Airbus/WSU Wingbox Challenge (Open Category) 2019-20

Showcase your aviation heritage
Design, build, and predict the performance of the lightest, strongest, and stiffest Wingbox possible!

AIRBUS

Prize money

1st Prize : $2000

2nd Prize : $1000

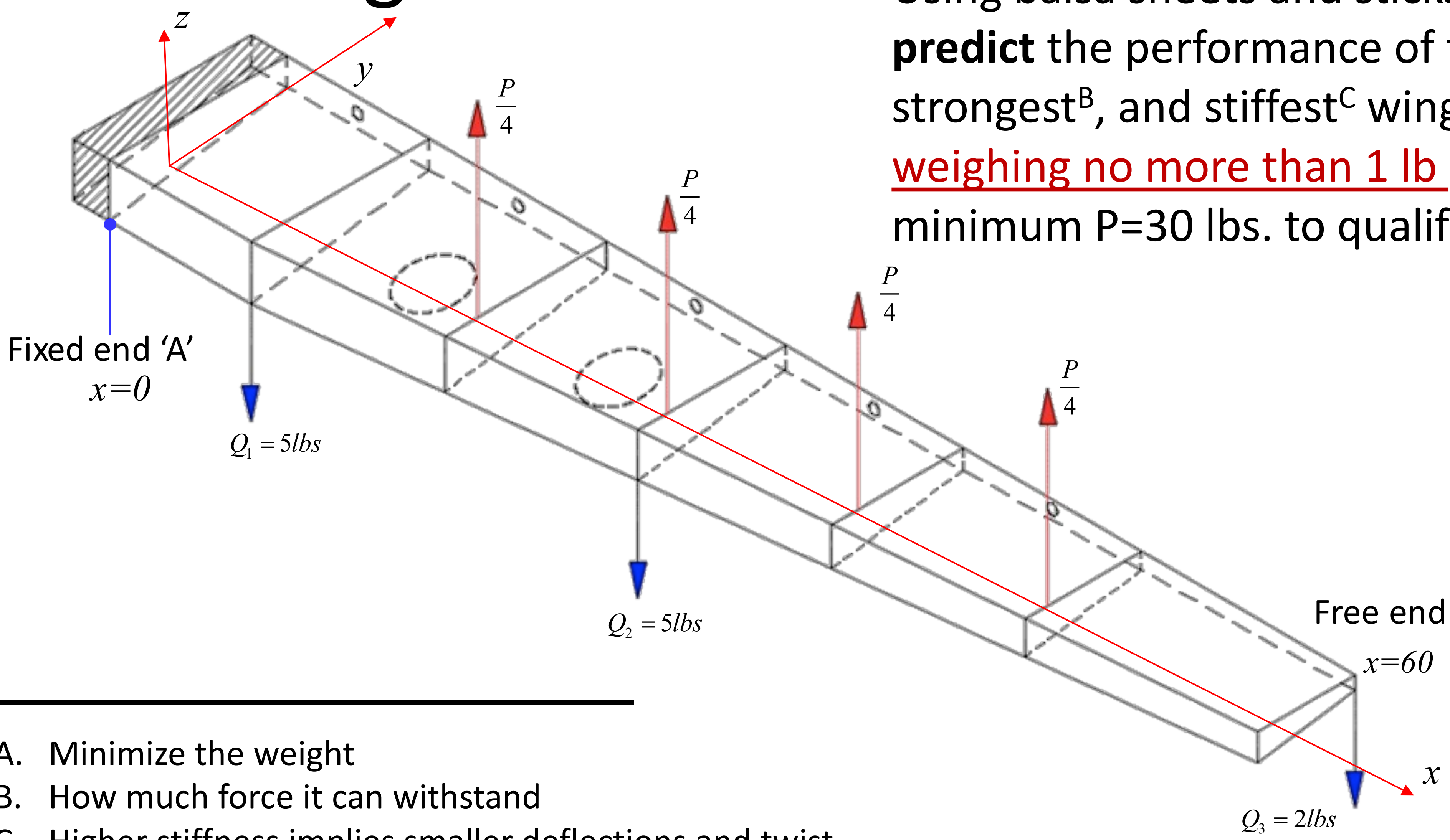
3rd prize : $500

WSU

Deadline : April 1st , 2020

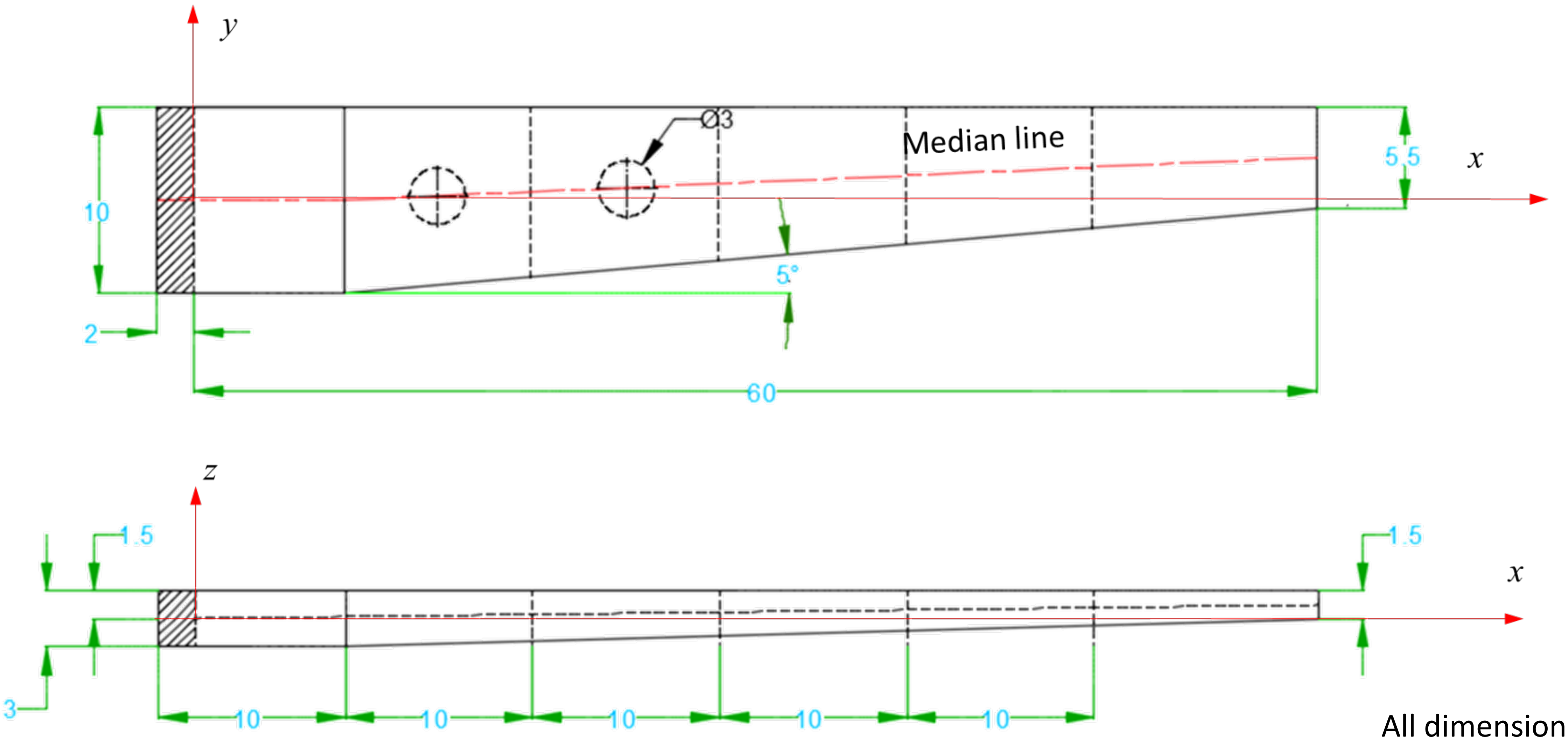
The Challenge

Using balsa sheets and sticks, **design**, **build,** and **predict** the performance of the lightest[A], strongest[B], and stiffest[C] wingbox. The wingbox weighing no more than 1 lb should withstand a minimum P=30 lbs. to qualify.



