizontal tail
- Lever arm of the horizontal tail L_{HT} (distance between 25% MAC points)
- MAC vertical tail
- 25%-point MAC on the vertical tail
- Lever arm of the vertical tail L_{VT} (distance between 25% MAC points)

By multiplying these values with the drawings' scale factors, the actual size dimensions of the aircraft are obtained (columns highlighted in blue). The lengths of the vertical tail and horizontal tail lever arms of all aircraft can be expressed relative to their fuselage lengths and plotted in graphs for further statistical analysis (Chapter 3.3).

Figure 3.5 shows an excerpt from the Excel sheet. For the complete listing of all 30 investigated aircraft and more dimensions see Appendix A.

Manufacturer	Aircraft	MAC wing [cm]	MAC wing [m]	25%-P. MAC wing	MAC h-tail [cm]	MAC h-tail [m]	25%-P. MAC h-tail	L_ht [cm]	L_ht [m]	% fuselage (H)
Airbus	A300-600	0,85	6,56	0,21	0,56	4,32	0,14	3,41	26,31	48,6
	A310	0,77	5,80	0,19	0,58	4,37	0,15	2,96	22,29	48,1
	A320	0,71	4,18	0,18	0,50	2,94	0,13	3,10	18,24	48,2
	A350-900	1,06	8,83	0,27	0,56	4,67	0,14	3,74	31,17	46,7
	A380	0,93	12,55	0,23	0,56	7,56	0,14	2,43	32,79	45,3
Antonov	An-124	0,85	10,76	0,21	0,58	7,34	0,15	2,46	31,14	45,1
Comac	ARJ21-700	0,74	3,48	0,19	0,50	2,35	0,13	2,94	13,82	45,0
	ARJ21-900	0,74	3,48	0,19	0,50	2,35	0,13	3,20	15,05	44,1
Boeing	B737-100	0,77	3,76	0,19	0,58	2,83	0,15	2,51	12,26	44,1
	B737-400	0,77	3,90	0,19	0,58	2,93	0,15	3,25	16,44	45,5
	B747-300	0,93	9,51	0,23	0,66	6,75	0,17	3,10	31,69	44,9
	B777-300	0,82	8,58	0,21	0,50	5,23	0,13	3,20	33,48	46,0
	B787-300	0,82	7,24	0,21	0,50	4,42	0,13	2,99	26,41	47,3
	B787-800	0,63	6,55	0,16	0,45	4,68	0,11	2,49	25,88	46,1
	B787-900	0,63	6,55	0,16	0,45	4,68	0,11	2,75	28,59	46,4

Figure 3.5 Excel sheet with aircraft dimensions obtained by the graphical method

Table 3.2 lists the discussed values for the Boeing 737-100 exemplary. For being able to compare these values to the drawing of the aircraft, Figure 3.6 shows the side view and the top view including all the drawn lines of the graphical method. A scale is included as well.

Table 3.2 Geometrical values regarding L_{VT} and L_{HT}

Aircraft	Fuselage length	MAC (Wing)	MAC (h.tail)	L_{HT}	% of the fuselage (h.tail)	MAC (v.tail)	L_{VT}	% of the fuselage (v.tail)
Boeing 737-100	27.66 m	3.76 m	2.83 m	12.26 m	44.1 %	3.76 m	11.24 m	40.4 %

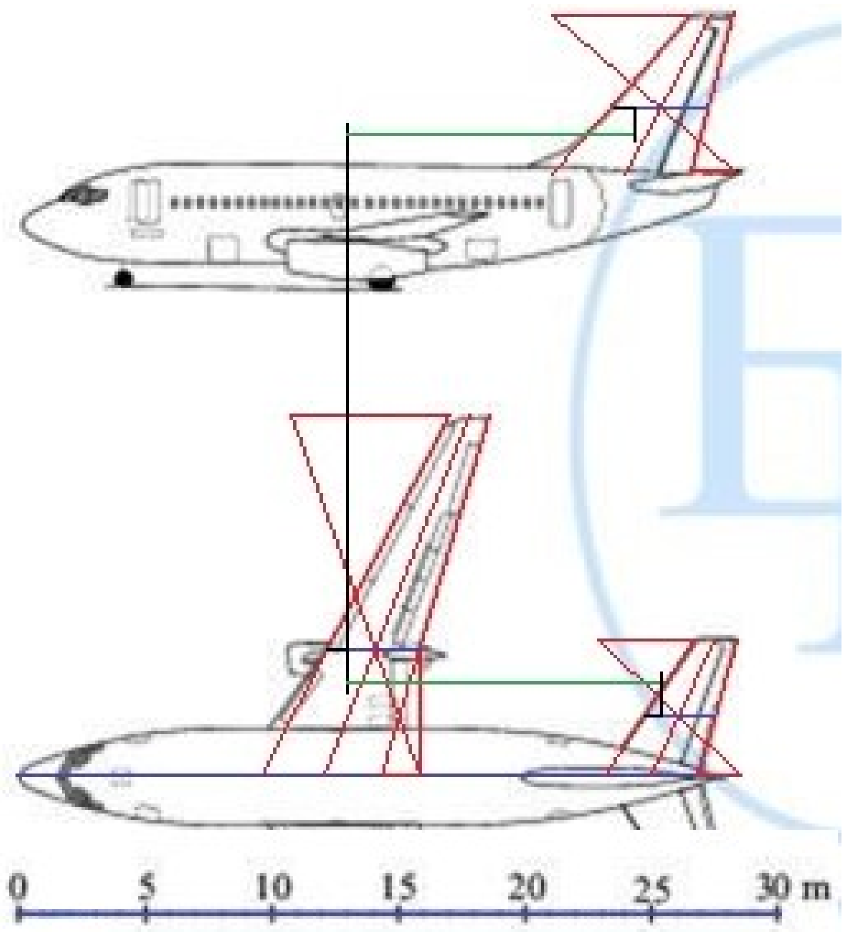

Figure 3.6 Boeing 737-100 side and top view (**Roux 2012**)

3.3 Statistics

The mean value for the tail lever arm of the horizontal tail of all 30 investigated aircraft is 46.1% of the fuselage length. The mean value for the tail lever arm of the vertical tail of all 30 investigated aircraft is 41.8% of the fuselage length. The standard deviations are 2.8 percentage points for the horizontal tail lever arm and 4.8 percentage points for the vertical tail lever arm.

Figure 3.7 shows the tail lever arms for the horizontal tail of all 30 investigated aircraft as a percentage of their fuselage lengths. Due to the trendline being nearly horizontal, no correlation between the fuselage length of the aircraft and their tail lever arms for the horizontal tail can be concluded. In
Figure **3.8**, the same is plotted but for the vertical tail. Here, a slight slope of the trendline can be seen, which indicates, that the longer the aircraft, the more the percentage of tail lever arm of the vertical extends.

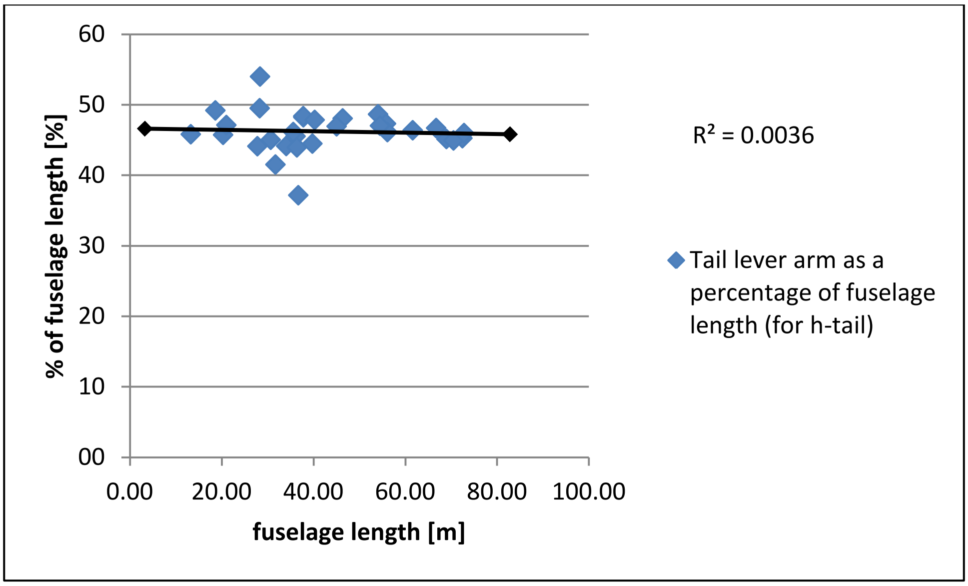

Figure 3.7 Tail lever arm as a percentage of the fuselage length (for the horizontal tail)

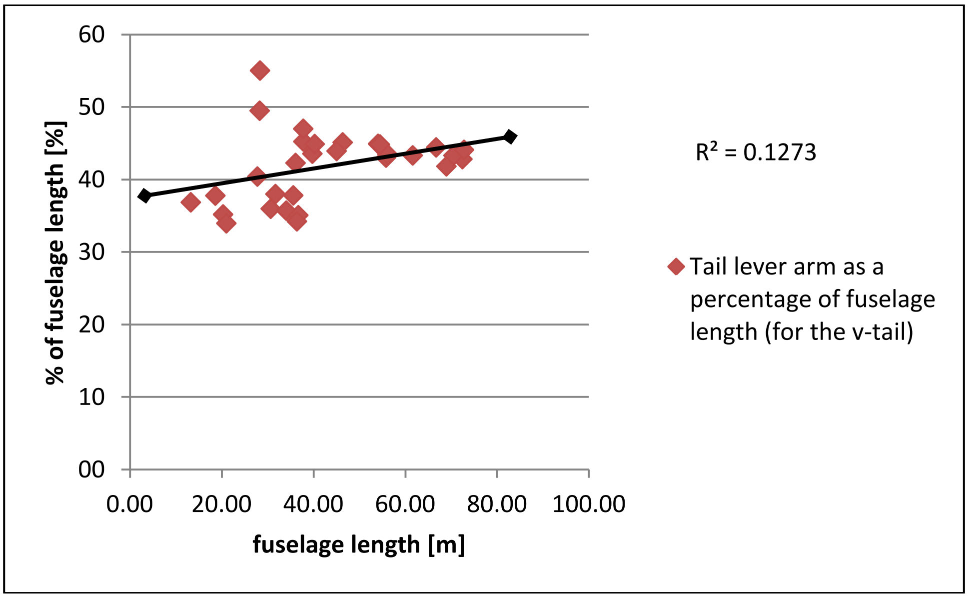

Figure 3.8 Tail lever arm as a percentage of the fuselage length (for the vertical tail)

In order to get a more meaningful overview of the correlation of the tail lever arm and the fuselage length, the data of the 30 aircraft is divided into two different categories**. Category A contains all the aircraft which have the engines attached to the wing, while category B contains all the aircraft which have the engines attached to the fuselage.** Out of the 30 investigated aircraft, 10 fall into category B, namely the ARJ21-700 and ARJ-900 from Comac, the Fokker 100, the Caravelle 1 and Caravelle 12 from Sud Aviation, the Challenger 300 and Challenger 605 from Bombardier, the Citation CJ1 and Citation X from Cessna and the Yak-42 from Yakovlev.

Figure 3.9 and Figure 3.10 show the data of category A. A slight descent of the trendline can be seen which indicates that the longer the aircraft's fuselage gets, the smaller the percentage increase of the tail lever arms are.

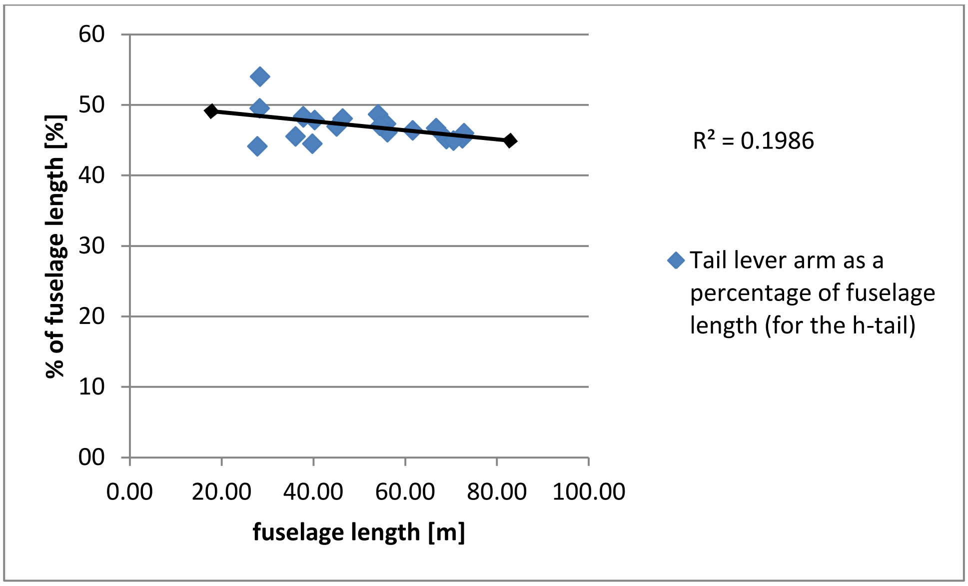

Figure 3.9 Tail lever arm as a percentage of the fuselage length (for the horizontal tail) – Category A

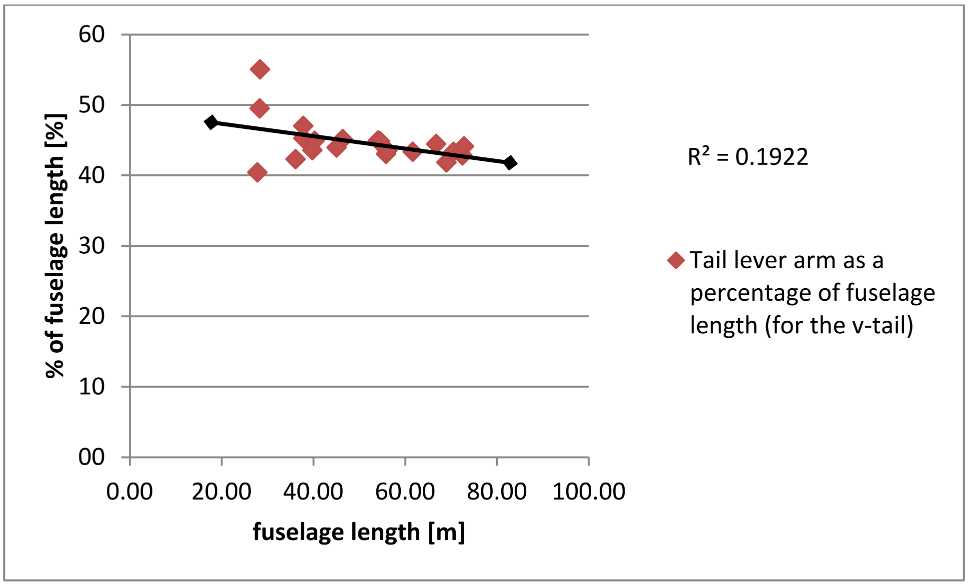

Figure 3.10 Tail lever arm as a percentage of the fuselage length (for the vertical tail) – Category A

A similar impression do the diagrams of category B (engines attached to the fuselage), namely of Figure 3.11 and Figure 3.12, provide. However, it should be noted that there is hardly any coherence in case of the vertical tail ($R^2 = 0{,}0111$).

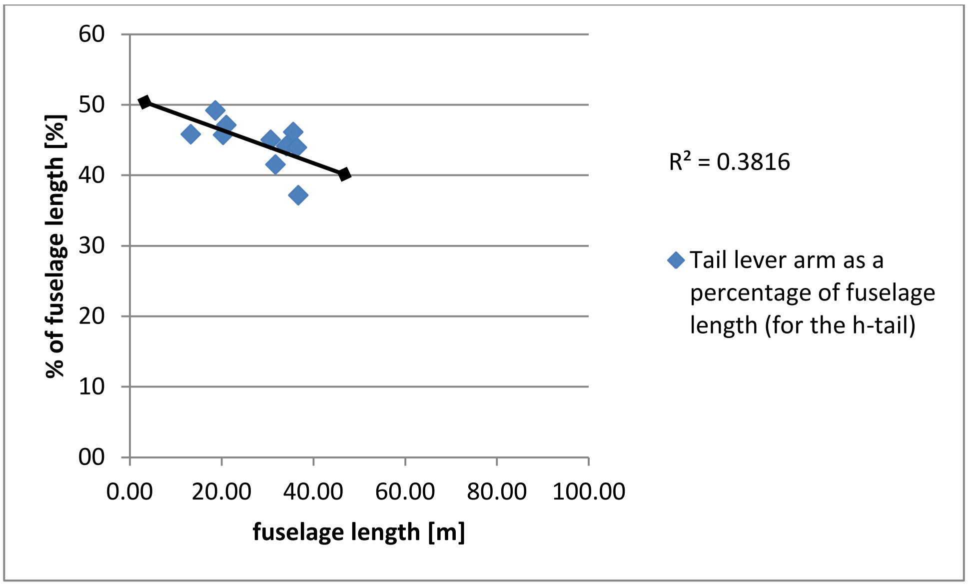

Figure 3.11 Tail lever arm as a percentage of the fuselage length (for the horizontal tail) – Category B

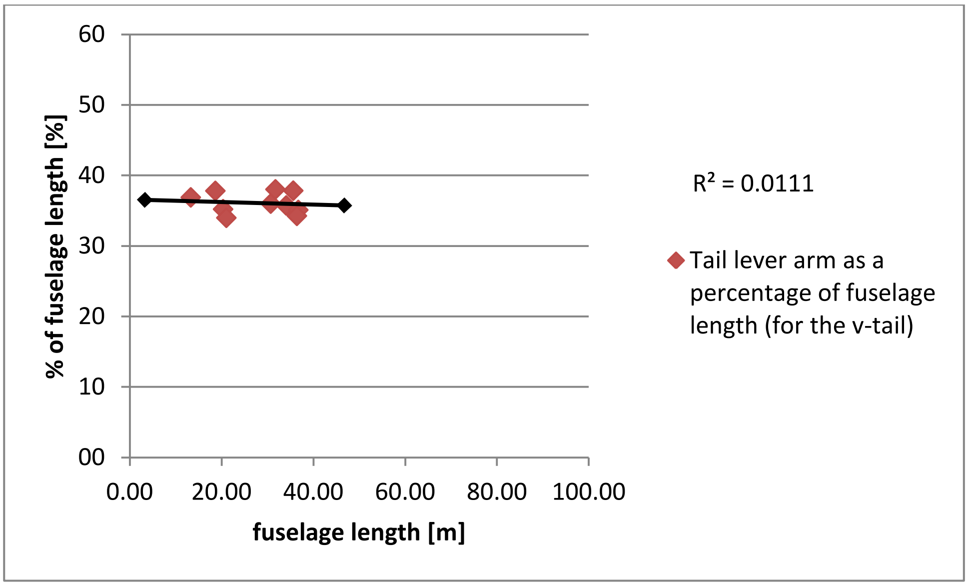

Figure 3.12 Tail lever arm as a percentage of the fuselage length (for the vertical tail) – Category B

In order to complete the overview of the collected data, Table 3.3 lists the average values for the tail lever arms with respect to the different categories. The relatively high value of the standard deviation of the horizontal tail values of category B is due to the short horizontal tail lever arm (of only 37.2% of the fuselage length) of the Caravelle 12 from Sud Aviation.