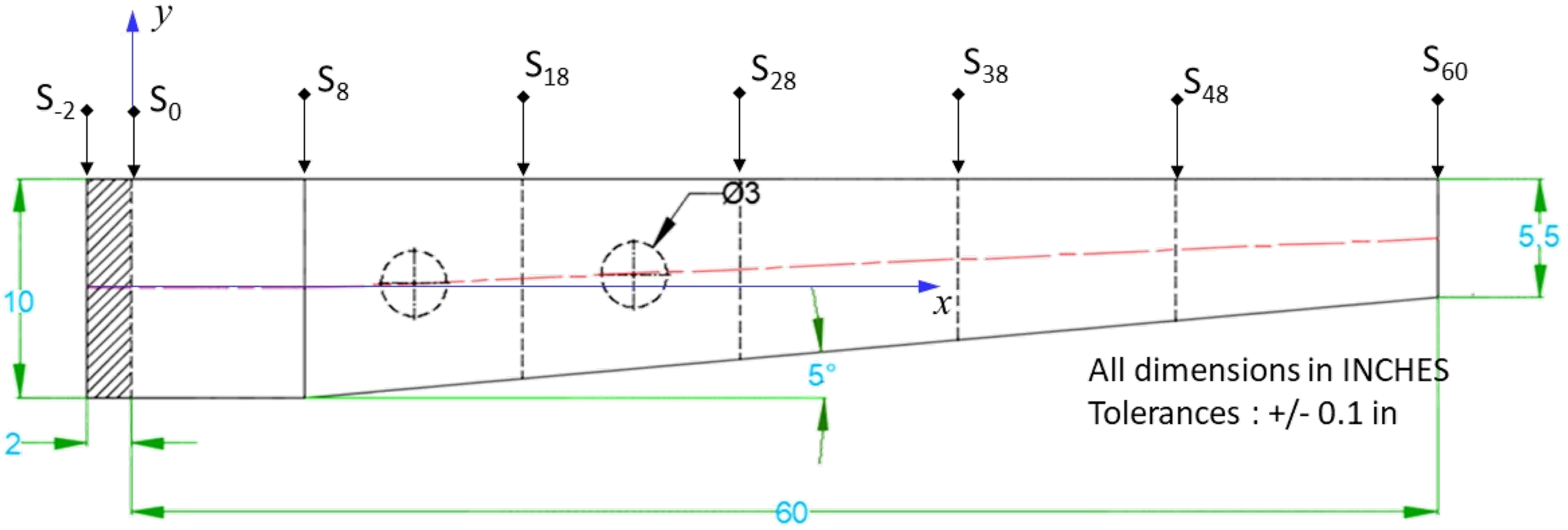
A. Minimize the weight
B. How much force it can withstand
C. Higher stiffness implies smaller deflections and twist

Geometry



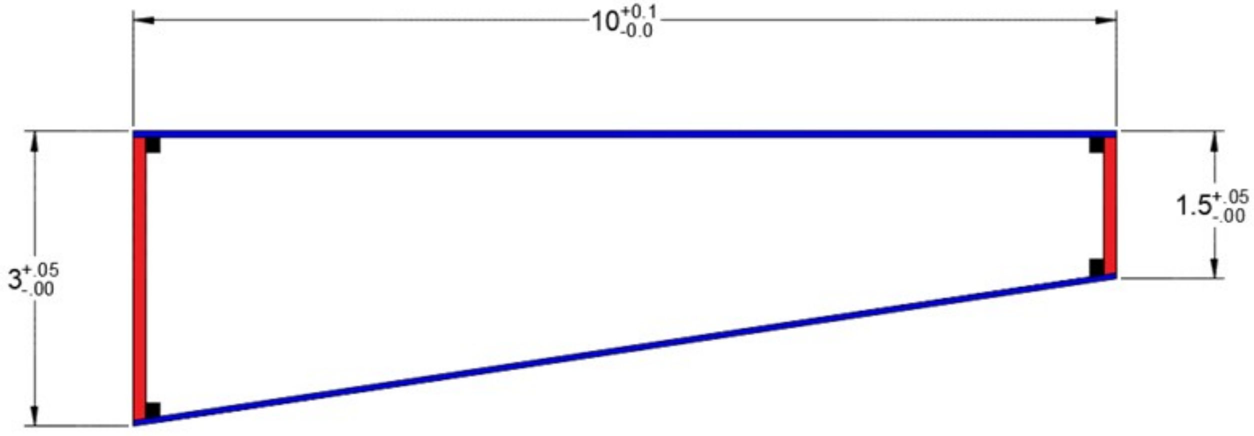
All dimensions in INCHES
Tolerances : +/- 0.1 in

Geometry: Rib Locations

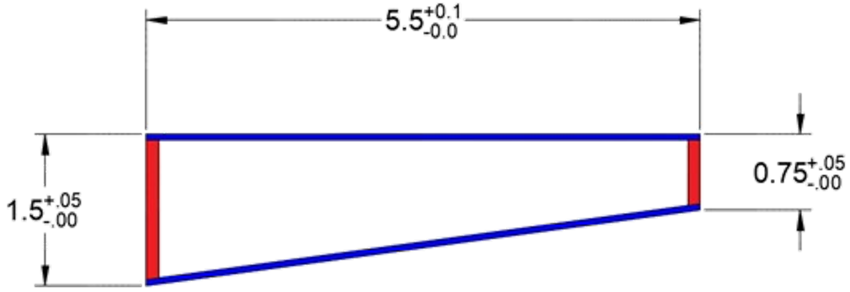


- 1/8in thick balsa ribs are mandatory at stations S_8, S_{18}, S_{28}, S_{38} , S_{48}, and $S_{60.}$ These ribs are required for load introduction.
- There should be 2 inches thick **rib placed** between stations S_{-2} and S_0 as illustrated by the hatched region. The hatched region will be encased (potted) in a polymeric matrix to provide end-fixity.
- The 2 inches thick rib must be bonded to the surrounding parts
- The skins, spars, stringers must extend all the way till station S_{-2}.
- Additional ribs may be placed at other locations as dictated by your design

Cross-section geometry



Exterior dimensions not to be exceeded between stations S_{-2} and S_8



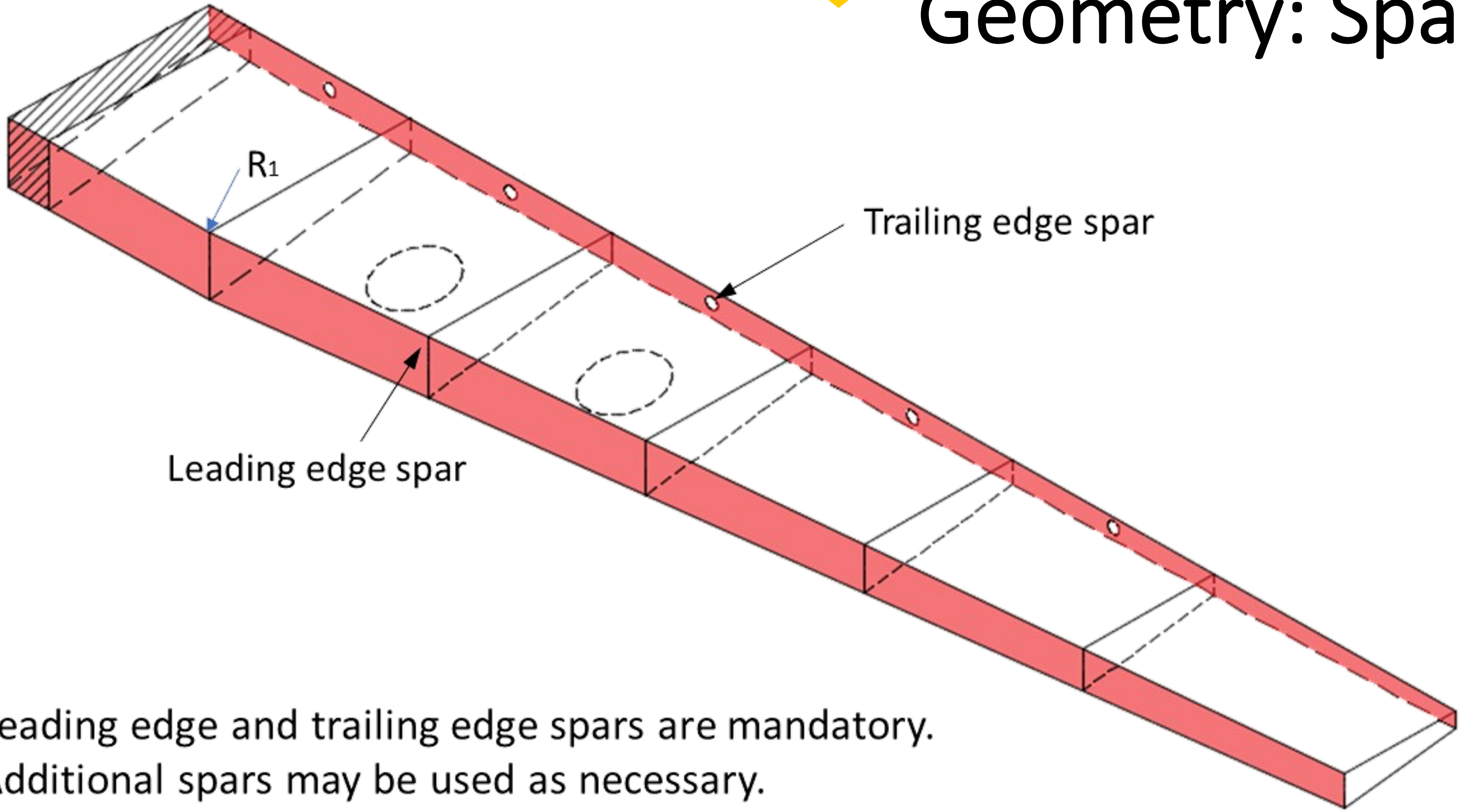
Exterior dimensions not to be exceeded at station S_{60}

Exterior dimensions vary linearly between S_8 and S_{60}

All dimensions in INCHES

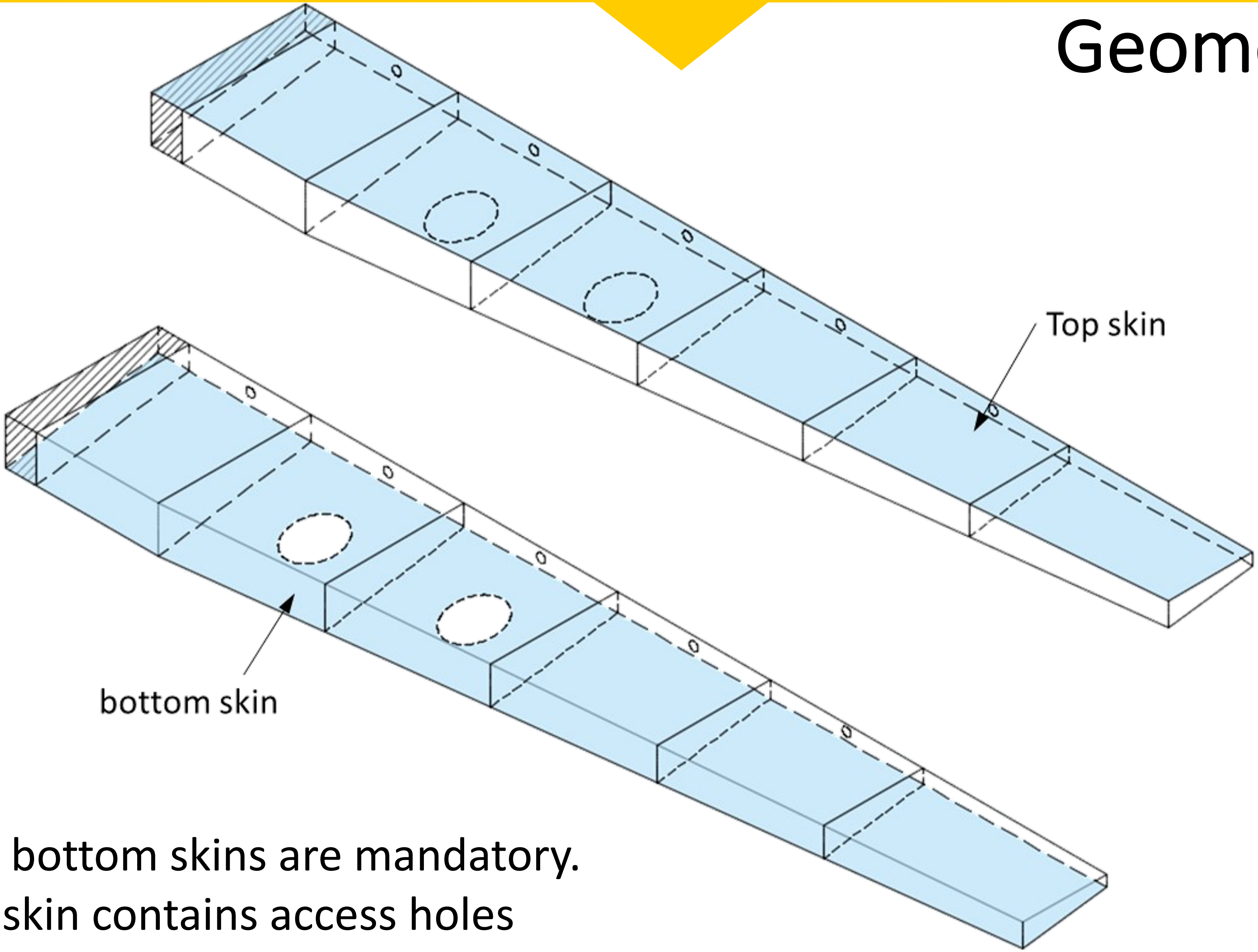
Note: The spar, skin and stiffeners shown in the figure are for illustration only.

Geometry: Spar Locations



- Leading edge and trailing edge spars are mandatory.
- Additional spars may be used as necessary.
- The spars should extend to station S_{-2} to provide end-fixity.
- Transition radii R_1 not to exceed 4 inches.

Geometry: Skins



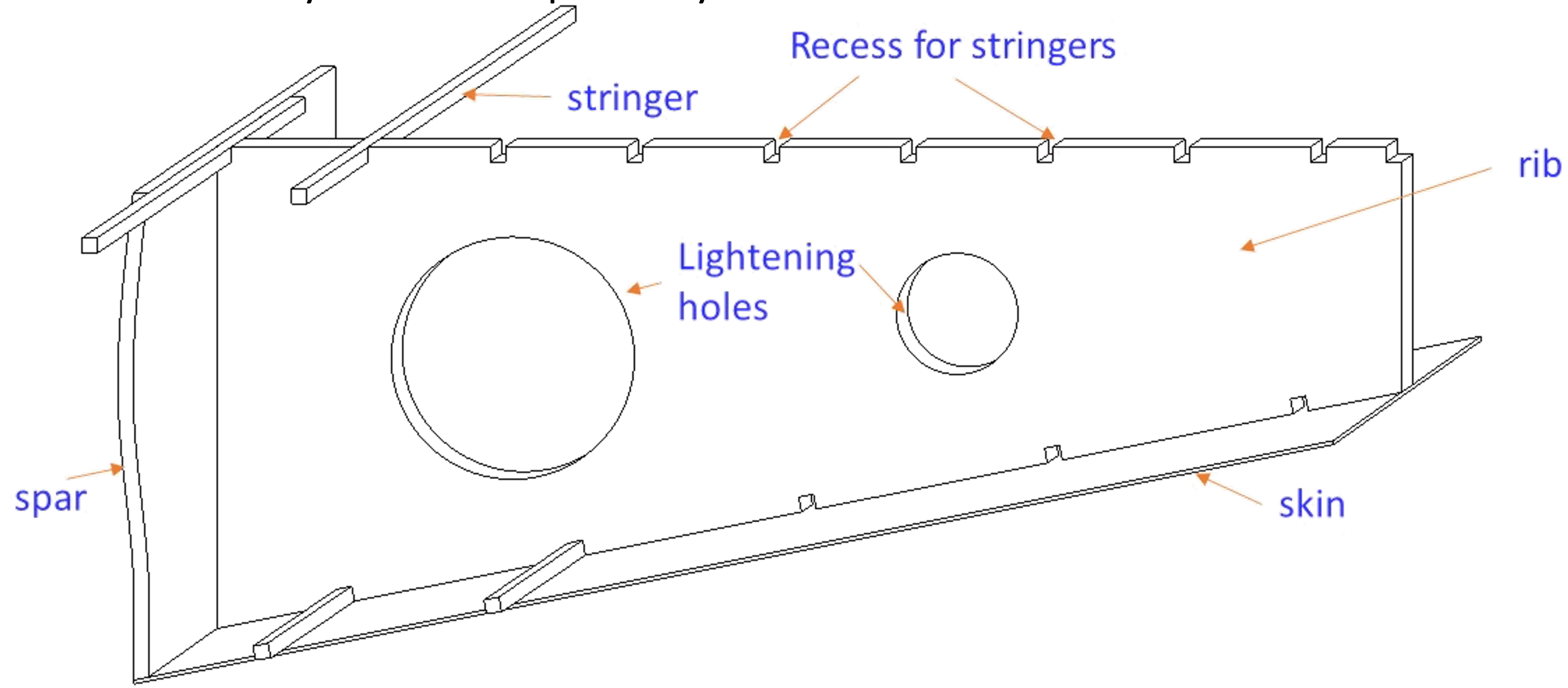
- Top and bottom skins are mandatory.
- Bottom skin contains access holes

NOTES

1) The balsa sticks (extending the length of the wingbox) must pass through recesses cut in the ribs as illustrated in the figure below.