Table 3.3 Summarizing overview of the collected data

	Average tail lever arm as a percentage of the fuselage length for the horizontal tail	Standard deviation	Average tail lever arm as a percentage of the fuselage length for the vertical tail	Standard deviation
Entire 30 aircraft	46.2%	2.8	41.8%	4.8
Category A (engine: wing)	47.0%	2.2	44.7%	3.0
Category B (engine: fuselage)	44.6%	3.1	36.1%	1.4

3.4 Calculation of the Tail Volume Coefficients

Values for the tail volume coefficients are calculated and discussed exemplary within this chapter, using the data of the Boeing 737-100. For this purpose, the formulas introduced in Chapter 2 are written down:

$$C_{HT} = \frac{S_{HT} L_{HT}}{S_W MAC}$$

$$C_{VT} = \frac{S_{VT} L_{VT}}{S_W b}$$

The values for the tail lever arms L_{HT} and L_{VT} and the ones for the MACs are known from the graphical determination and listed in Table 3.2. The other values, area values and the wing span, are taken from data sheets (**B737 1999**):

$$S_W = 102.0\ m^2$$

$$S_{HT} = 28.99\ m^2$$

$$S_{VT} = 20.81\ m^2$$

$$b = 28.35\ m^2$$

It follows from above:

$$C_{HT} = \frac{S_{HT} L_{HT}}{S_W MAC} = \frac{28.99\ m^2 12.26\ m}{102.0\ m^2 3.76\ m} = 0.937$$

And:

$$C_{VT} = \frac{S_{VT}L_{VT}}{S_W b} = \frac{20.81\ m^2 11.24\ m}{102.0\ m^2\ 28.35\ m} = 0.081$$

These values are somewhere near the ones for general aviation – twin engines of Table 2.1, which the Boeing 737-100 is part of. There, the data for typical tail volume coefficients are 0.8 for the horizontal tail and 0.07 for the vertical tail. Due to the fact that both calculated values are higher than the typical ones of Table 2.1, it could be possible, that the real tail lever arms of the Boeing 737-100 are slightly shorter than the ones estimated with the graphical method. On the other hand, Table 2.1 only lists typical values and no exact ones and the deviations are rather small. So they can be considered as correct just as well.

4 Summary

After studying the literature in order to find a way to graphically determine values for the tail lever arms of aircraft with different sizes and configurations, 30 aircraft have been analyzed with a suitable method for this task. The deviation from real data which was made with the graphical analysis had been somewhere around 1%.

The standard deviations for the average values of the tail lever arms were rather high due to the fact that the 30 investigated aircraft differ very much in size and configuration. In order to get average values with lower standard deviations, two categories have been created, one in which aircraft having their engines attached to the wing and the other one in which aircraft having their engines attached to the fuselage. Further, coherences between the fuselage length of an aircraft and its tail lever arms could be noticed.

For future work, aircraft which are investigated could be put into more specific categories were things like type of the tails (t-tail, cruciform tail, conventional tail with or without dorsal fins), number of engines, maximum take-off weights, the exact position of the engines with respect to the wing etc. are taken into account. This would lower the standard deviations even more which would lead to clearer links between aircraft and their tail lever arms.

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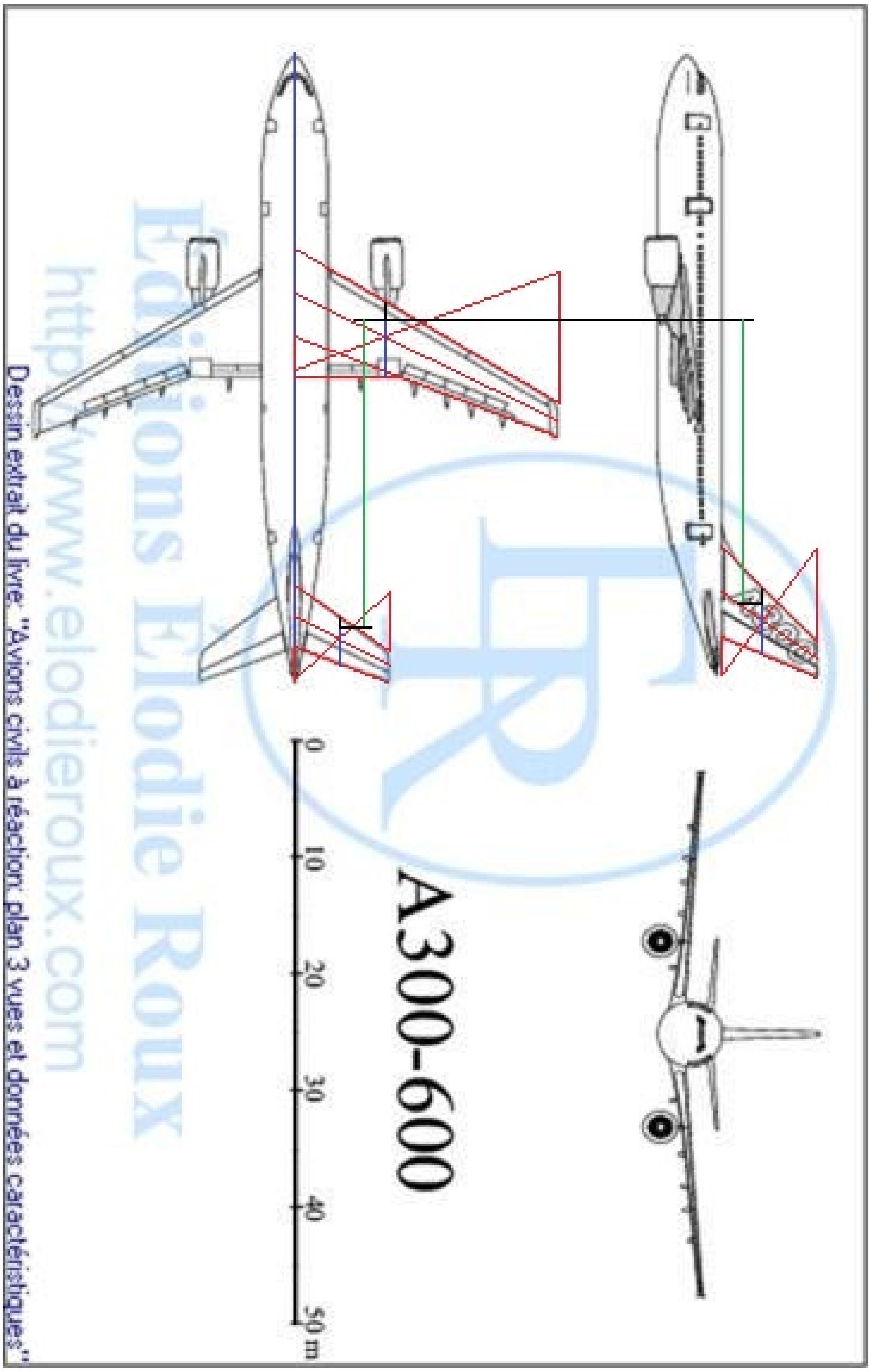
Appendix A: Excel Sheet

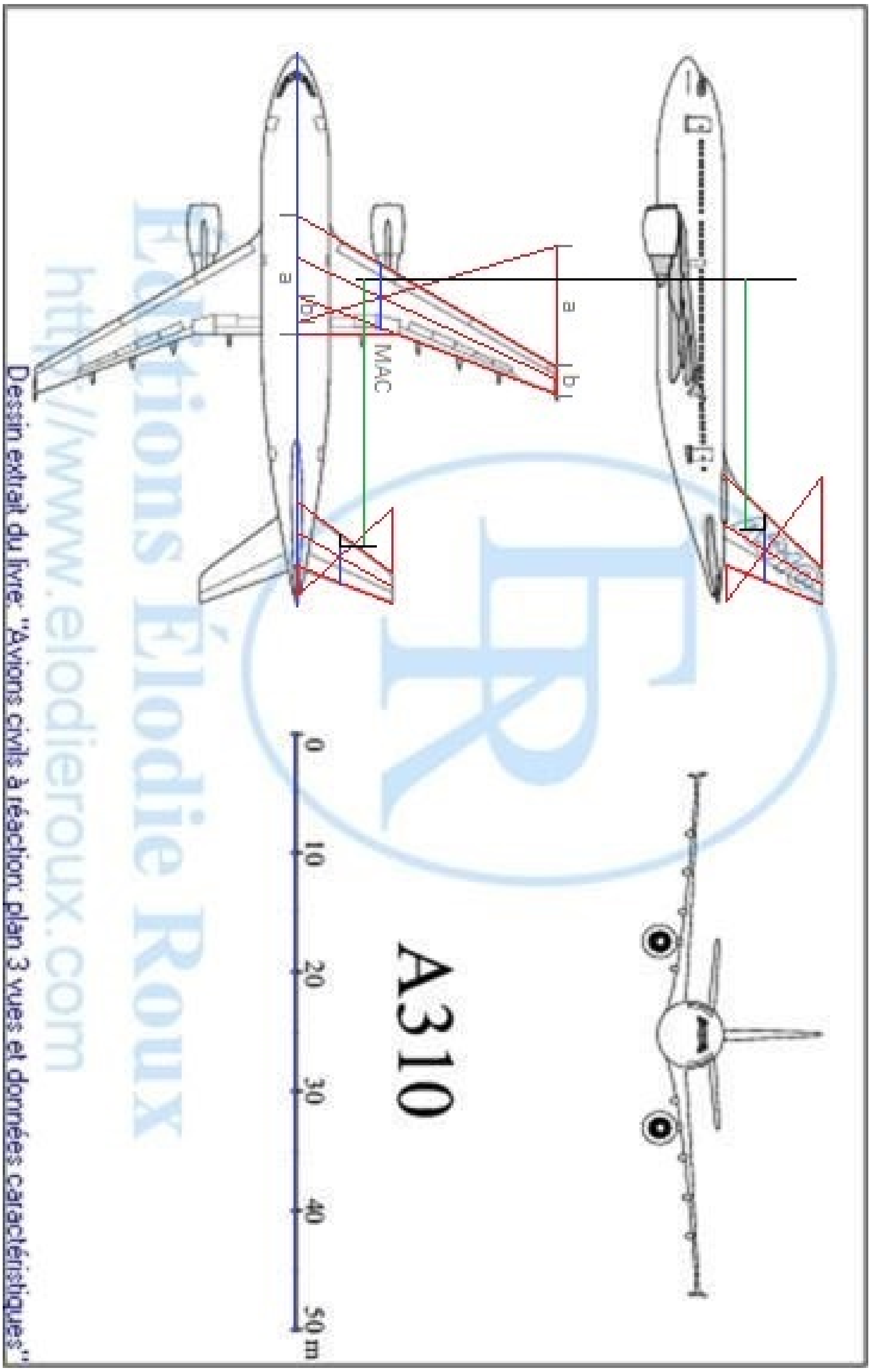
Actual size dimensions (results of multiplication by the scale factor) highlighted in blue, measured dimensions from drawings highlighted in green.

	A	B	C	D	E	F	G	H	I	J
1	Manufacture	Aircraft	Fuselage length [m]	MAC wing [m]	MAC h-tail [m]	L_ht [m]	% of fuselage (H)	MAC v-tail [m]	L_vt [m]	% of fuselage (V)
2	Airbus	A300-600	54.09	6.56	4.32	26.31	48.6	5.71	24.31	44.9
3		A310	46.39	5.80	4.37	22.29	48.1	5.80	20.93	45.1
4		A320	37.82	4.18	2.94	18.24	48.2	4.06	17.12	45.3
5		A350-900	66.75	8.83	4.67	31.17	46.7	5.92	29.67	44.4
6		A380	72.47	12.55	7.56	32.79	45.3	8.91	31.04	42.8
7	Antonov	An-124	68.99	10.76	7.34	31.14	45.1	9.37	28.86	41.8
8	Comac	ARJ21-700	30.71	3.48	2.35	13.82	45.0	4.23	11.05	36.0
9		ARJ21-900	34.09	3.48	2.35	15.05	44.1	4.23	12.18	35.7
10	Boeing	B737-100	27.80	3.76	2.83	12.26	44.1	3.76	11.24	40.4
11		B737-400	36.12	3.90	2.93	16.44	45.5	3.90	15.28	42.3
12		B747-300	70.53	9.51	6.75	31.69	44.9	8.69	30.56	43.3
13		B777-300	72.83	8.58	5.23	33.48	46.0	6.38	32.12	44.1
14		B787-300	55.83	7.24	4.42	26.41	47.3	6.10	24.03	43.0
15		B787-800	56.13	6.55	4.68	25.88	46.1	5.20	24.43	43.5
16		B787-900	61.64	6.55	4.68	28.59	46.4	5.20	26.72	43.3
17	Fokker	Fokker 100	35.62	3.83	2.42	16.43	46.1	3.83	13.47	37.8
18	Sud Aviation	Caravelle 1	31.74	4.98	2.81	13.18	41.5	4.16	12.06	38.0
19		Caravelle 12	36.72	4.98	3.28	13.65	37.2	4.51	12.88	35.1
20	Bombardier	Challenger 300	20.33	2.74	1.61	9.30	45.7	2.84	7.16	35.2
21		Challenger 605	18.65	1.89	1.52	9.17	49.2	2.66	7.05	37.8
22	Cessna	Citation CJ1	13.29	1.83	1.04	6.09	45.8	2.15	4.90	36.9
23		Citation X	21.05	2.87	1.62	9.92	47.1	3.14	7.15	34.0
24	de Havilland	Comet 1	28.38	6.02	2.98	15.32	54.0	2.39	15.62	55.0
25		Comet 2	28.30	6.25	2.81	14.01	49.5	2.53	14.01	49.5
26	Douglas	DC-8-20	45.07	7.32	3.74	21.15	46.9	4.19	19.81	43.9
27		DC-8-61	54.51	7.02	3.91	25.63	47.0	4.14	24.45	44.9
28	Tupolev	Tu110 Cooker	37.80	5.82	3.23	18.29	48.4	3.62	17.77	47.0
29		Tu204-100	39.78	5.68	3.60	17.70	44.5	4.96	17.34	43.6
30	Yakovlev	Yak-42	36.41	5.12	2.94	16.00	43.9	5.47	12.47	34.2
31		Yak-46-1	40.28	4.10	2.61	19.27	47.8	4.91	18.09	44.9