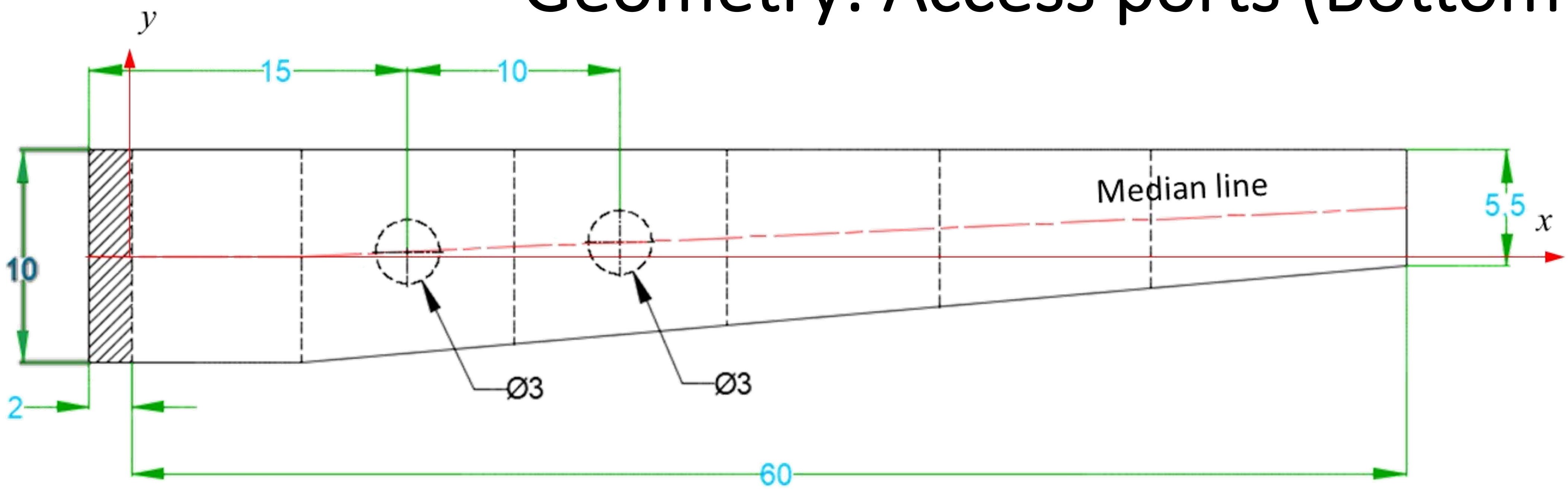
2) You may cut lightening (weight saving) holes in the ribs.

3) Once you have decided on the locations and dimensions of the recesses in the ribs, you may utilize the **laser cutter** at WSU to have your ribs cut precisely.



Note: The recesses and holes shown in the figure are for illustration purposes only. Their size, shape, and locations may be different for your design.

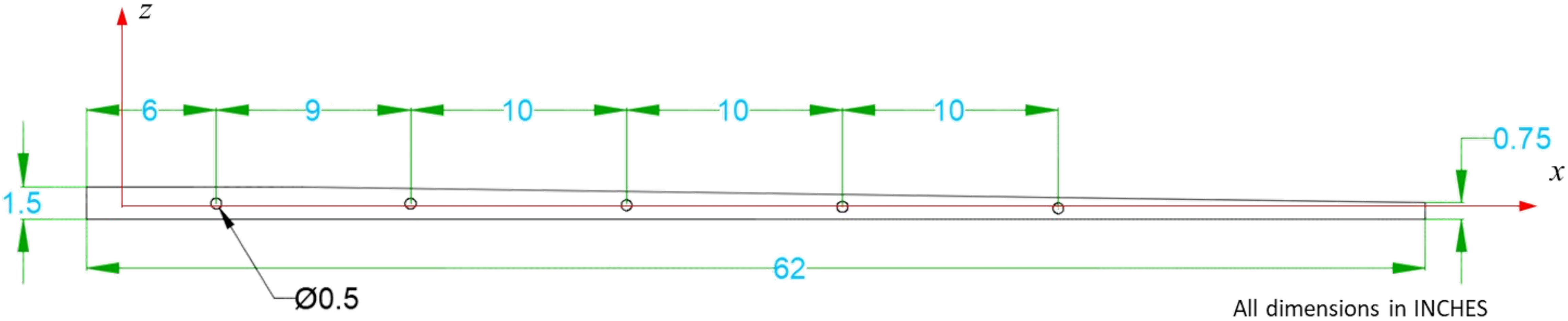
Geometry: Access ports (Bottom skin)



All dimensions in INCHES

1) Circular access ports measuring 3 inches in diameter must be cut in the bottom skin of the wingbox at locations (on median line) identified in the above drawing. The holes may be cut using the laser cutter at the WSU Experiential Engineering building.
2) You may reinforce the edges of the holes using balsa sheets and/or sticks. The reinforcements must be on the interior of the skin.

Geometry: Access ports (Rear Spar)

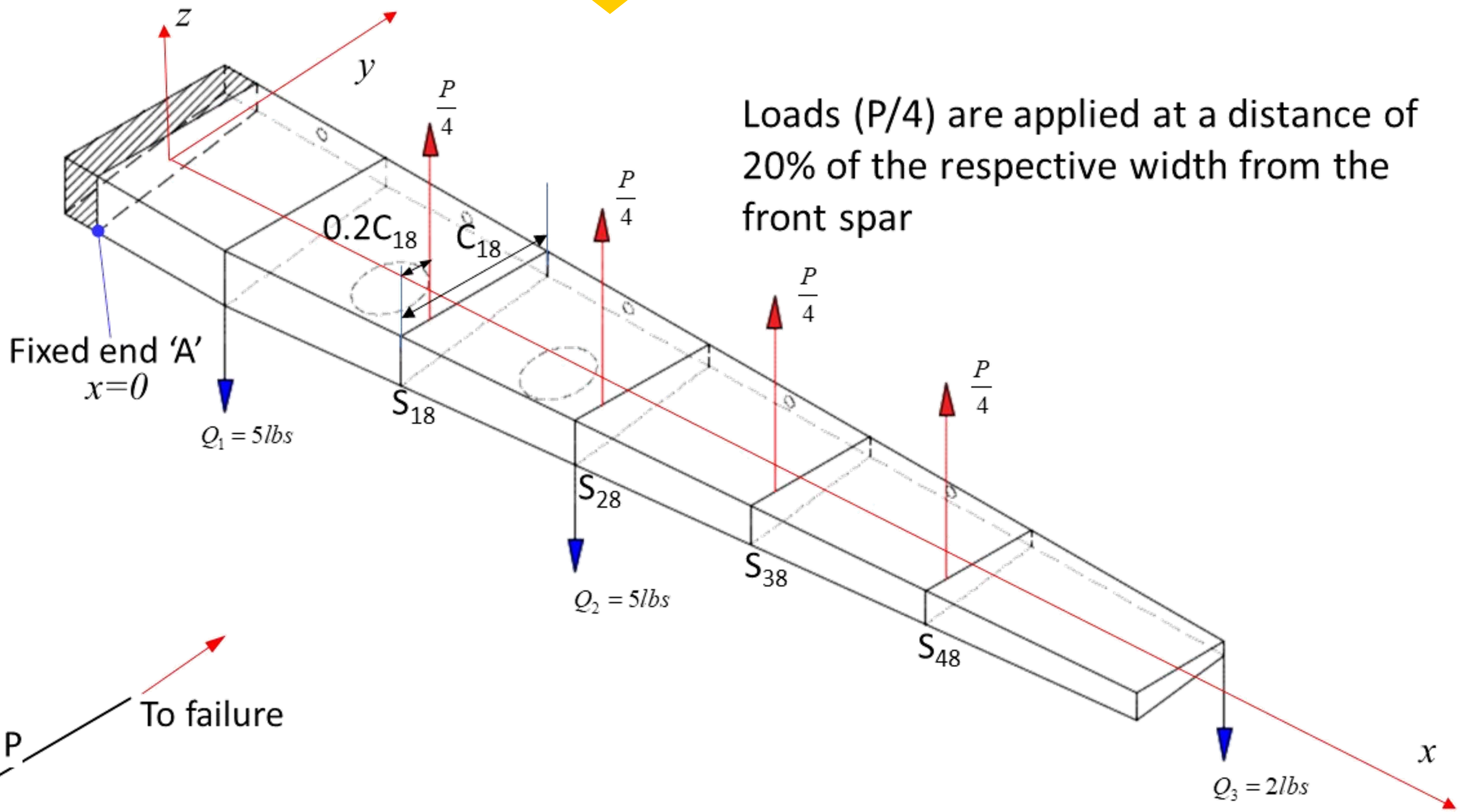


1) Circular access ports measuring 0.5 inches in diameter must be cut in the rear spar of the wingbox at locations identified in the above drawing. The holes may be cut using the laser cutter at the WSU Experiential Engineering building.
2) The access holes in the rear spar are located half way across the depth at locations indicated in the above figure
3) The rear spar has a depth of 1.5 inches for $-2 \leq x \leq 8\ in,$ and then tapers from 1.5 inches to 0.75 inches as shown in the figure
4) You may reinforce the edges of the holes using balsa sheets and/or sticks. The reinforcements must be on the interior of the skin.