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Manufacture**	**Aircraft**	**Fuselage length [cm]**	**MAC wing [cm]**	**25%-P. MAC wing [cm]**	**MAC h-tail [cm]**	**25%-P. MAC h-tail [cm]**	**L ht [cm]**	**% of fuselage (H)**	**MAC v-tail [cm]**	**25%-P. MAC v-tail [cm]**	**L vt [cm]**	**% of fuselage (V)**
2	**Airbus**	**A300-600**	7.01	0.85	0.21	0.56	0.14	3.41	**48.6**	0.74	0.19	3.15	**44.9**
3		**A310**	6.16	0.77	0.19	0.58	0.15	2.96	**48.1**	0.77	0.19	2.78	**45.1**
4		**A320**	6.43	0.71	0.18	0.50	0.13	3.10	**48.2**	0.69	0.17	2.91	**45.3**
5		**A350-900**	8.01	1.06	0.27	0.56	0.14	3.74	**46.7**	0.71	0.18	3.56	**44.4**
6		**A380**	5.37	0.93	0.23	0.56	0.14	2.43	**45.3**	0.66	0.17	2.30	**42.8**
7	**Antonov**	**An-124**	5.45	0.85	0.21	0.58	0.15	2.46	**45.1**	0.74	0.19	2.28	**41.8**
8	**Comac**	**ARJ21-700**	6.53	0.74	0.19	0.50	0.13	2.94	**45.0**	0.90	0.23	2.35	**36.0**
9		**ARJ21-900**	7.25	0.74	0.19	0.50	0.13	3.20	**44.1**	0.90	0.23	2.59	**35.7**
10	**Boeing**	**B737-100**	5.69	0.77	0.19	0.58	0.15	2.51	**44.1**	0.77	0.19	2.30	**40.4**
11		**B737-400**	7.14	0.77	0.19	0.58	0.15	3.25	**45.5**	0.77	0.19	3.02	**42.3**
12		**B747-300**	6.90	0.93	0.23	0.66	0.17	3.10	**44.9**	0.85	0.21	2.99	**43.3**
13		**B777-300**	6.96	0.82	0.21	0.50	0.13	3.20	**46.0**	0.61	0.15	3.07	**44.1**
14		**B787-300**	6.32	0.82	0.21	0.50	0.13	2.99	**47.3**	0.69	0.17	2.72	**43.0**
15		**B787-800**	5.40	0.63	0.16	0.45	0.11	2.49	**46.1**	0.50	0.13	2.35	**43.5**
16		**B787-900**	5.93	0.63	0.16	0.45	0.11	2.75	**46.4**	0.50	0.13	2.57	**43.3**
17	**Fokker**	**Fokker 100**	7.35	0.79	0.20	0.50	0.13	3.39	**46.1**	0.79	0.20	2.78	**37.8**
18	**Sud Aviation**	**Caravelle 1**	5.42	0.85	0.21	0.48	0.12	2.25	**41.5**	0.71	0.18	2.06	**38.0**
19		**Caravelle 12**	6.27	0.85	0.21	0.56	0.14	2.33	**37.2**	0.77	0.19	2.20	**35.1**
20	**Bombardier**	**Challenger 300**	6.08	0.82	0.21	0.48	0.12	2.78	**45.7**	0.85	0.21	2.14	**35.2**
21		**Challenger 605**	5.53	0.56	0.14	0.45	0.11	2.72	**49.2**	0.79	0.20	2.09	**37.8**
22	**Cessna**	**Citation CJ1**	5.37	0.74	0.19	0.42	0.11	2.46	**45.8**	0.87	0.22	1.98	**36.9**
23		**Citation X**	6.24	0.85	0.21	0.48	0.12	2.94	**47.1**	0.93	0.23	2.12	**34.0**
24	**de Havilland**	**Comet 1**	4.76	1.01	0.25	0.50	0.13	2.57	**54.0**	0.40	0.10	2.62	**55.0**
25		**Comet 2**	5.03	1.11	0.28	0.50	0.13	2.49	**49.5**	0.45	0.11	2.49	**49.5**
26	**Douglas**	**DC-8-20**	6.03	0.98	0.25	0.50	0.13	2.83	**46.9**	0.56	0.14	2.65	**43.9**
27		**DC-8-61**	7.38	0.95	0.24	0.53	0.13	3.47	**47.0**	0.56	0.14	3.31	**44.9**
28	**Tupolev**	**Tu110 Cooker**	5.85	0.90	0.23	0.50	0.13	2.83	**48.4**	0.56	0.14	2.75	**47.0**
29		**Tu204-100**	5.53	0.79	0.20	0.50	0.13	2.46	**44.5**	0.69	0.17	2.41	**43.6**
30	**Yakovlev**	**Yak-42**	6.19	0.87	0.22	0.50	0.13	2.72	**43.9**	0.93	0.23	2.12	**34.2**
31		**Yak-46-1**	6.48	0.66	0.17	0.42	0.11	3.10	**47.8**	0.79	0.20	2.91	**44.9**

Appendix B: Drawings

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b
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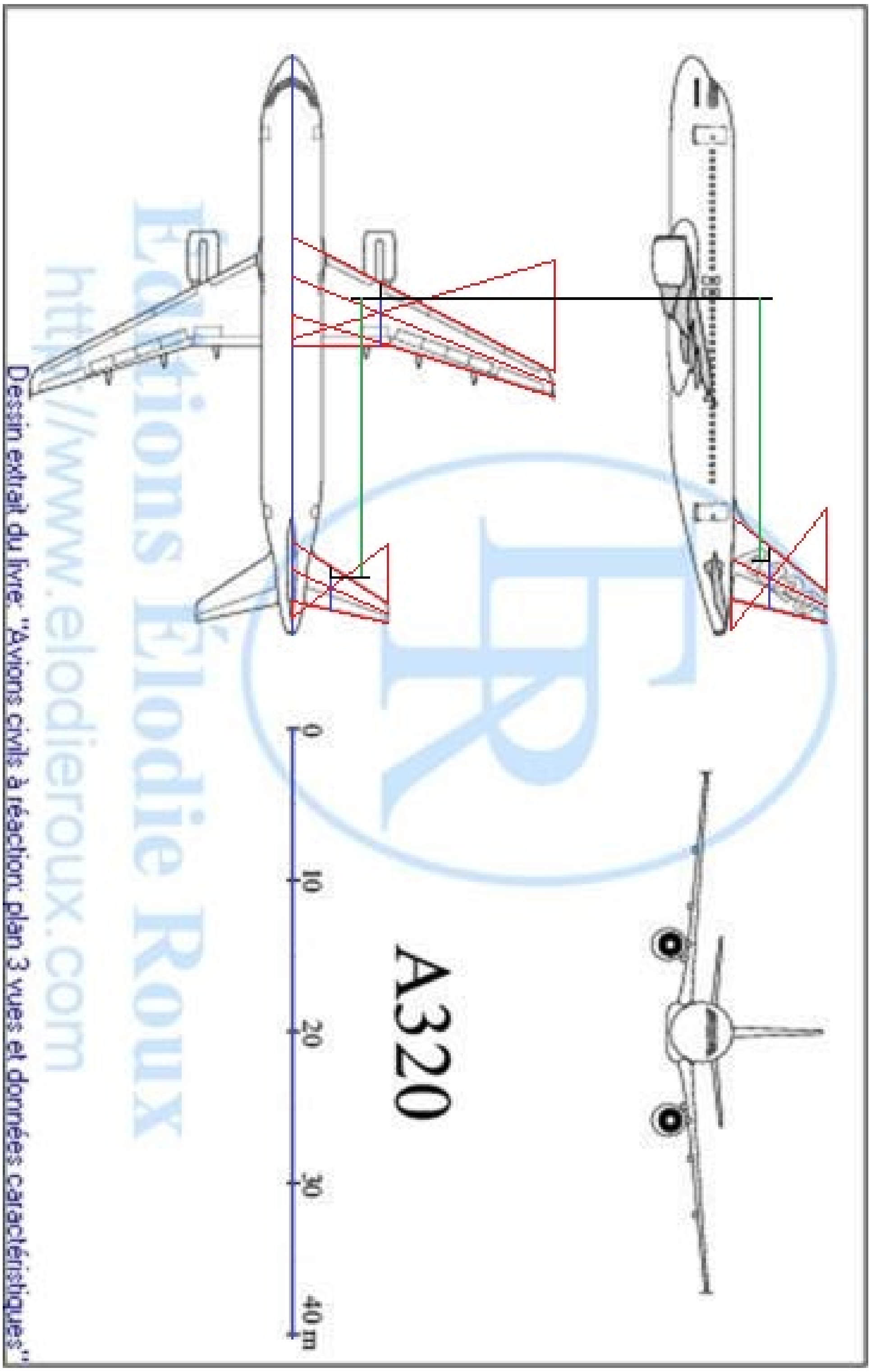
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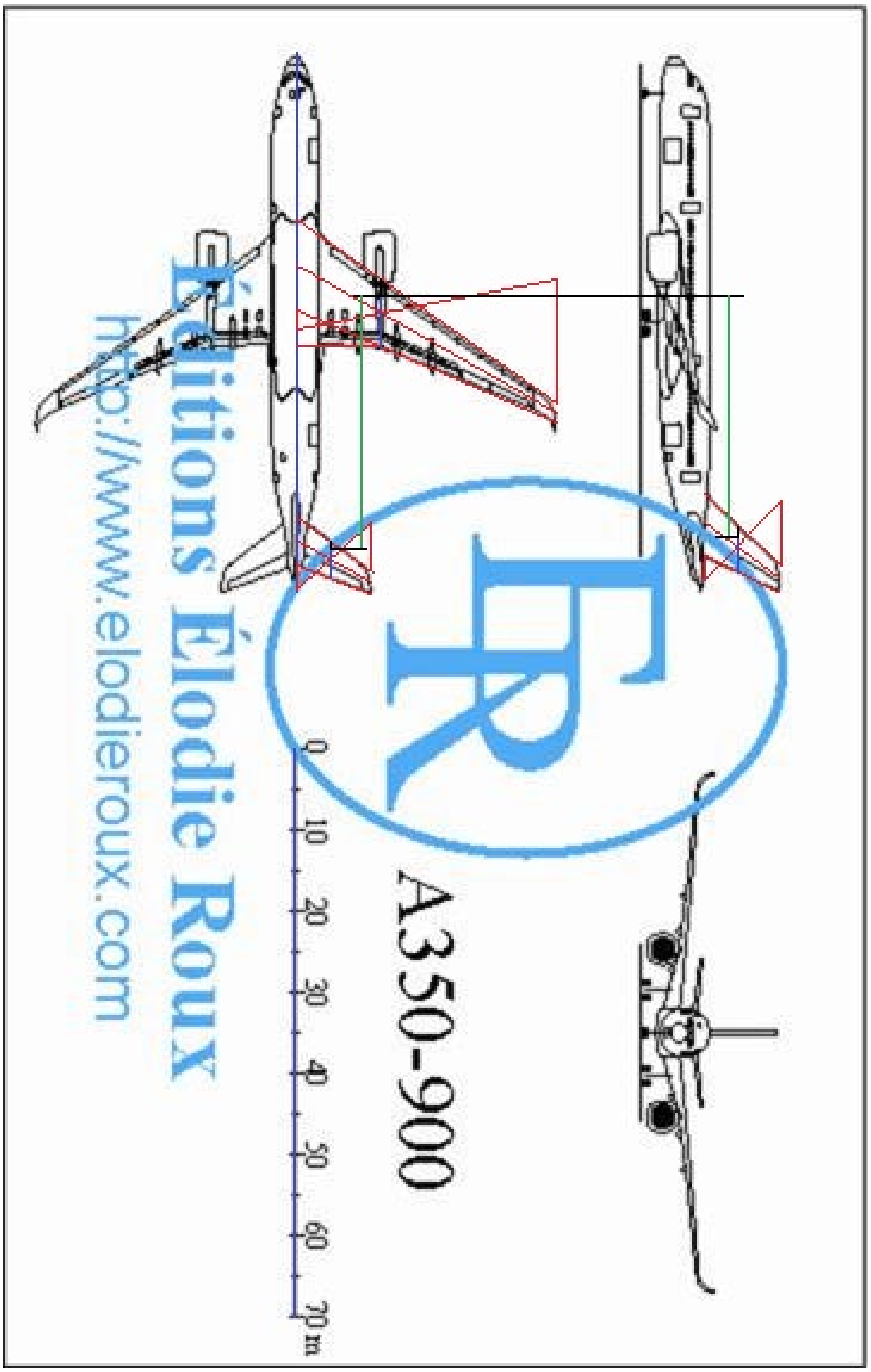
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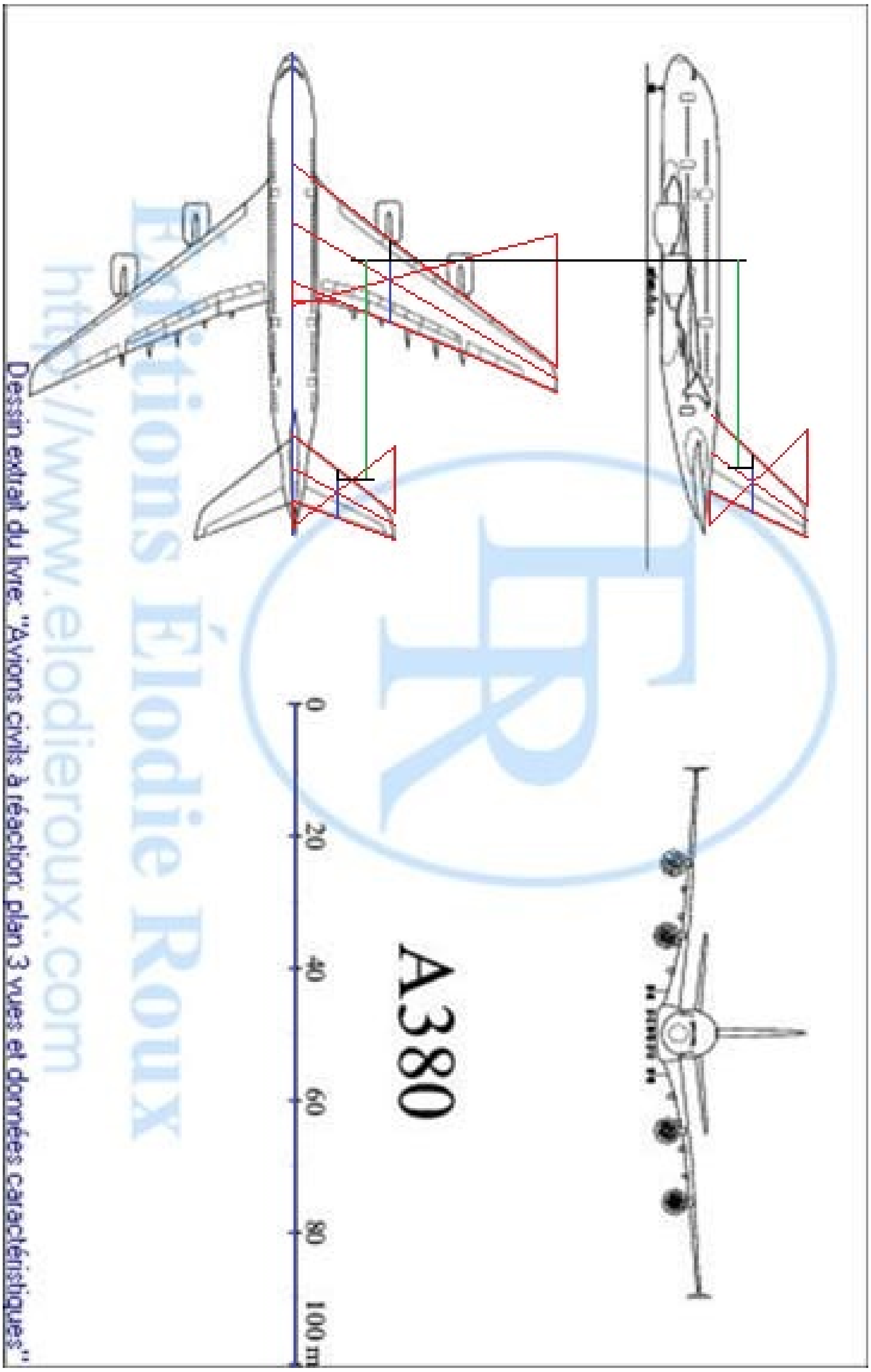
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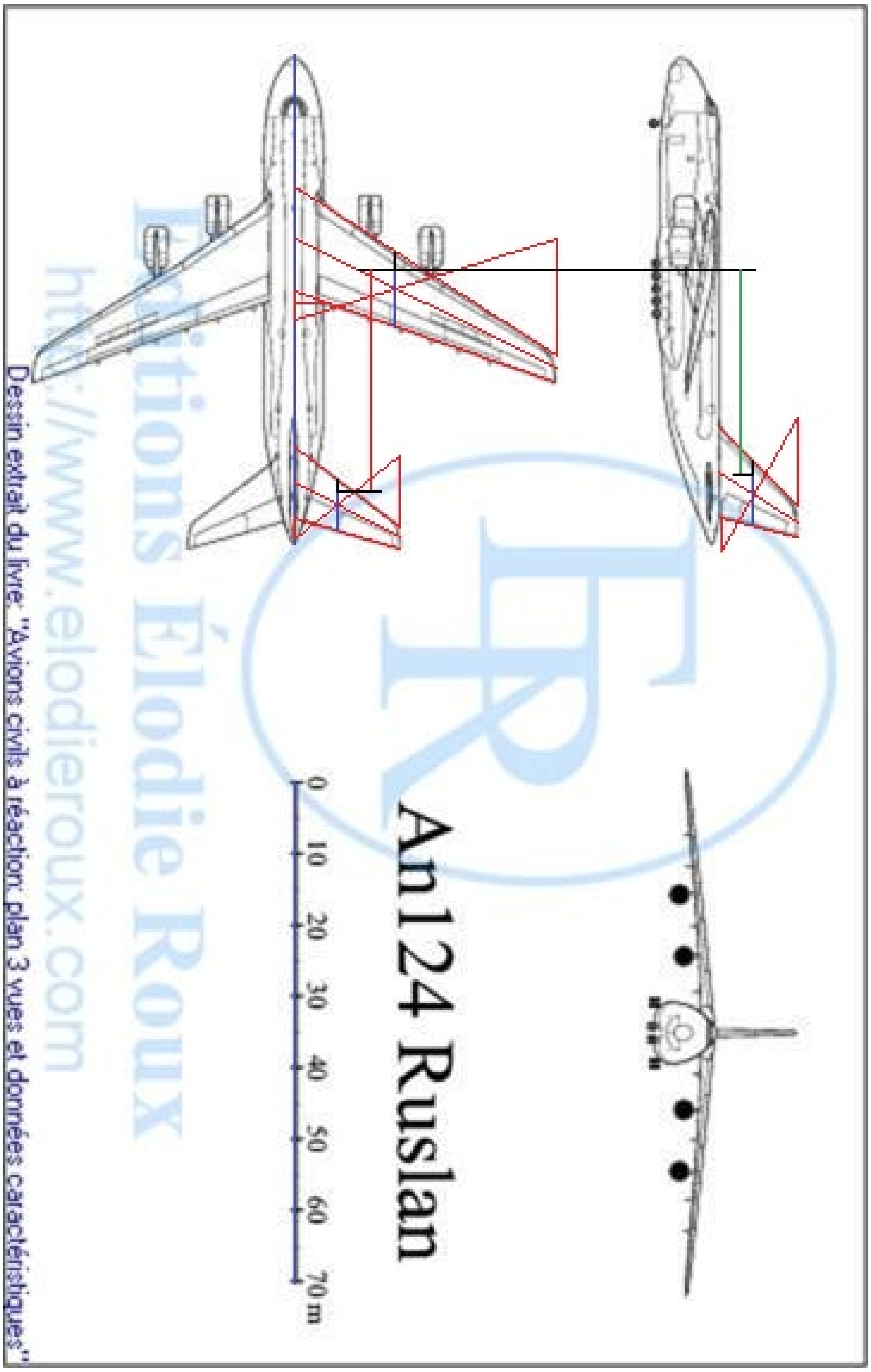
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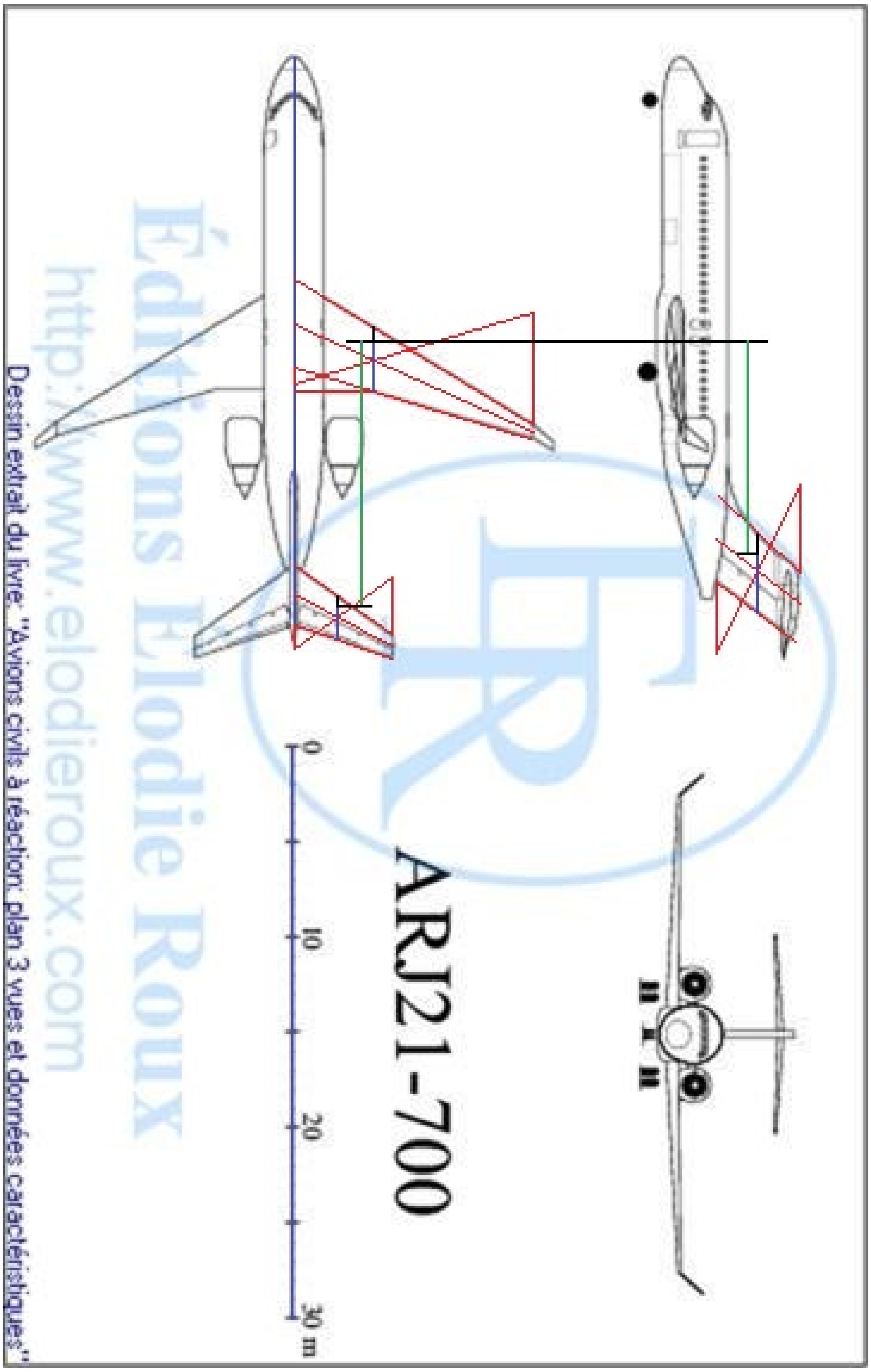