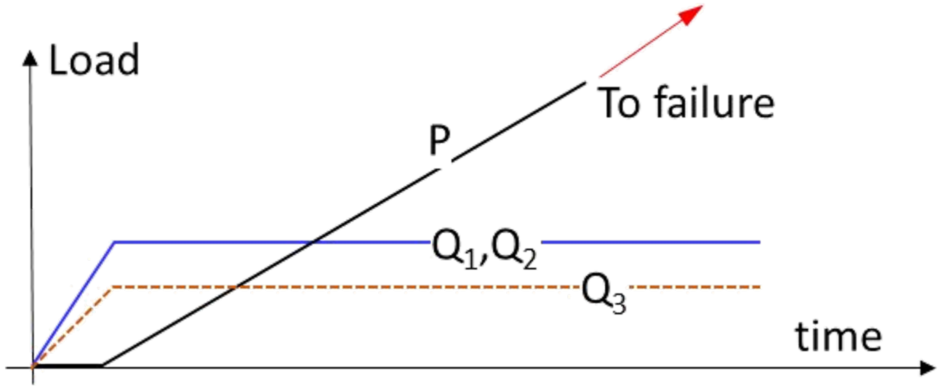
Materials

- The balsa skins should be no more than 1/16 inches thick.
  - You may laminate thinner sheets together as necessary
  - The skin thickness may be varied as required without exceeding the above limit
- The balsa spars should be no more than 1/8 inches thick.
  - You may laminate thinner sheets together as necessary
  - The spar thickness may be varied as required without exceeding the above limit
  - Apart from the mandatory leading edge and training edge spars, you may use additional spars in between.
- Balsa sticks with only 1/8-inch or 1/16-inch <u>square</u> cross-section dimensions are allowed. (May not be laminated)
  - The balsa sticks(stringers) must be placed on the interior of the structure.
  - Any combination of balsa sticks may be used
  - The balsa sticks may run in any direction (lengthwise, diagonal, etc)
  - The stringers can be terminated ahead of the free end if required
- The balsa ribs must be no greater than 1/8-inch thick.
- The rib at the fixed end (which will be encased in potting compound) must be 2 inches thick. You may use balsa or other wood for this rib. Use lightening holes not exceeding 1.00 inch in diameter (up to 4 holes) in this rib
- Use hobby store adhesives for bonding (Superglue, epoxy, etc.)

Loads

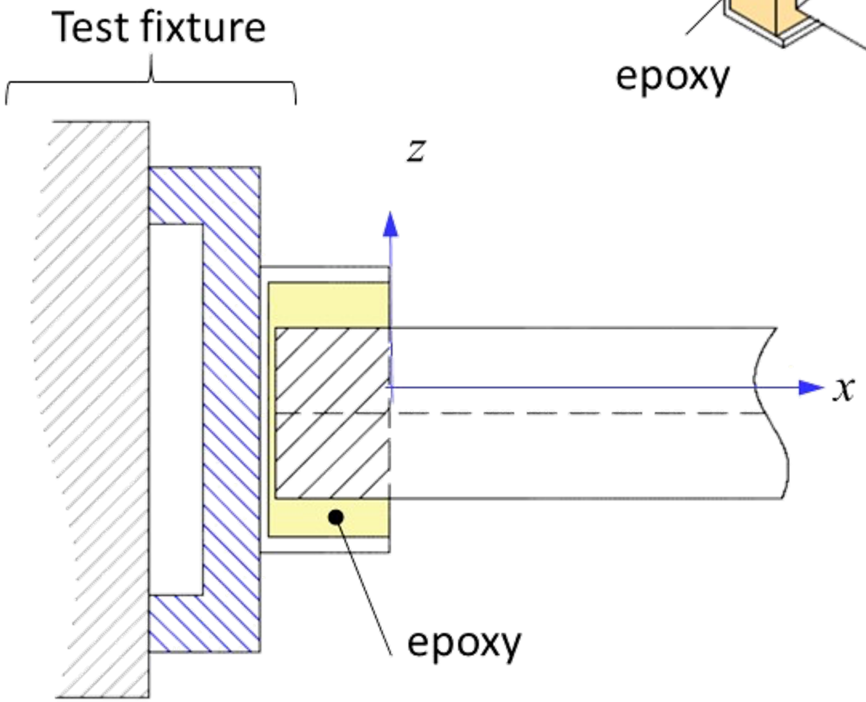


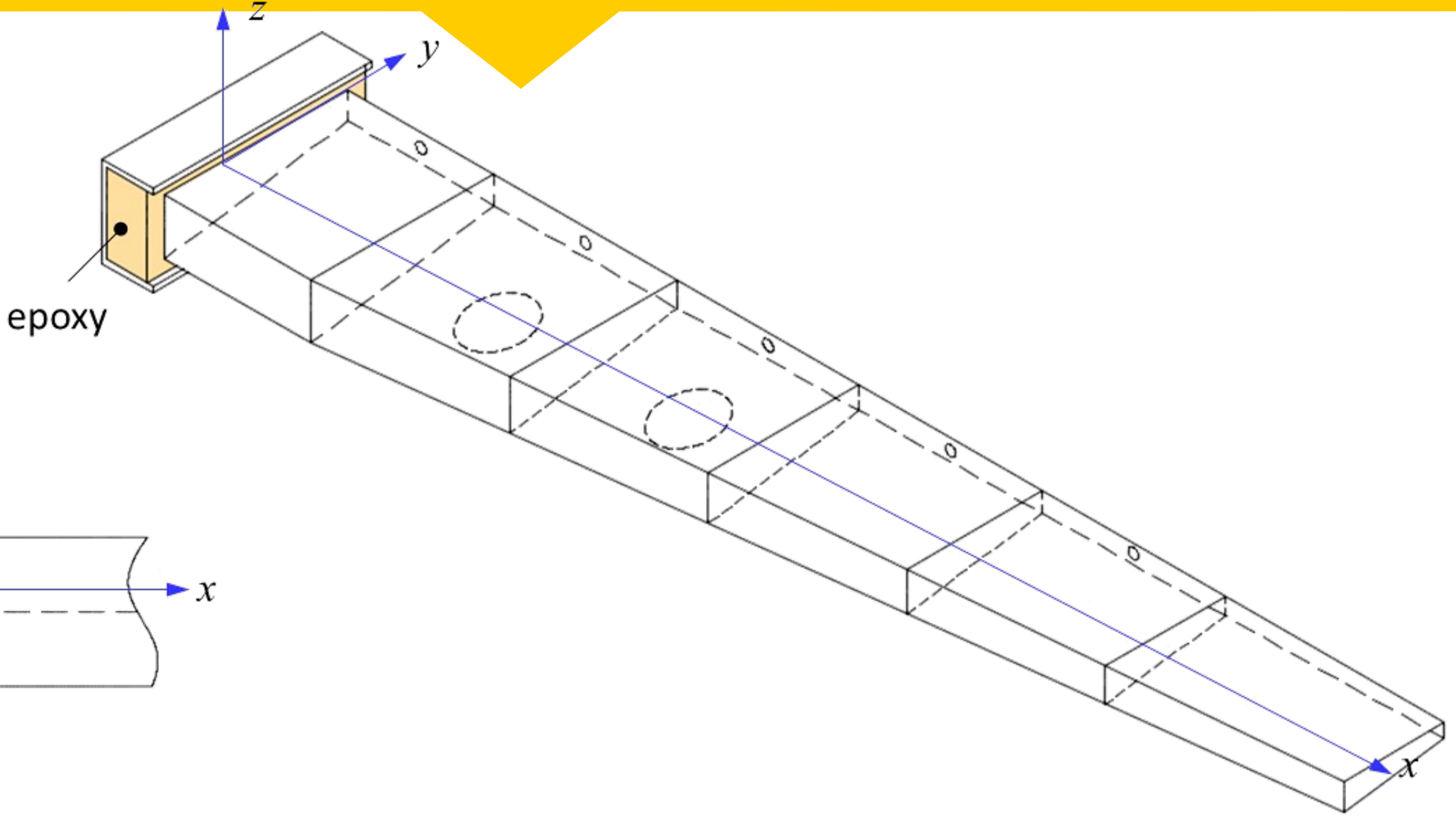
Loads (P/4) are applied at a distance of 20% of the respective width from the front spar



Initial loads of Q_i will be applied. While holding these loads, the force P will be increased until failure occurs

End fixity





- The extension behind station S_0 will be cast (potted) in epoxy resin to provide the necessary end support condition. You should NOT do the end casting. This will be done by WSU
- The skins, spars and stringers must extend behind station S_0 till S_{-2}. Failure to do so will result in rejection of wing box from the competition.

Wingbox Challenge Rubric

$$Score = S_{performance} + S_{analysis} + S_{report}$$

$$S_{performance} = g\left(\frac{P_{\max}}{W_{wing}}\right) + 0.1\frac{\sum Q}{\delta_Q} + 0.05\left[\frac{P_{30}}{\delta_{30}} + \frac{P_{30}}{\theta_{30}}\right] - 10\frac{W_{Wing}}{1.0} - 10\frac{W_{glue}}{W_{wing}}$$

$$S_{analysis} = 10\left(1 - f\left(P_{\max}, P_{pred}, 0.1\right)\right) + 10\left(1 - f\left(\delta_Q, \delta_{Q\_pred}, 0.1\right)\right) + 10\left(1 - f\left(\delta_{30}, \delta_{30\_pred}, 0.1\right)\right)$$

$$g\left(P_{\max}, W_{wing}\right) = \begin{cases} \dfrac{P_{\max}}{W_{wing}} & P_{\max} \le 150lbs \\ \dfrac{\left(300 - P_{\max}\right)}{W_{wing}} & P_{\max} > 150lbs \end{cases}$$

$$f\left(A, A_{pred}, \beta\right) = \begin{cases} 0 & \dfrac{\left|A - A_{pred}\right|}{A_{pred}} \le \beta \\ \dfrac{\left|A - A_{pred}\right|}{A_{pred}} - \beta & otherwise \end{cases}$$

Note : The tolerances for strength and stiffness are based on variability in material properties.

Wingbox Challenge Rubric….

W_{glue} ~ weight of glue (lbs)

W_{WING} ~ weight of wingbox (lbs)

$P_{\max}$ ~ Measured failure load (lbs)

P_{pred} ~ predicted failure load (lbs)

P_{30} ~ P=30 lbs (+Q_i, i=1..3)

δ_{30} ~ Measured end deflection (along load) at P=30 lbs (+Q_i, i=1..3)

δ_{30_pred} ~ Predicted end deflection (along load) at P=30 lbs (+Q_i, i=1..3)

δ_Q ~ Measured end deflection (along load) at Q_i, (i=1..3) lbs

δ_{Q_pred} ~ Predicted end deflection (along load) at Q_i, (i=1..3) lbs

$\delta_{\max}$ ~ Measured end deflection at failure

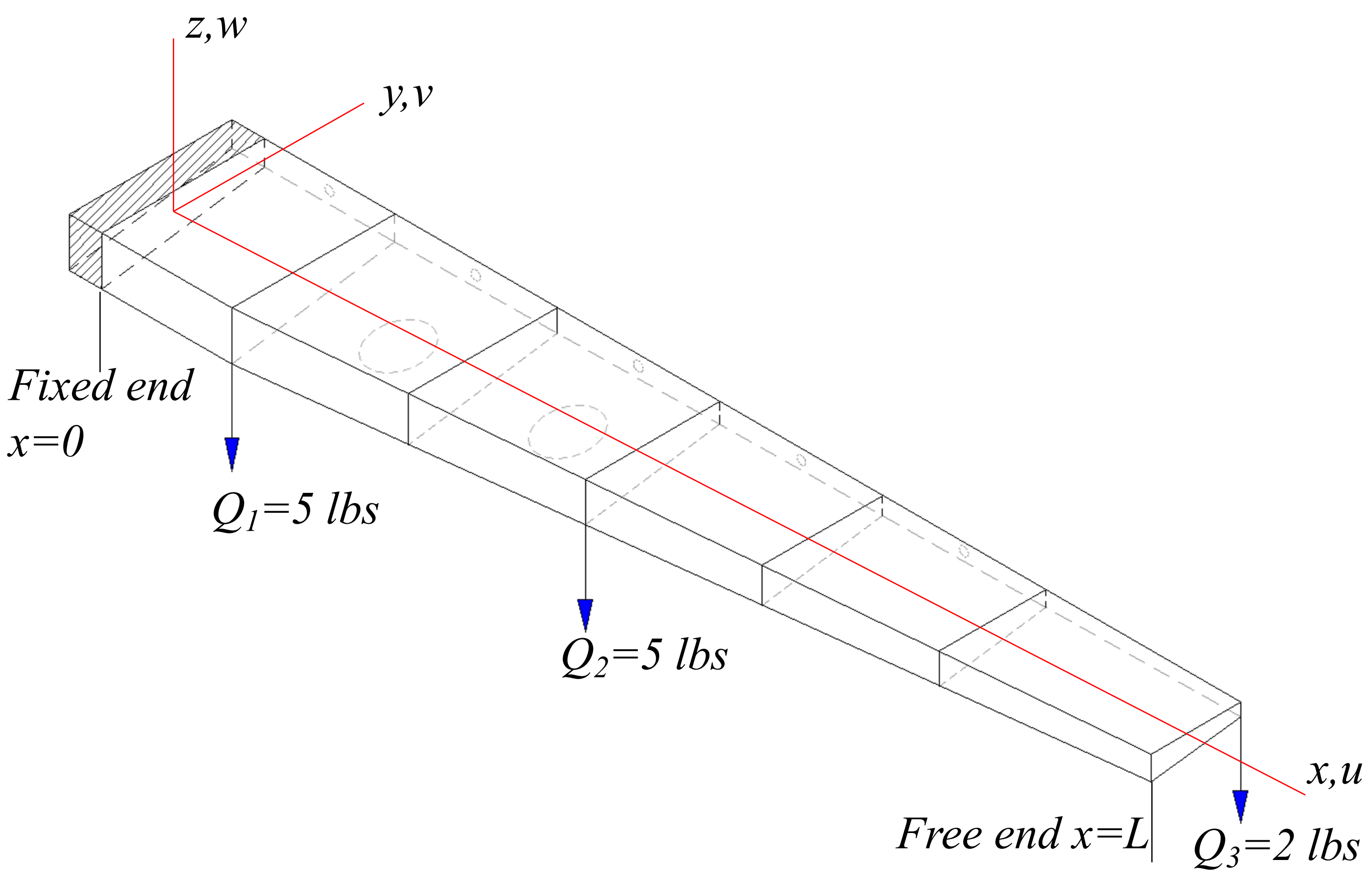
$\theta_{\max}$ ~ Measured end twist at failure (degrees)