ARJ21-700
Éditions Elodie Roux
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0
10
20
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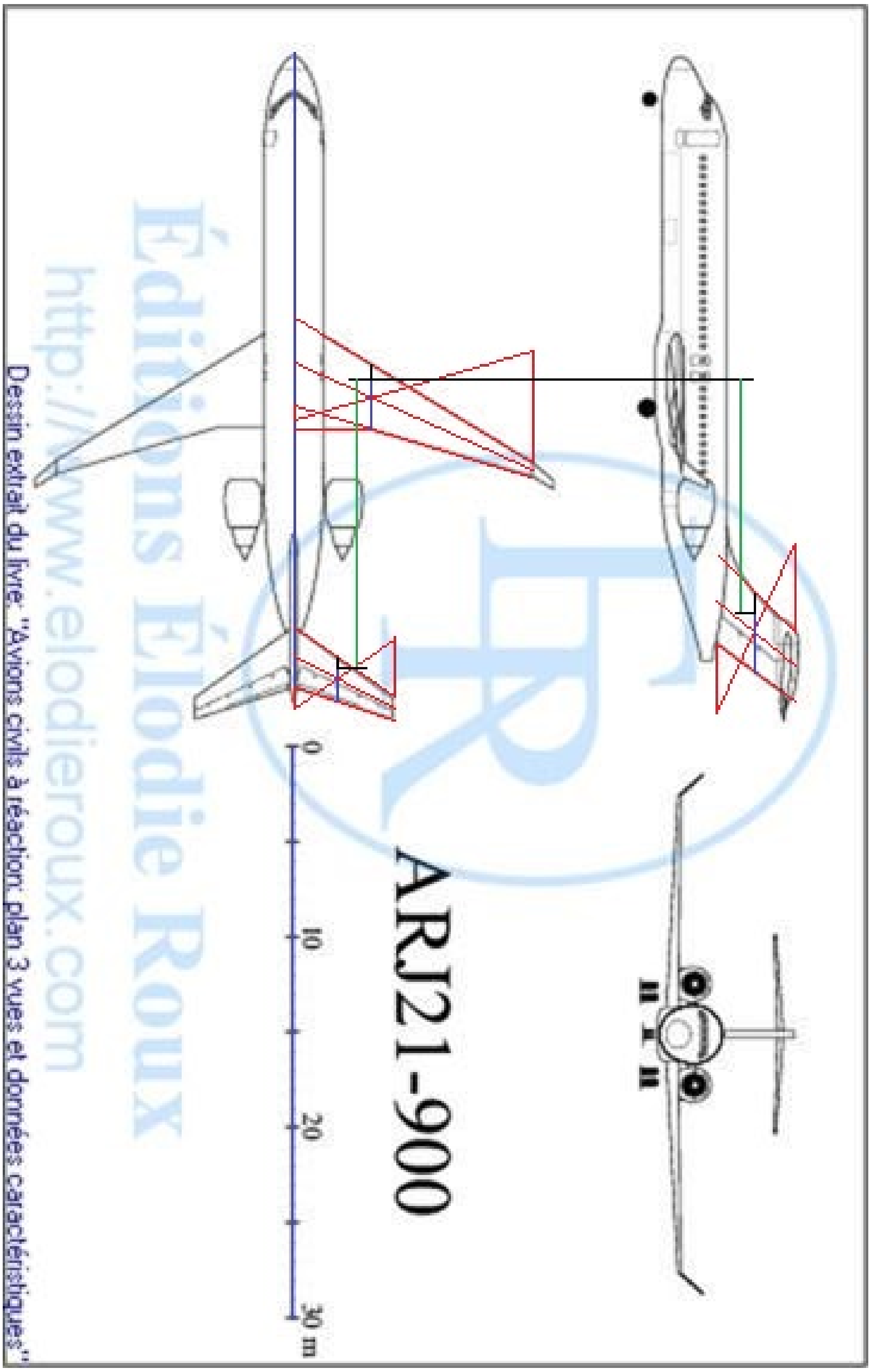
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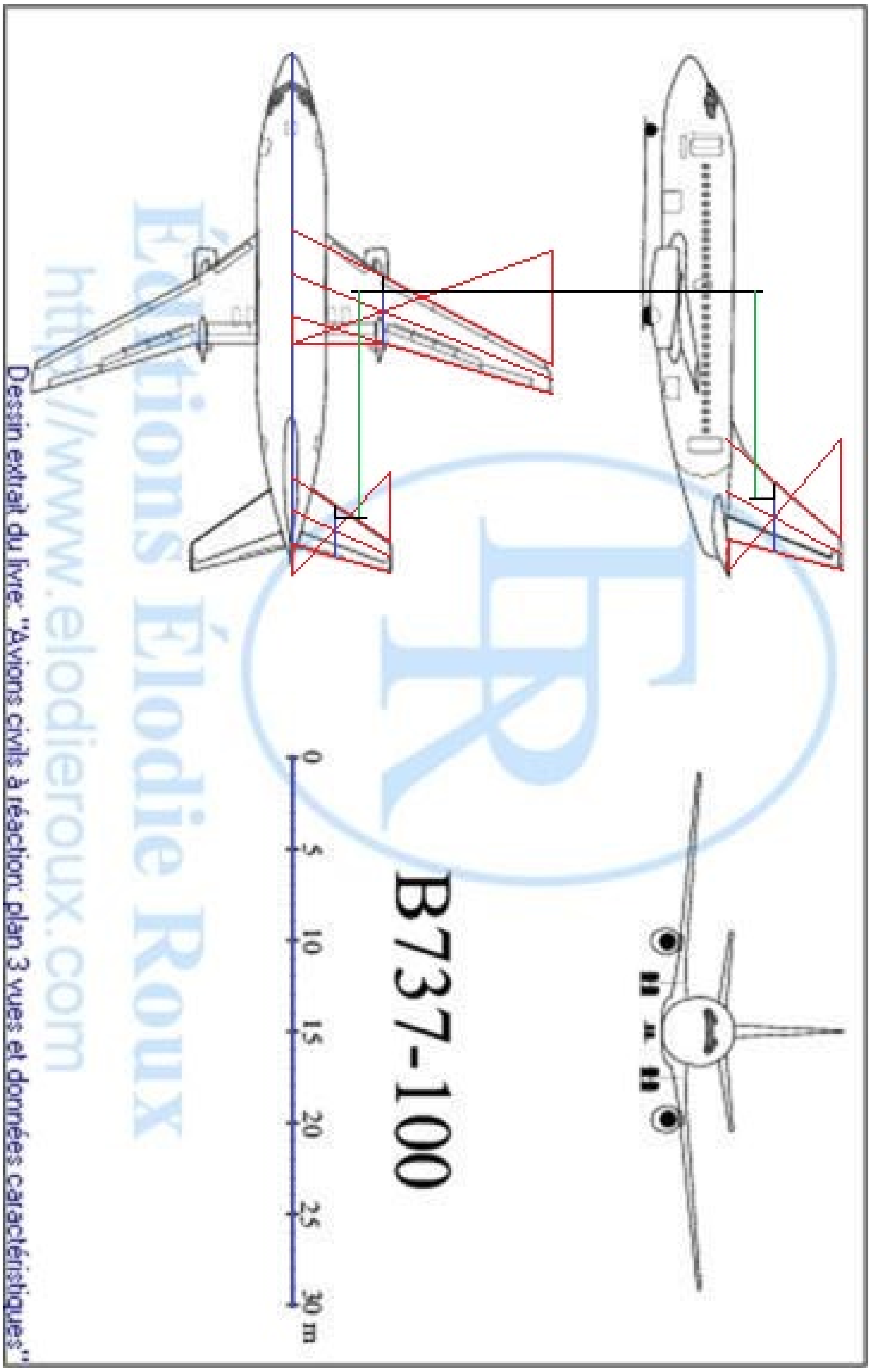
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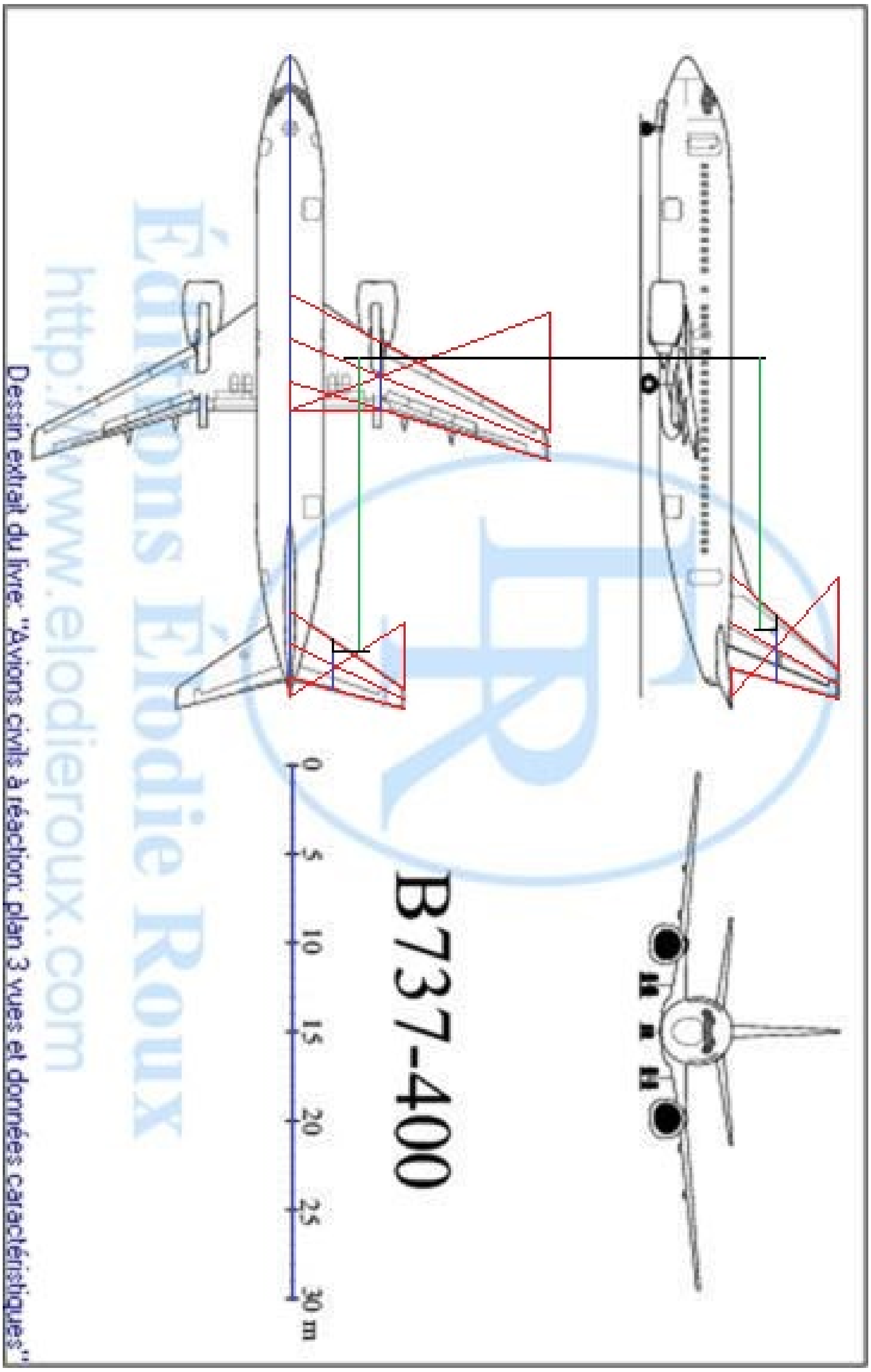
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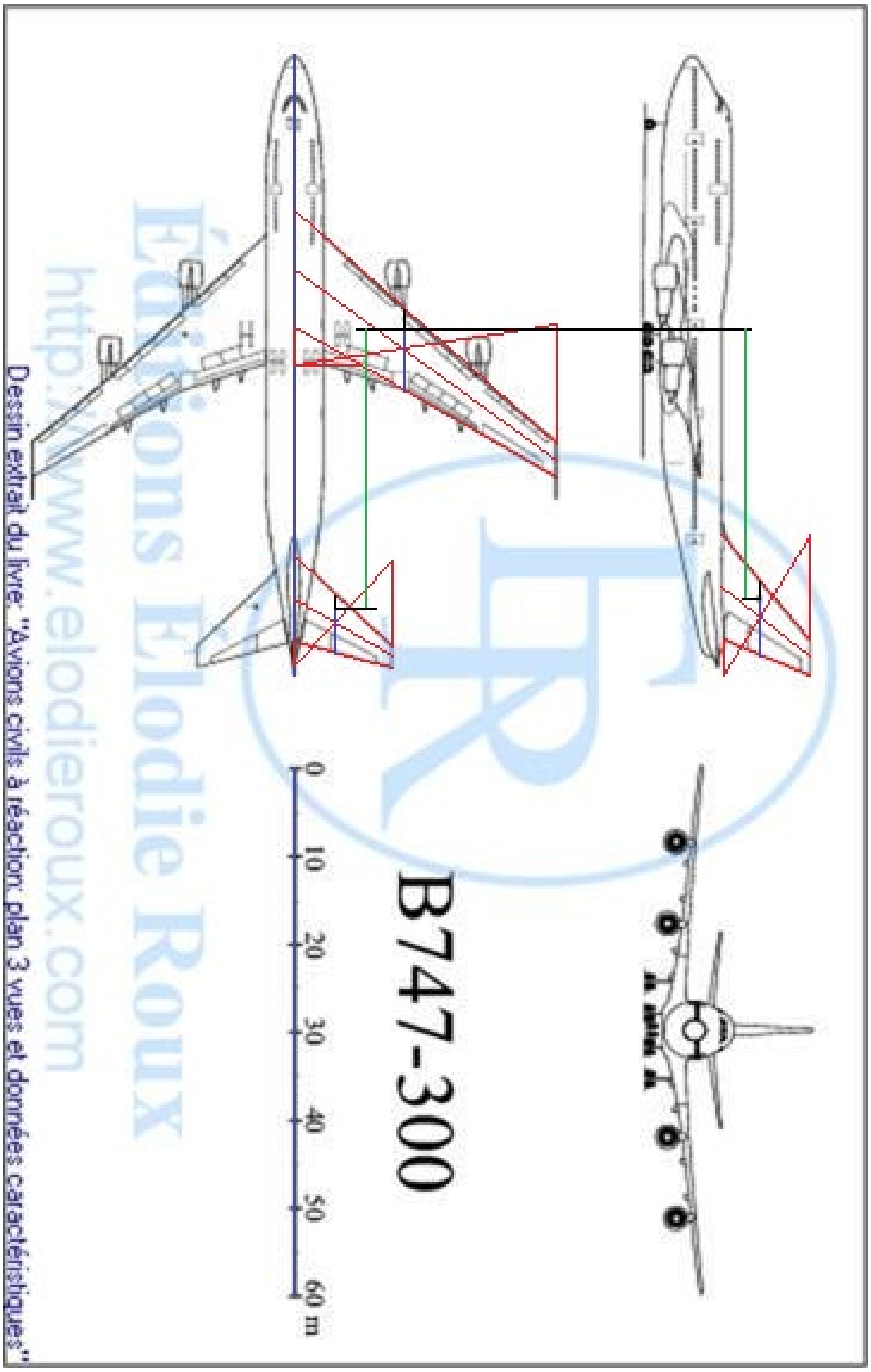
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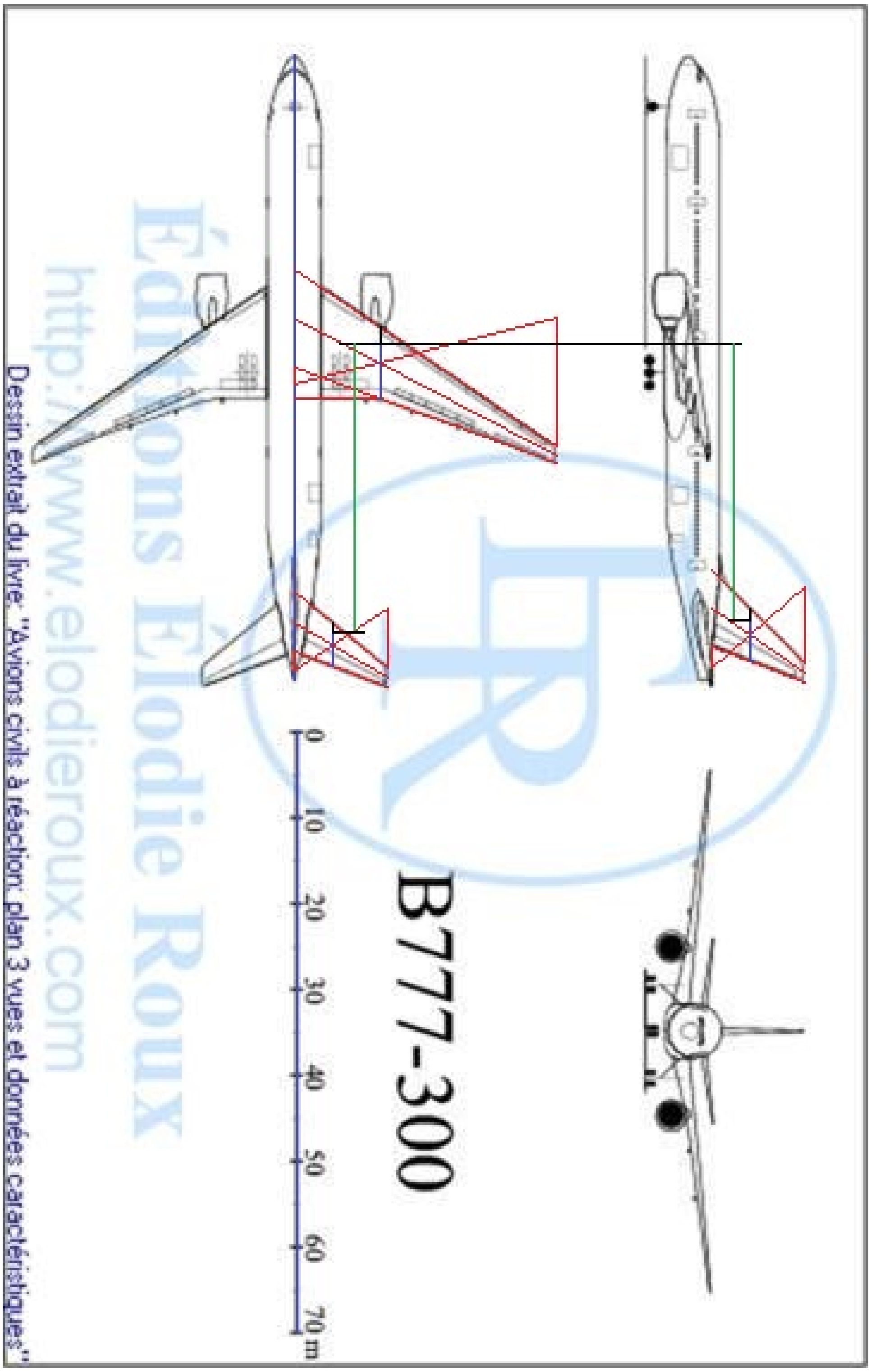
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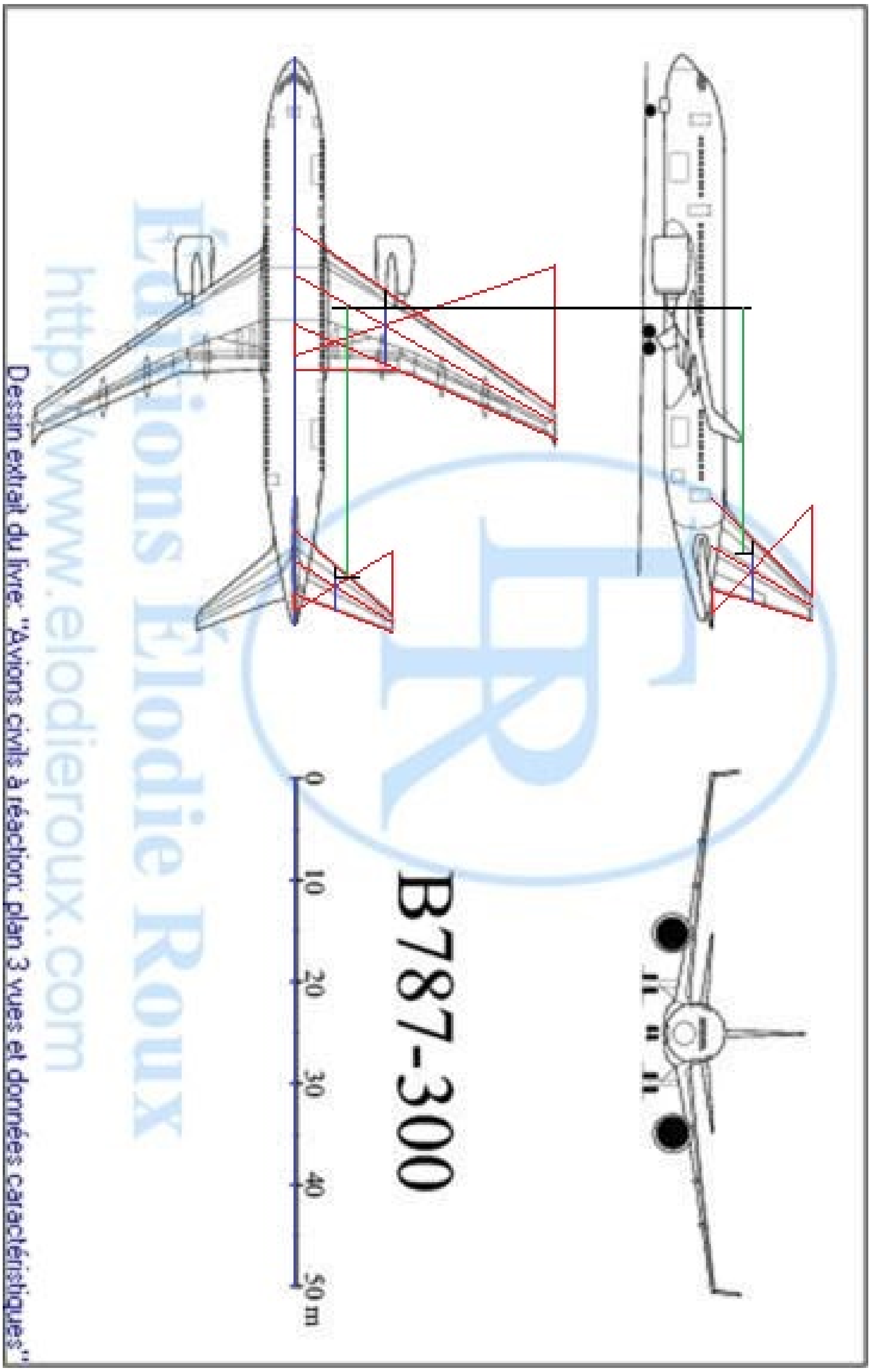
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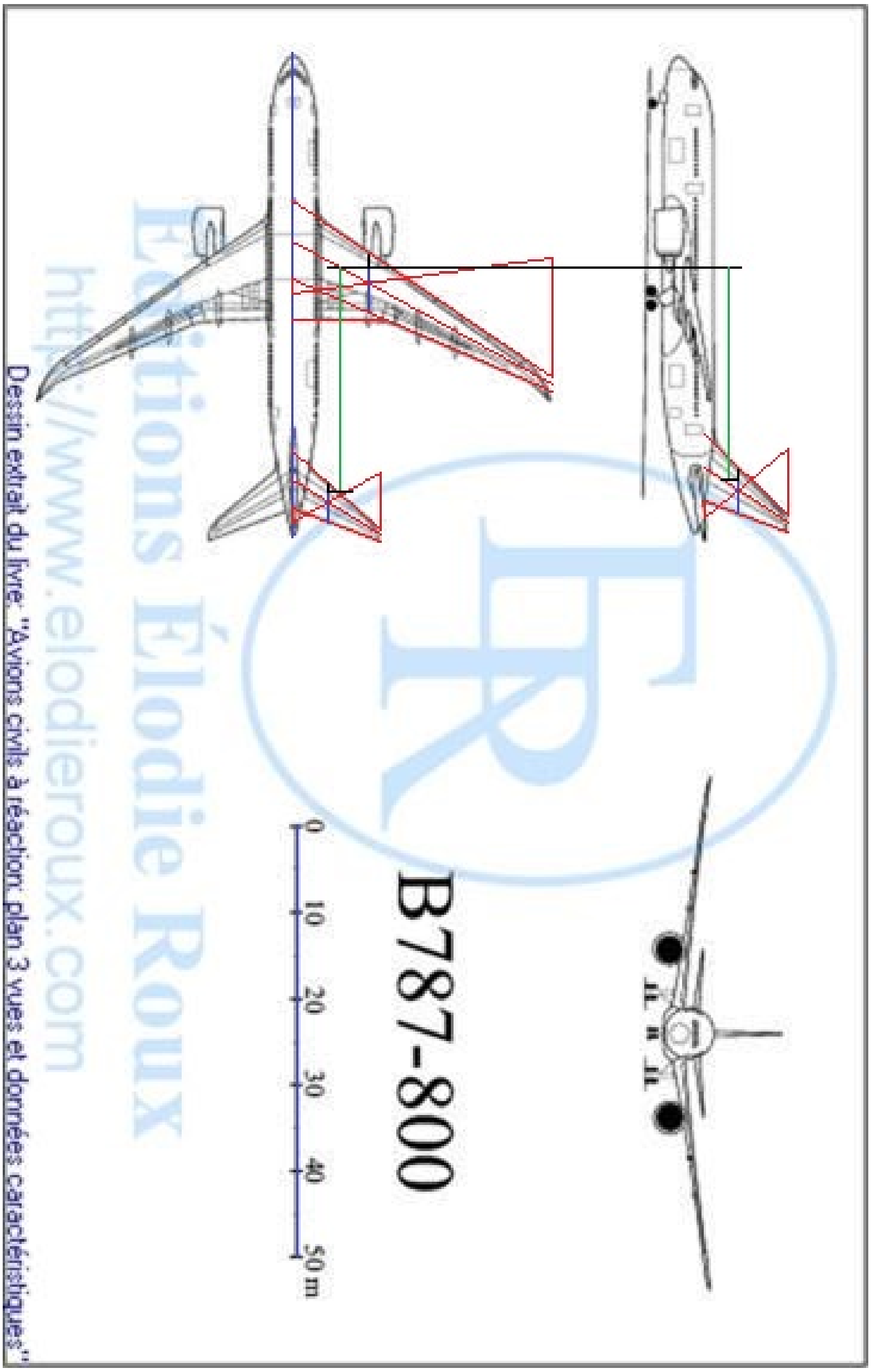
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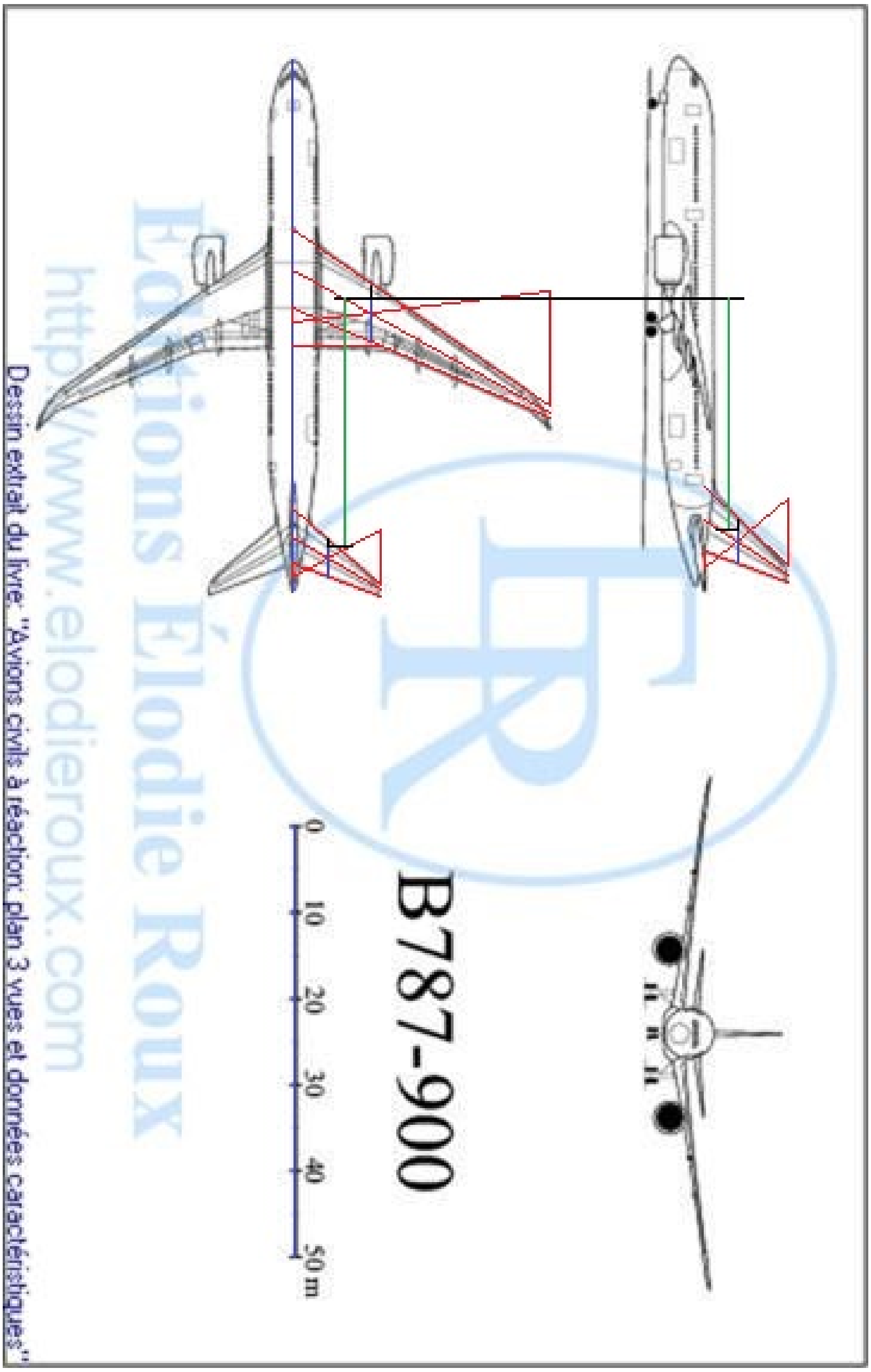
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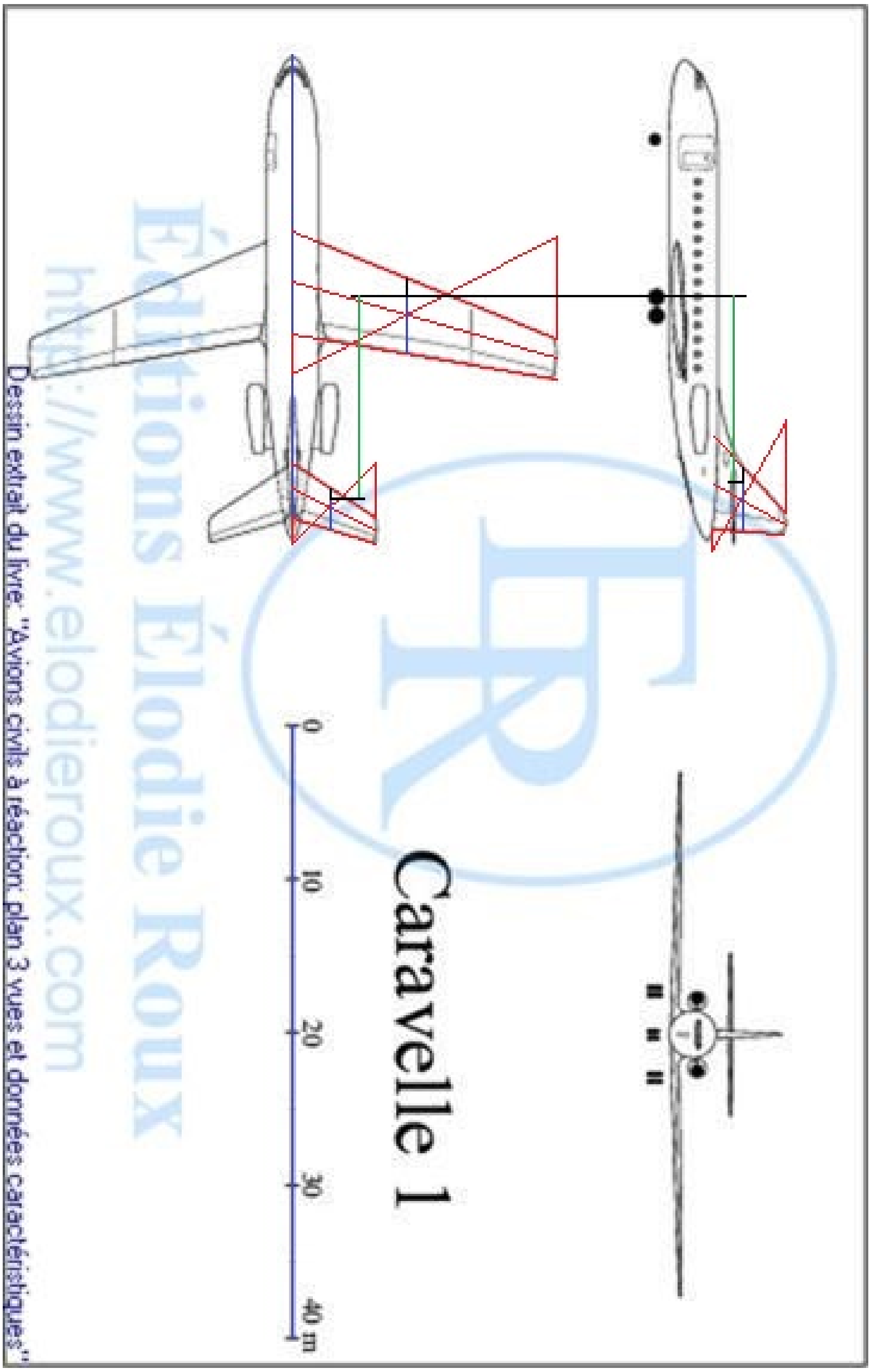
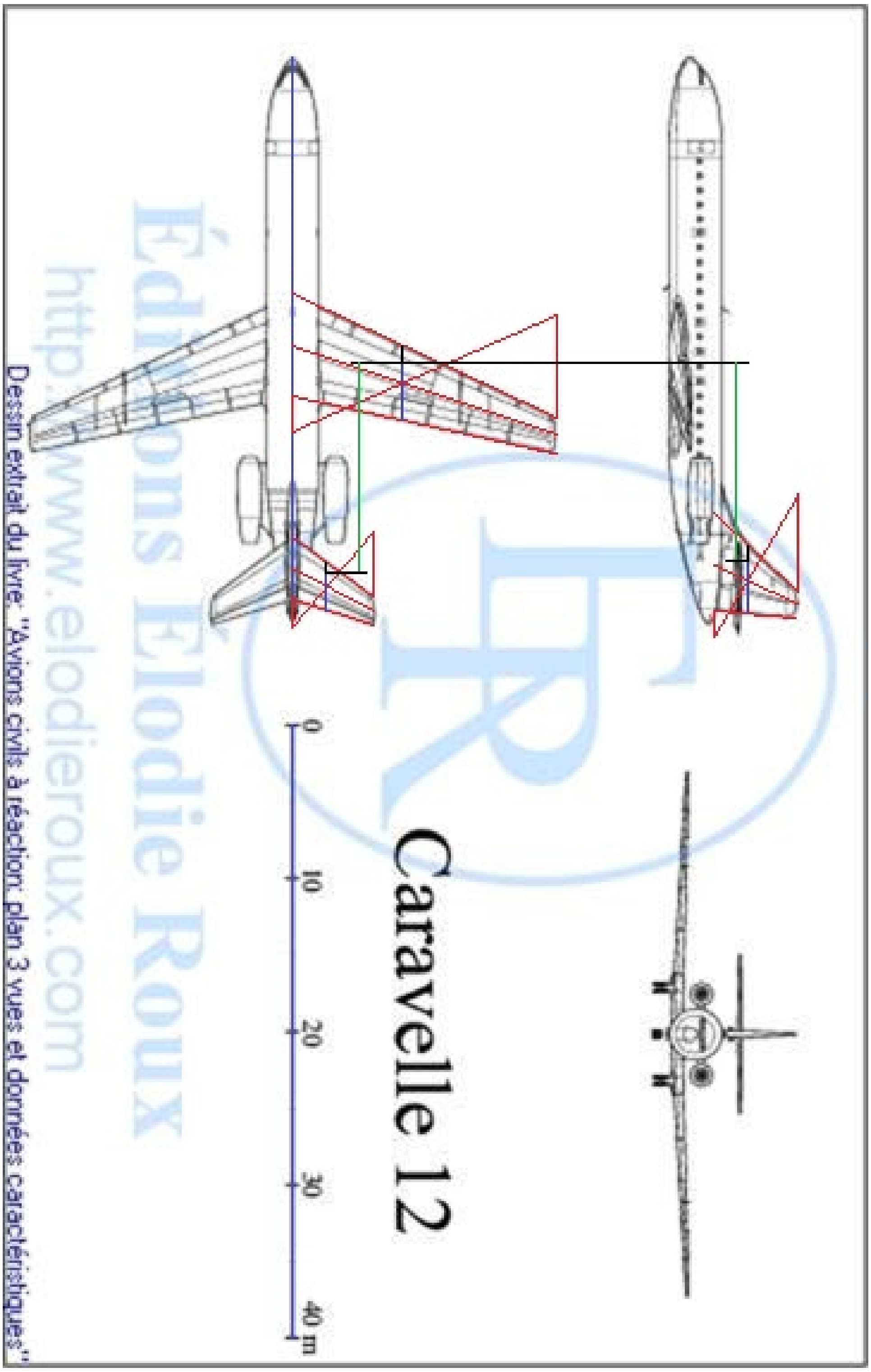