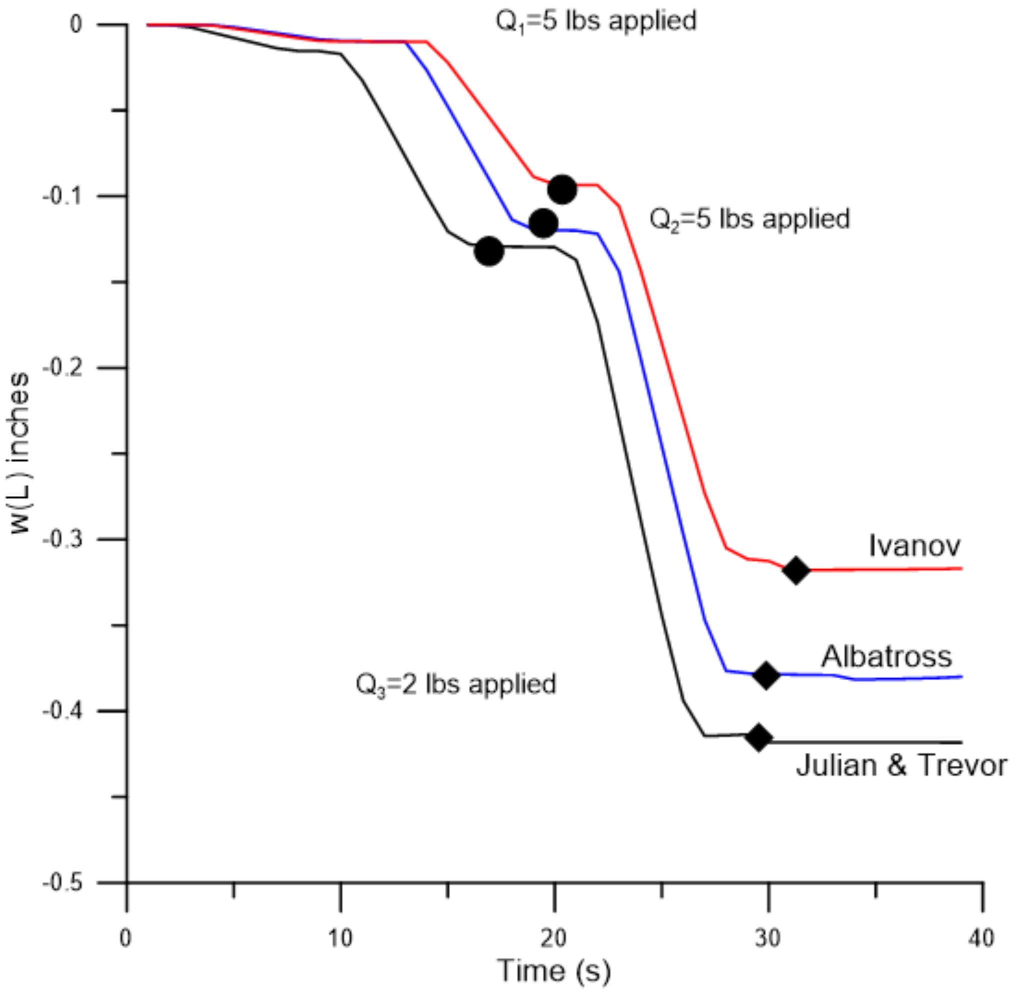
Wingbox Challenge Rubric…

- W_{glue} is the weight of the glue(adhesive) used. You may weigh each of the balsa parts used before assembling them and their sum gives you the total weight of balsa wood. This should be documented in your report. Weigh the completed WingBox and use it to estimate W_{glue}. If the weight of glue is not reported, for scoring purposes, W_{glue}=0.25 W_{wing} will be used.

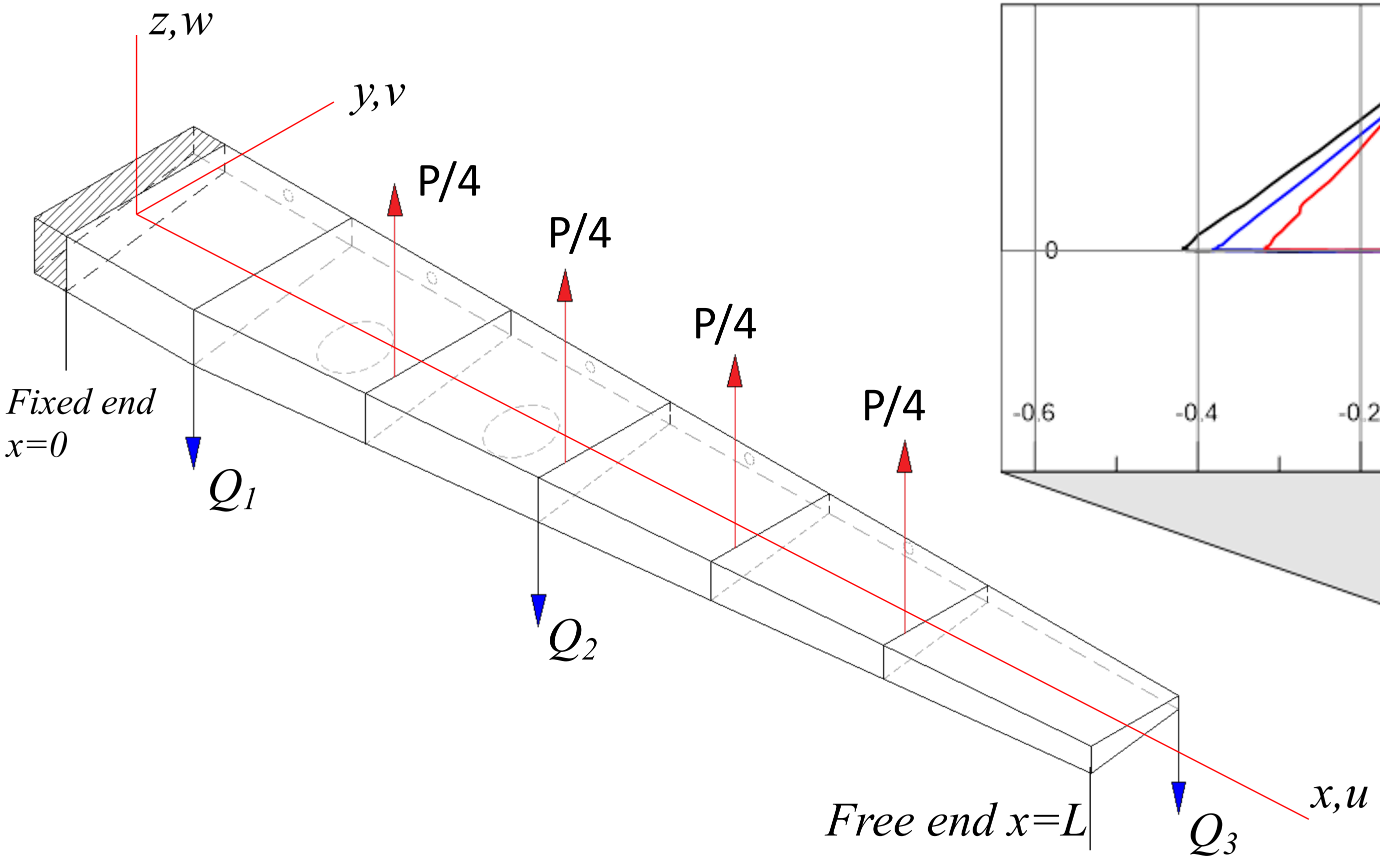
- S_{report} : (Maximum of 50 points for the report). The report shall include,
  - Drawing with dimensions and list of parts (10 points)
  - Itemized weight of Balsa/wood parts and glue (10 points)
  - Details of analysis (eqns, FEA models, etc) (20 points)
  - Summary of activities (5 points)
  - Design philosophy (5 points)