Caravelle 1
0
10
20
30
40 m
Éditions Élodie Roux
http://www.elodieroux.com
Dessin extrait du livre: "Avions civils à réaction: plan 3 vues et données caractéristiques"


Caravelle 12
0
10
20
30
40 m
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Challenger 300
0
5
10
15
20 m
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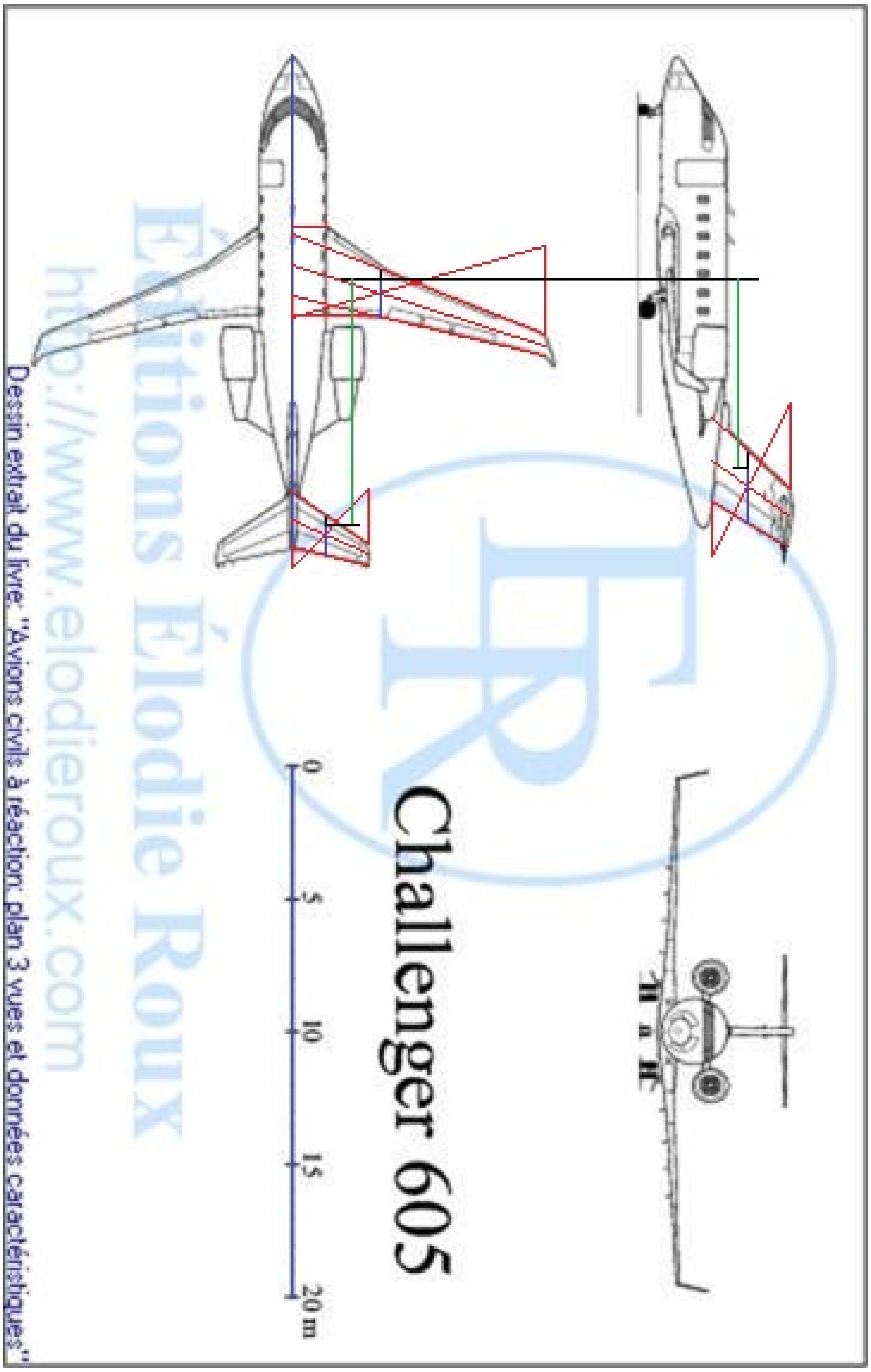
Challenger 605
0
5
10
15
20 m
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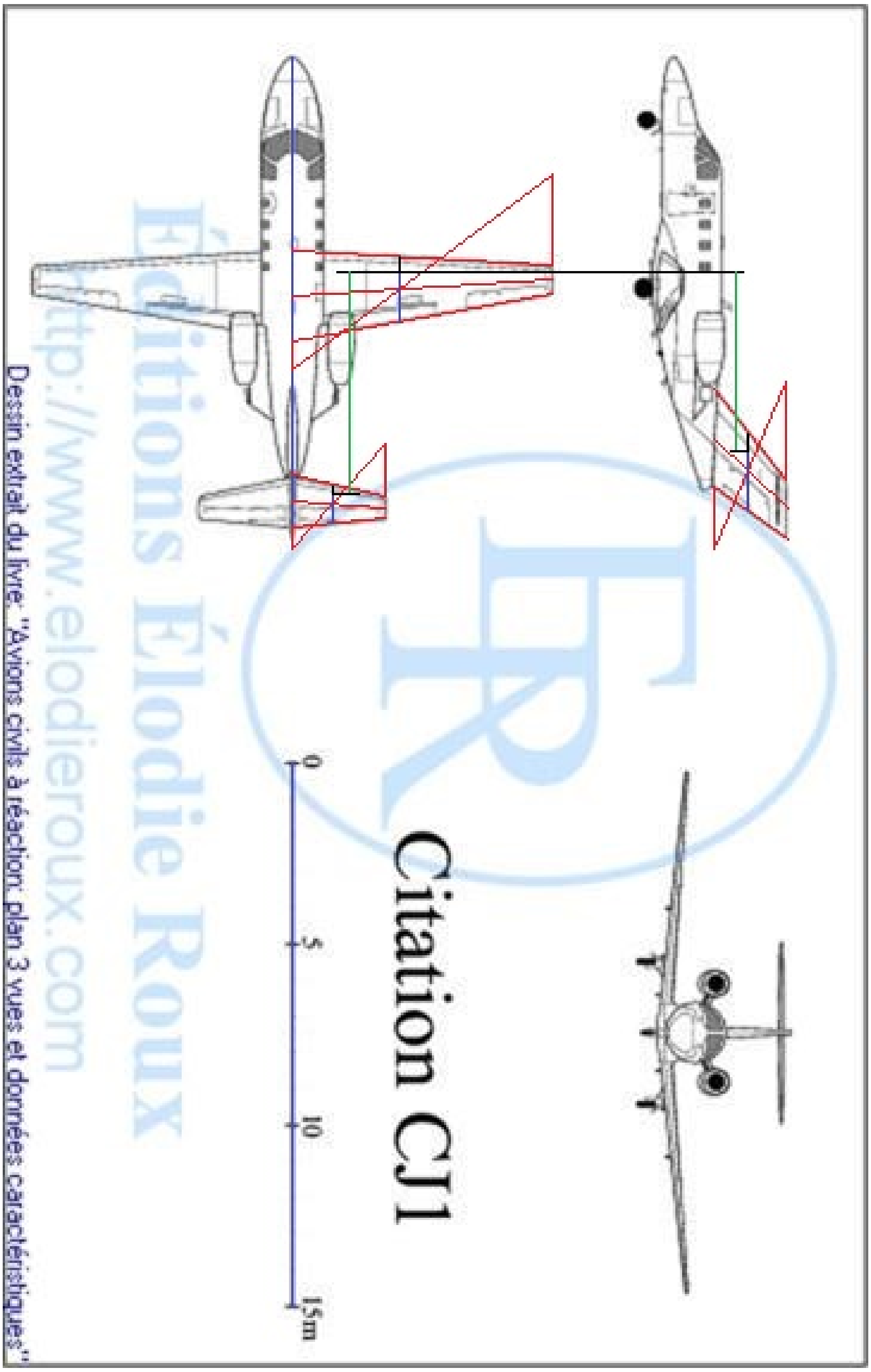
Citation CJ1
0
5
10
15m
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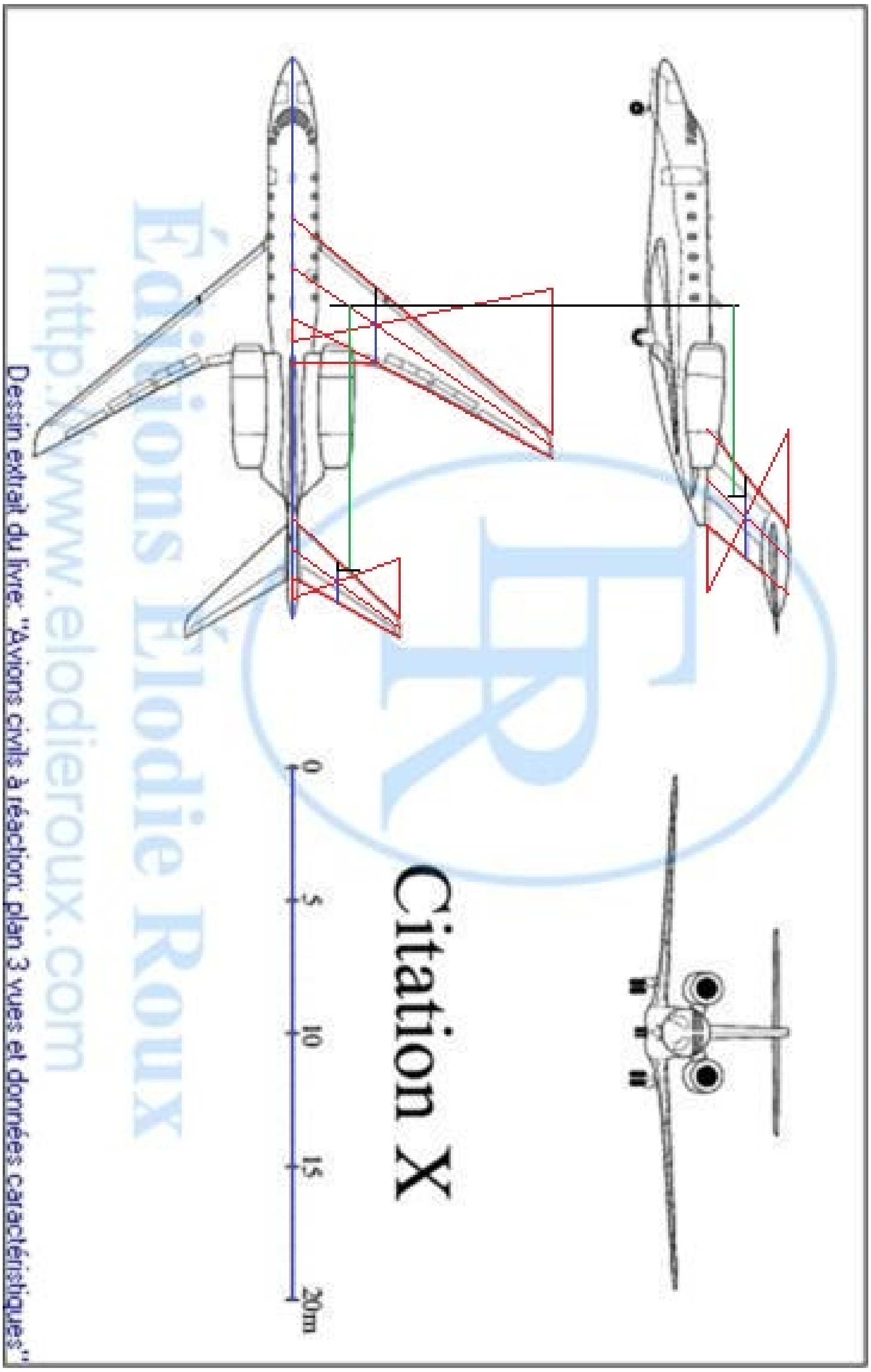
Citation X
0
5
10
15
20m
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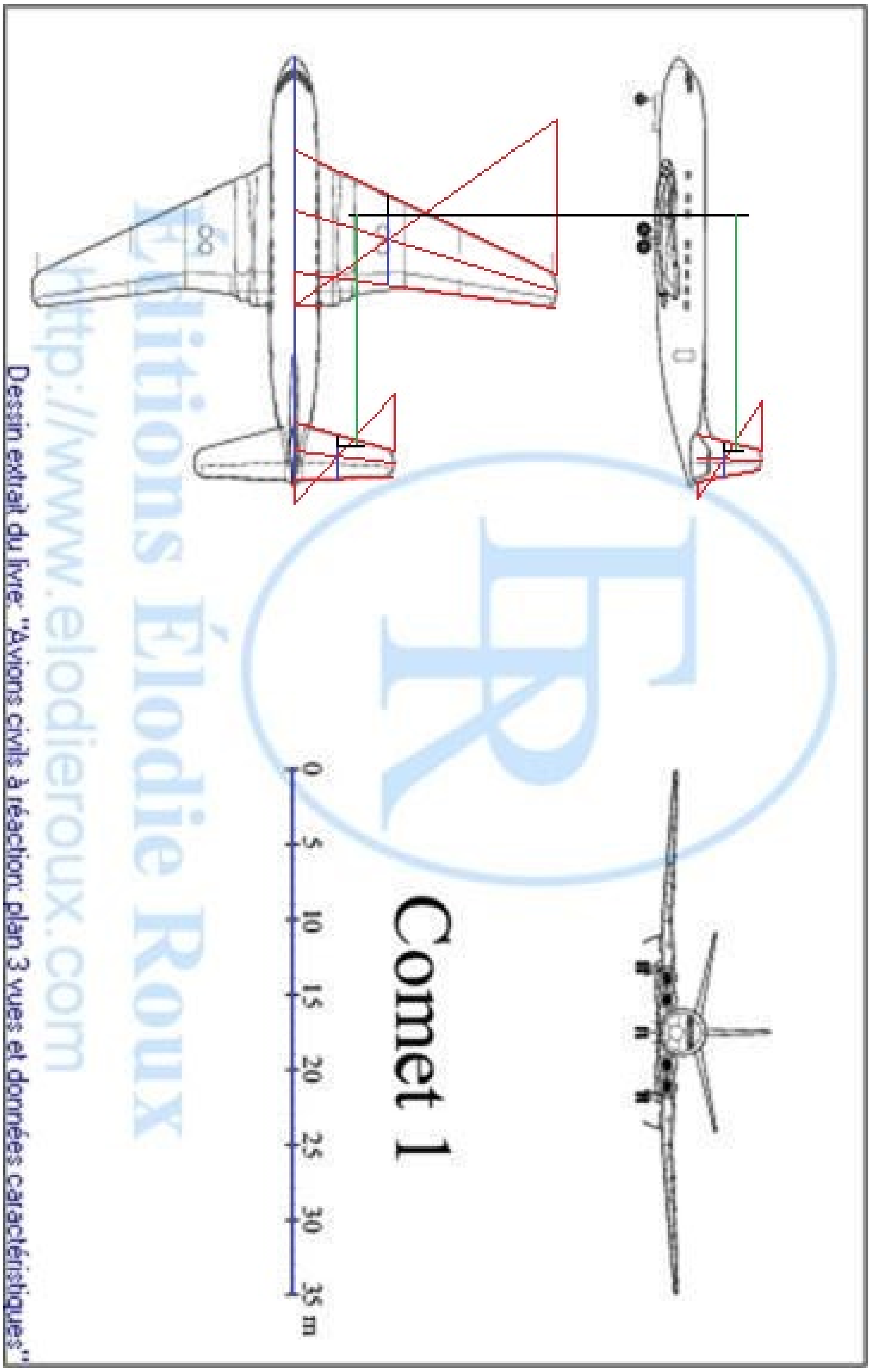
Comet 1
0 5 10 15 20 25 30 35 m
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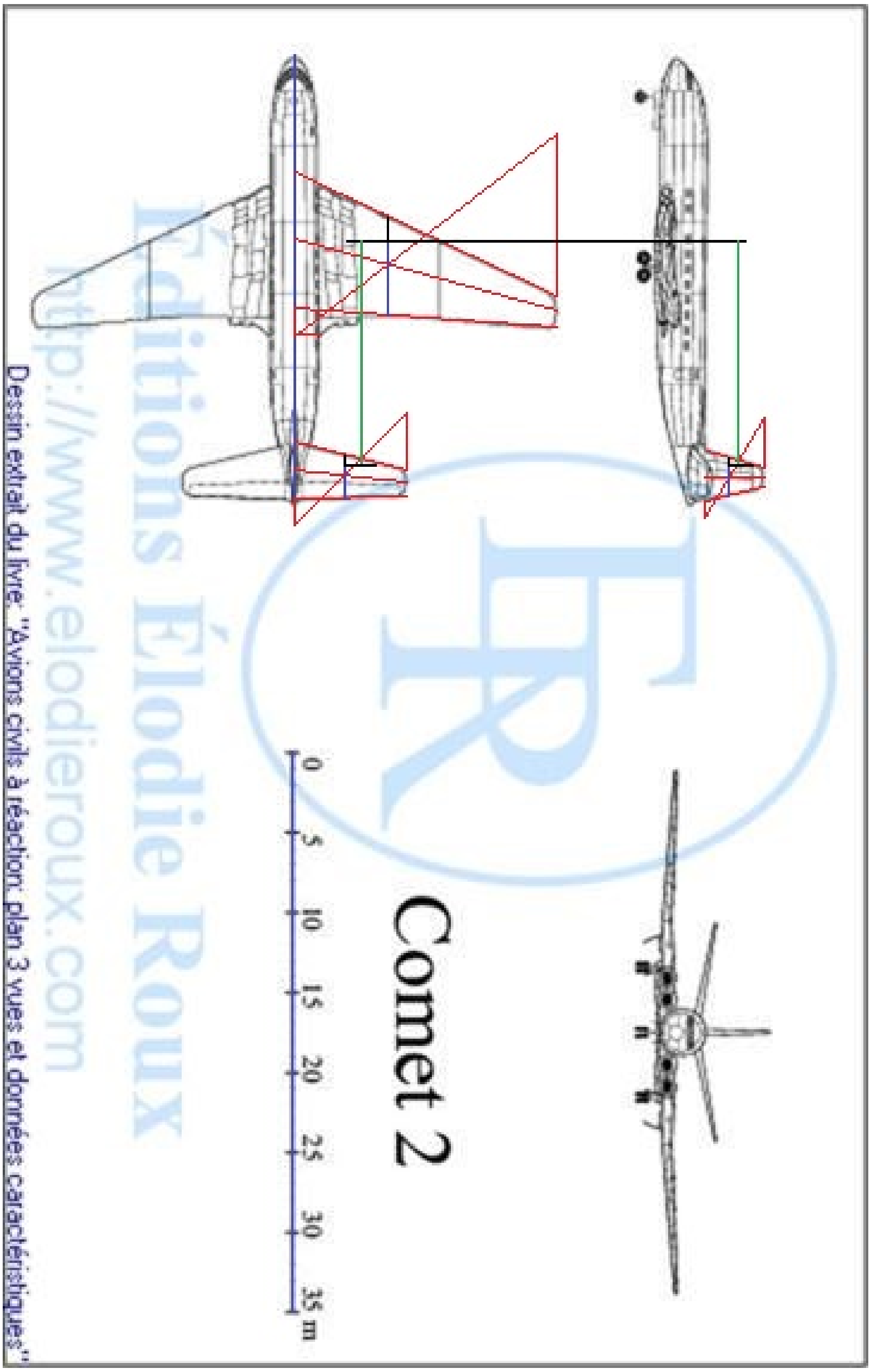
Comet 2
0 5 10 15 20 25 30 35 m
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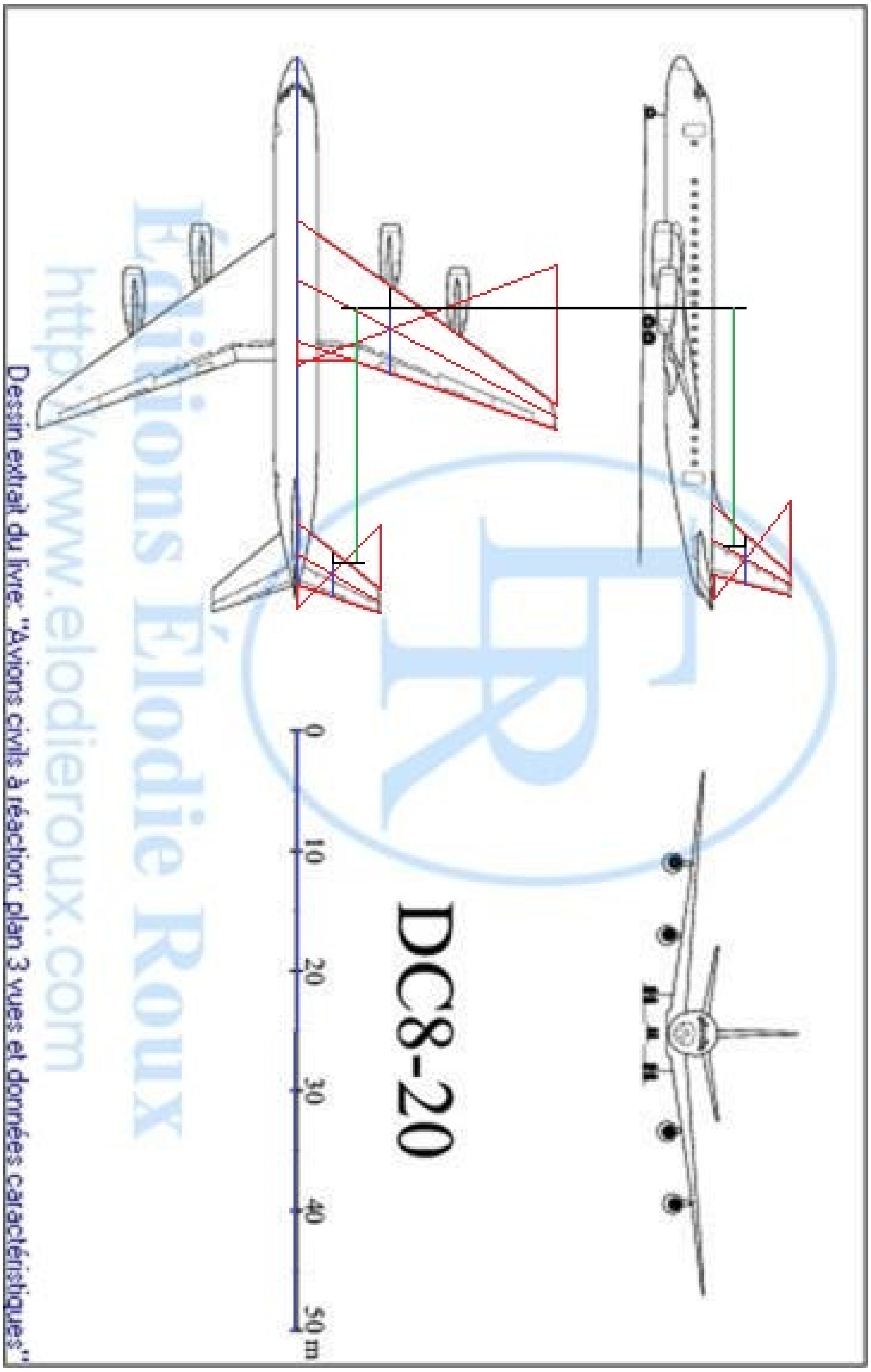
DC8-20
0 10 20 30 40 50 m
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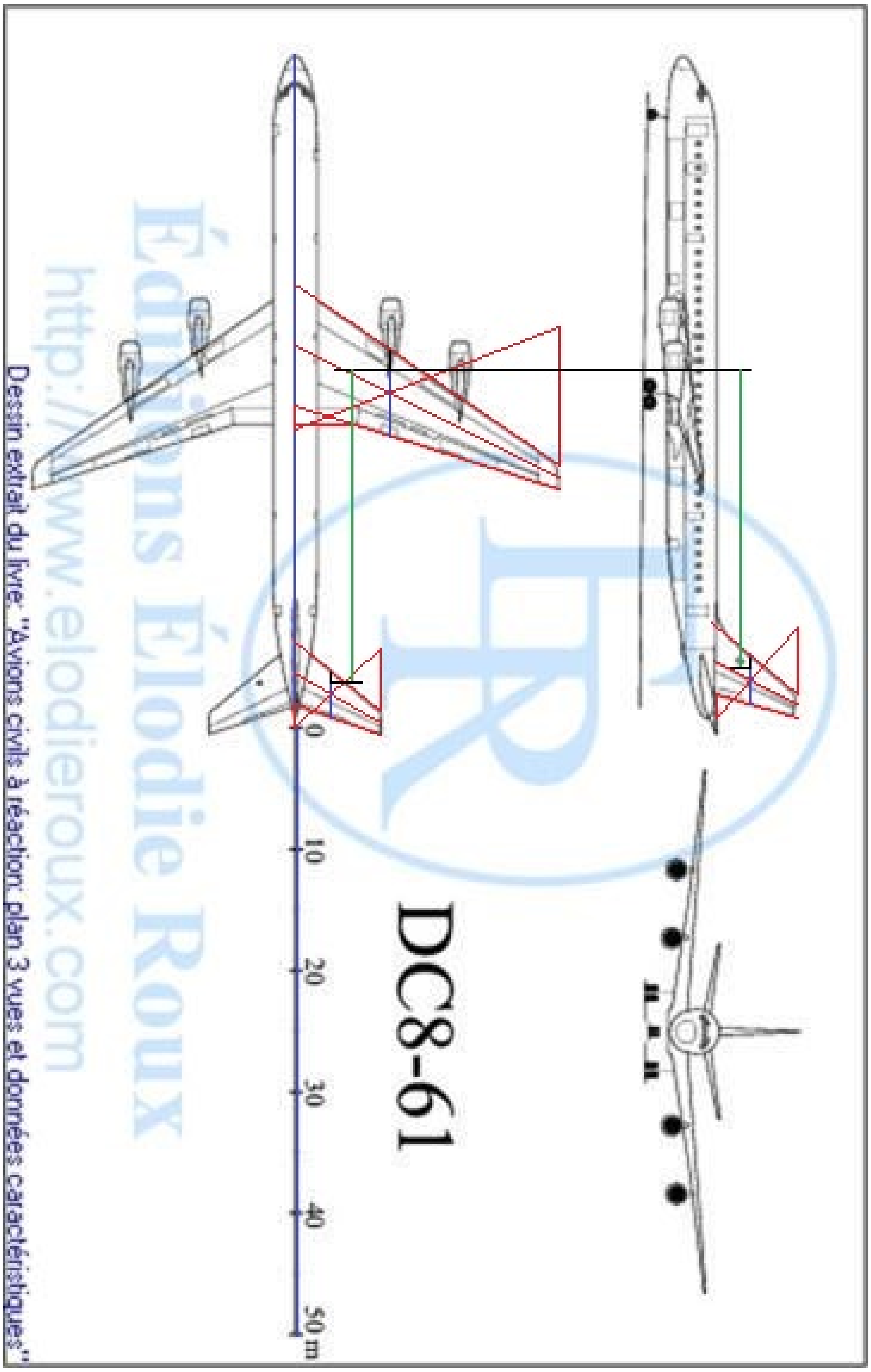
DC8-61
0
10
20
30
40
50 m
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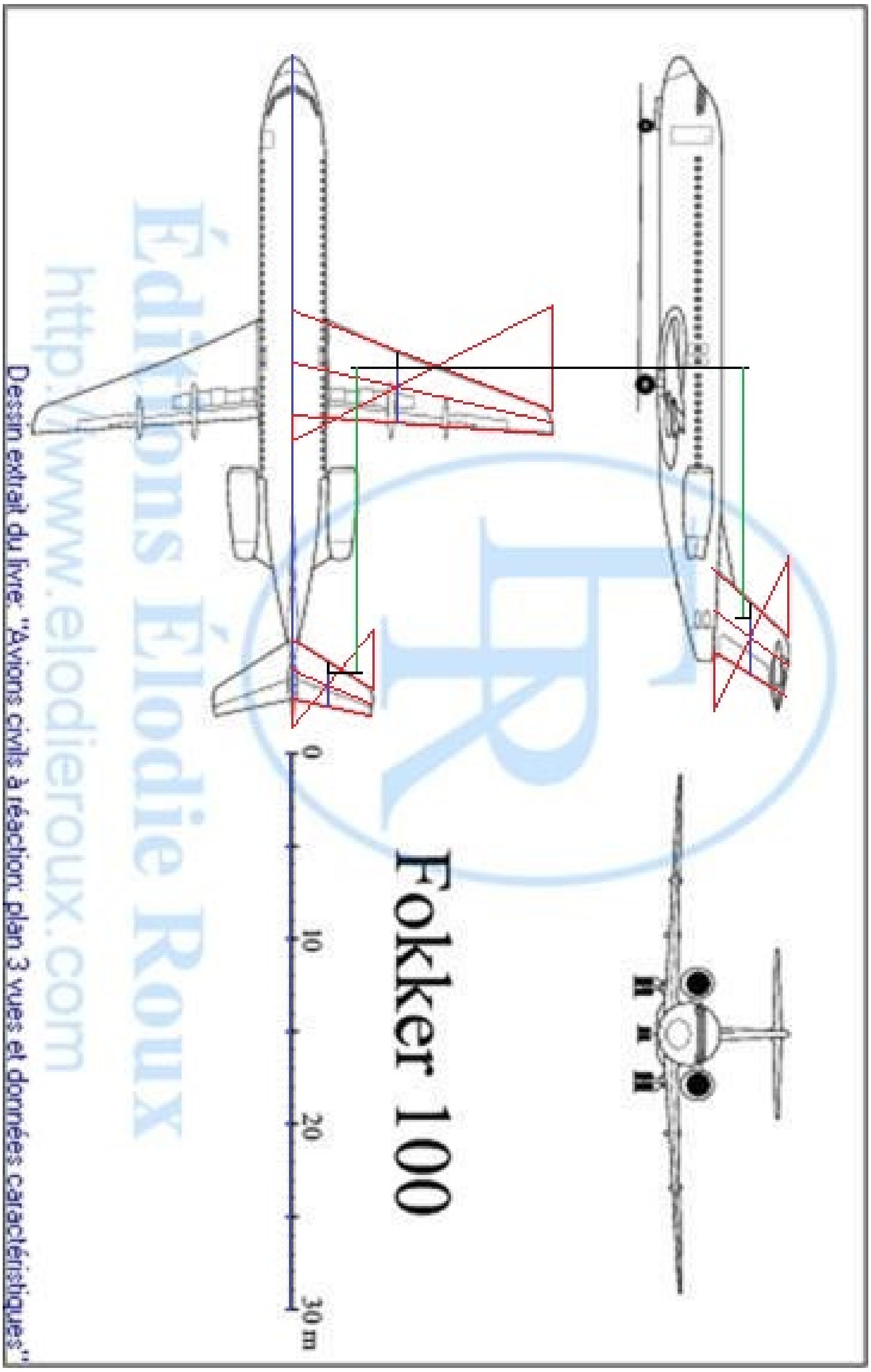
Fokker 100
0
10
20
30 m
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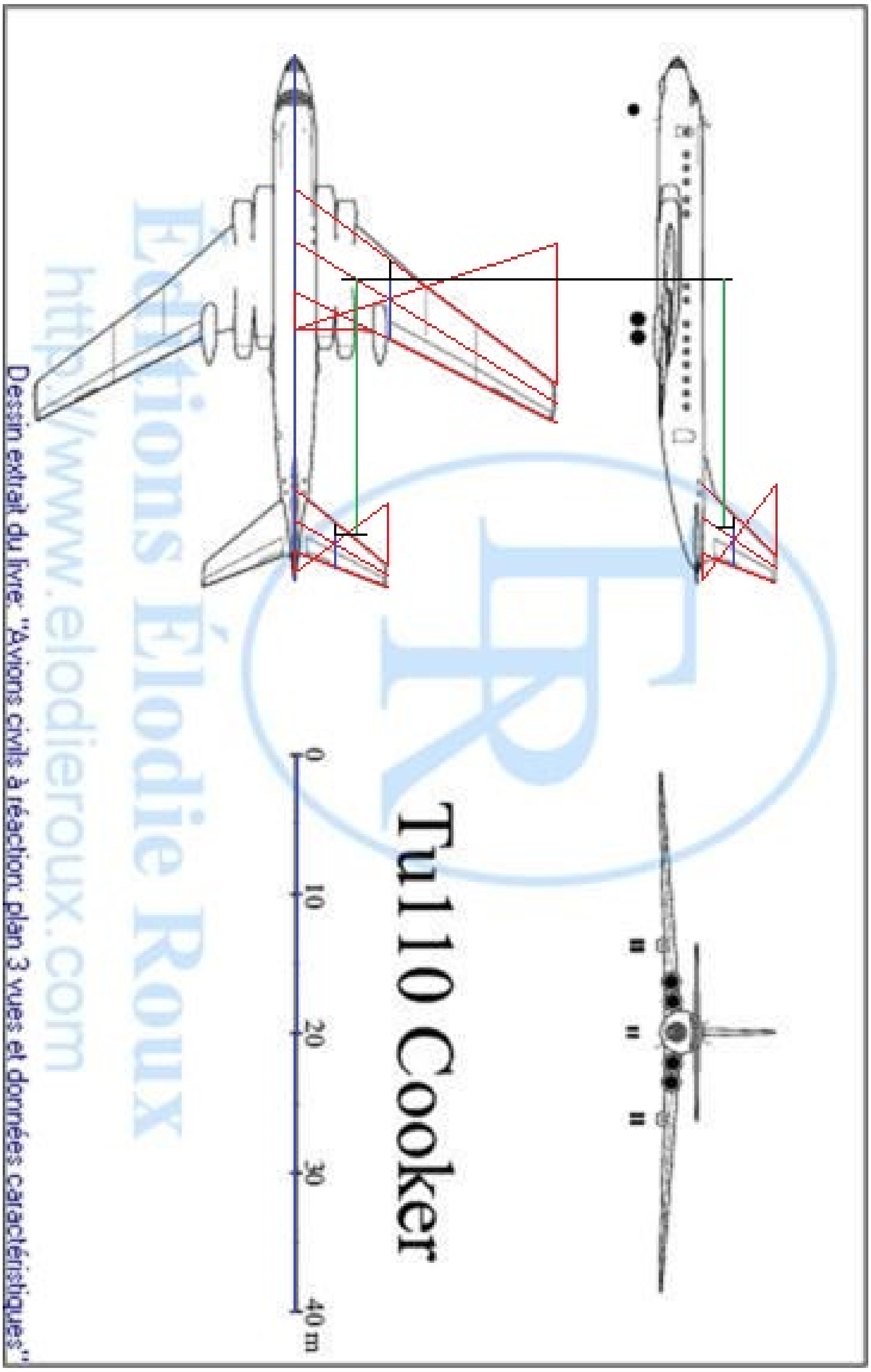
Tu110 Cooker
0
10
20
30
40 m
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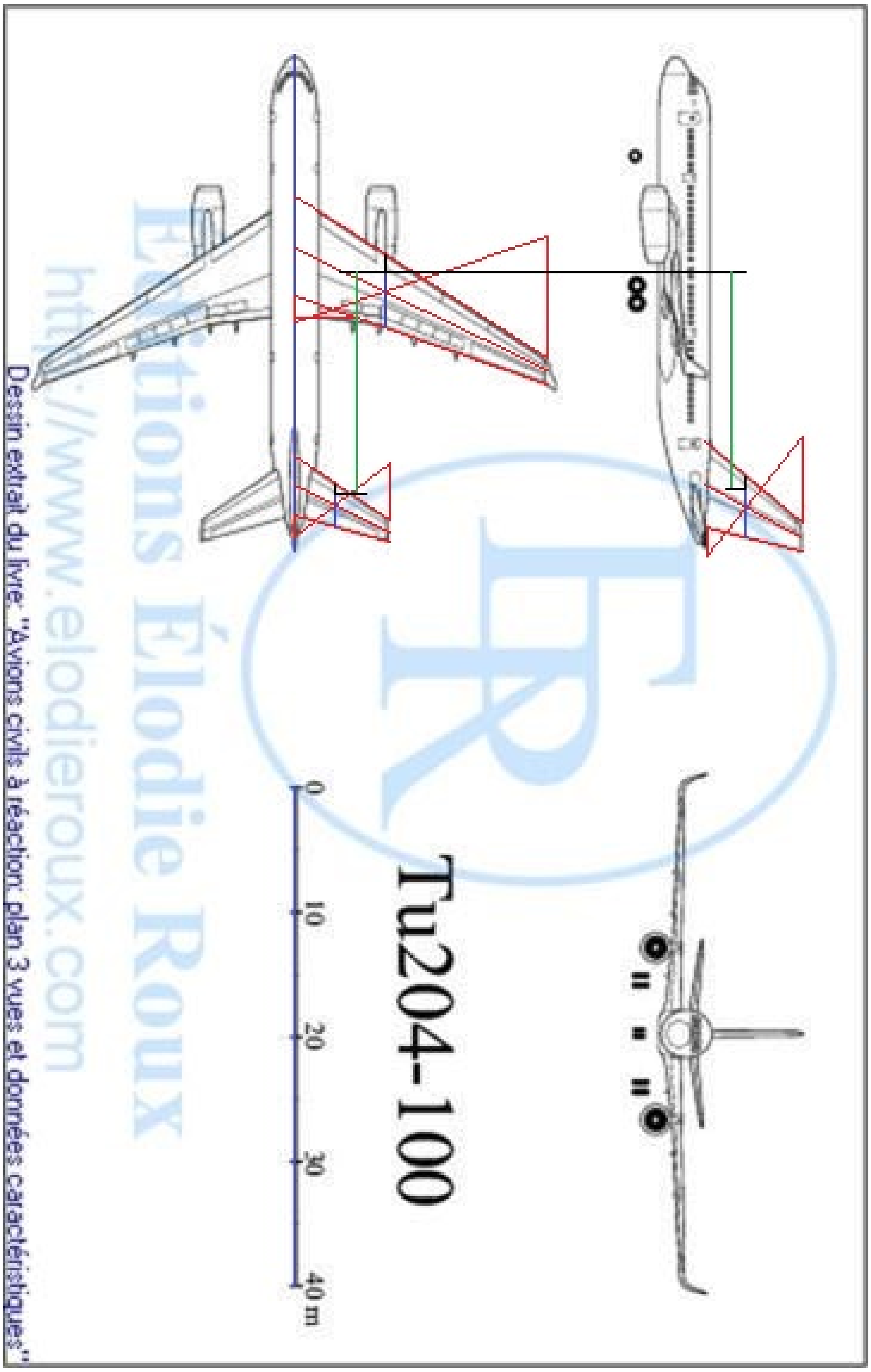
Tu204-100
0
10
20
30
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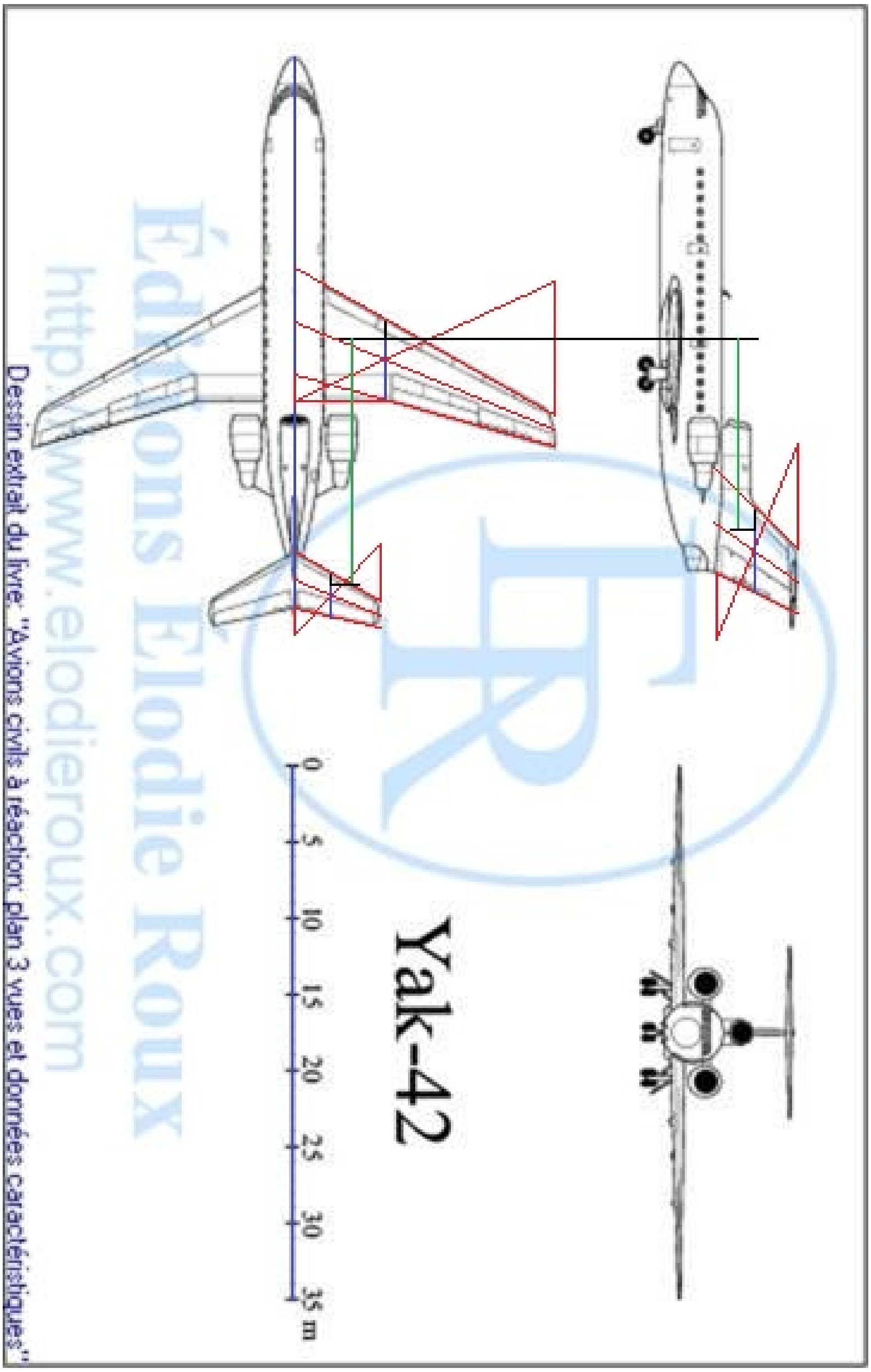
Yak-42
0
5
10
15
20
25
30
35 m
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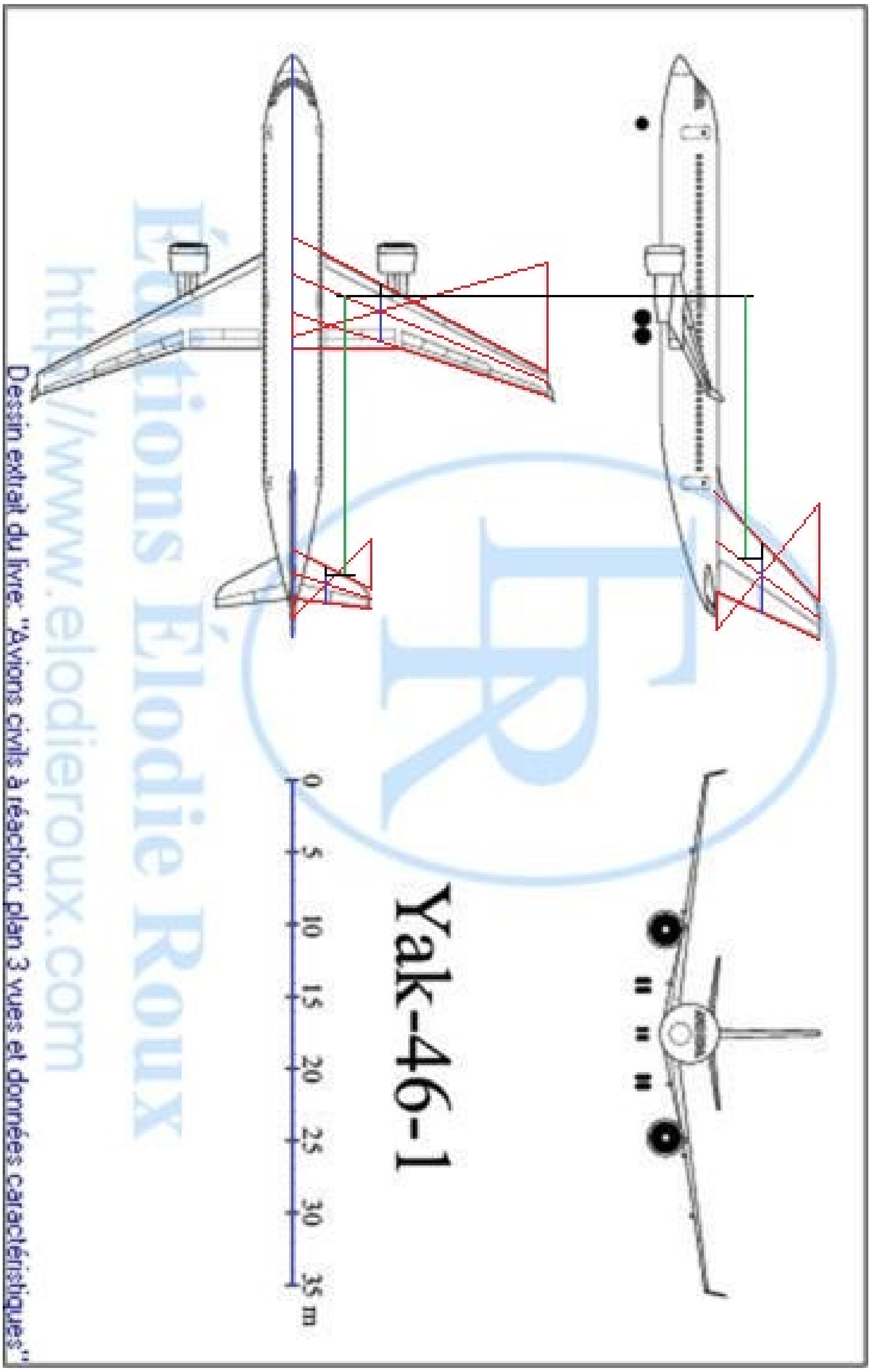
Yak-46-1
0 5 10 15 20 25 30 35 m
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