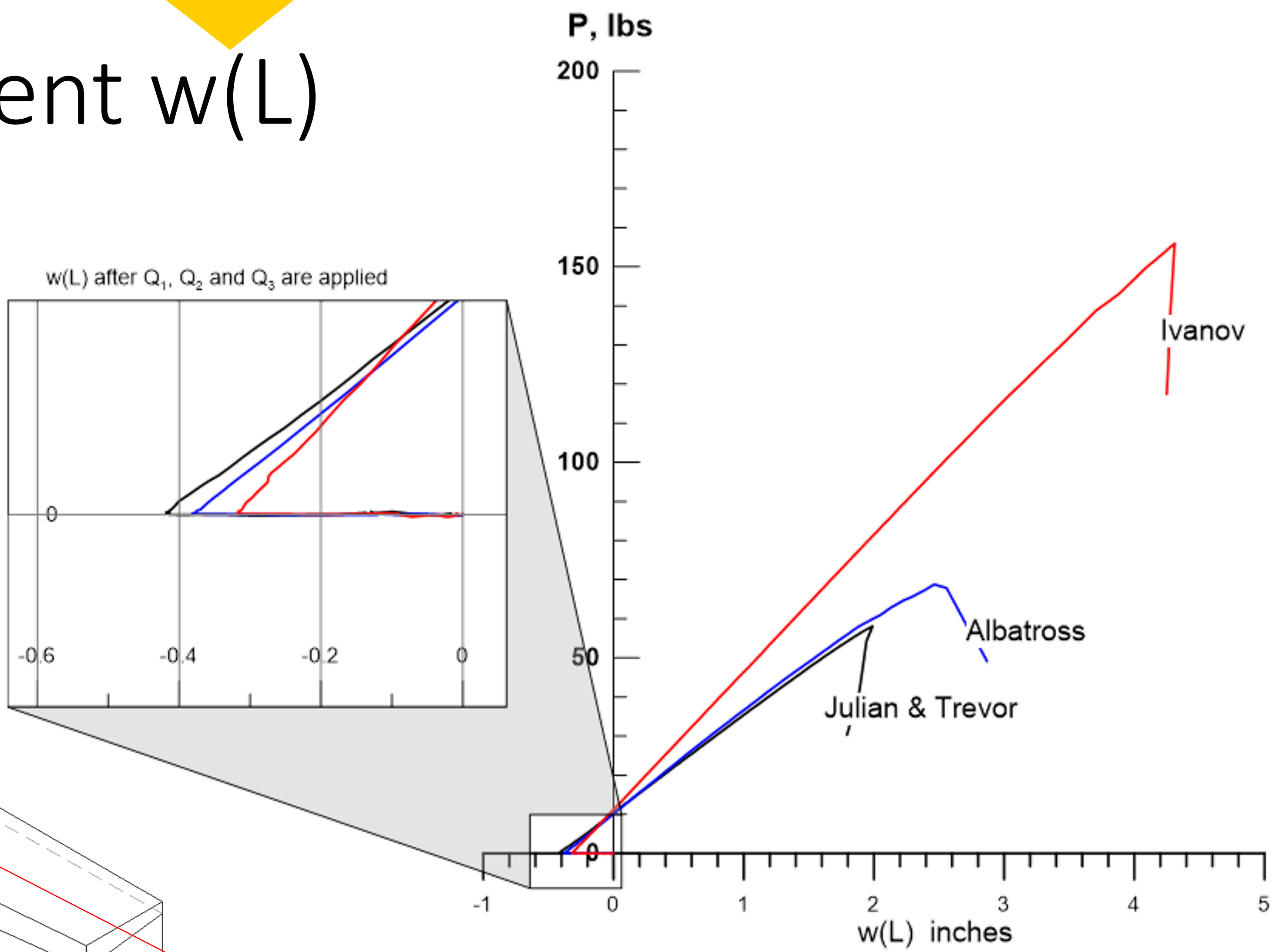
Free end displacement w(L)



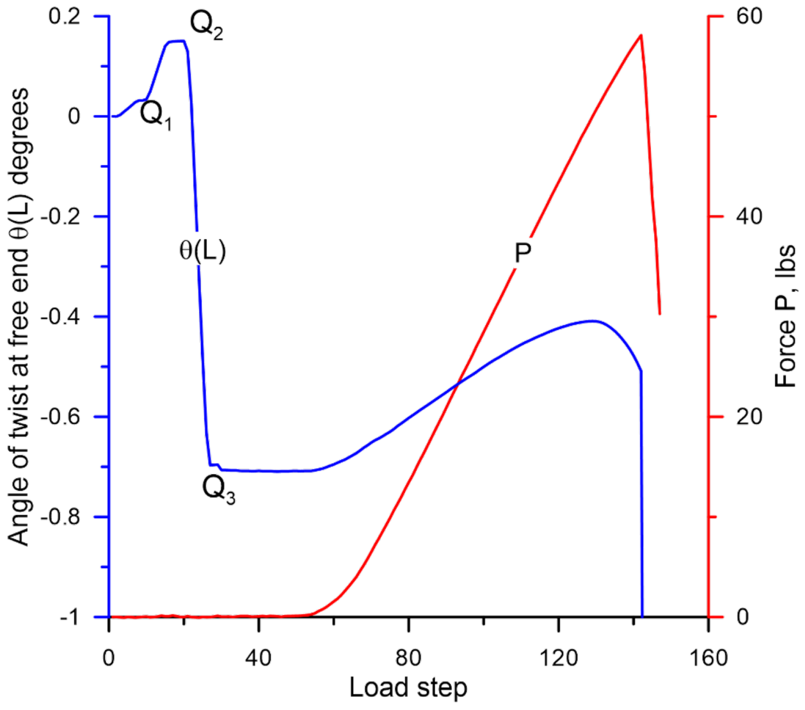


Free end displacement w(L)

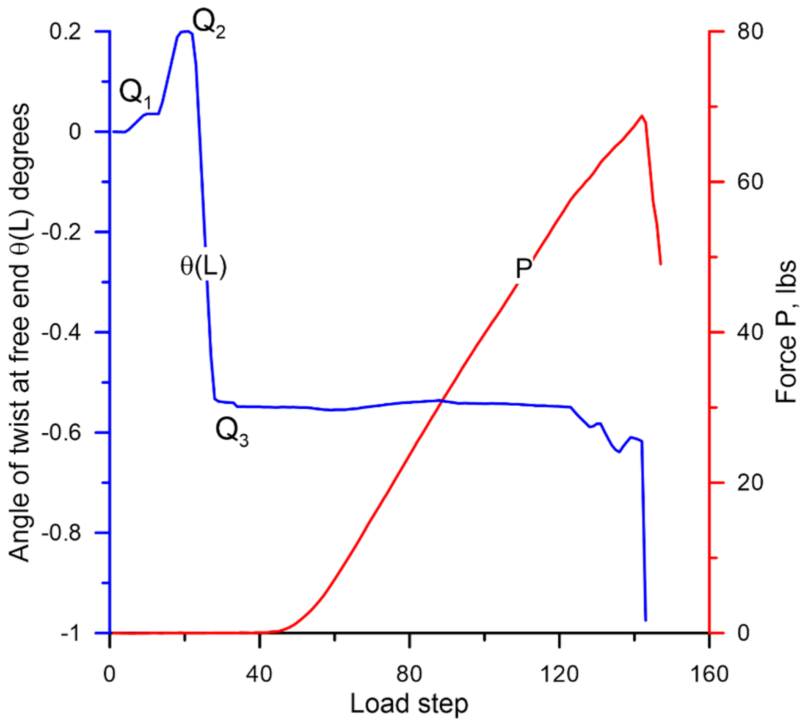




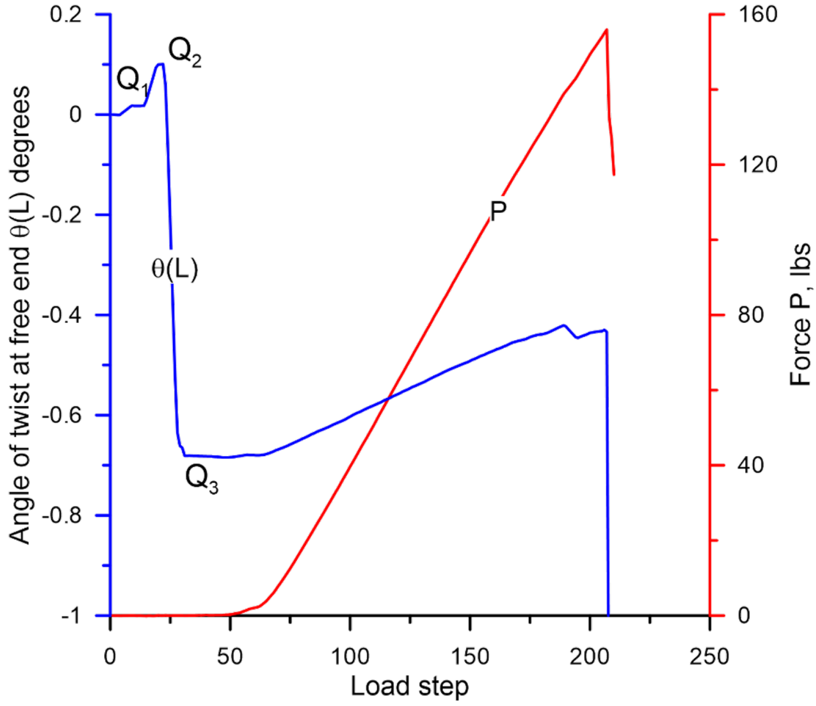
Angle of twist at free end θ(L)



‘Albatross’



‘Julian & Trevor’



‘Ivanov’

Wingbox Challenge Results

Team	W_{wing} (lbs)	W_{glue} (lbs)	Failure load P_{max} (lbs)		Deflection δ_Q (inches)		Deflection δ_{30} (inches)		Twist angle θ_{30} (deg)
			Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured
Julian & Trevor	0.960	0.037	65	135	-0.381	-1.148	0.752	0.574	0.535
Albatross	0.995	0.119	58	50	-0.418	-1.688	0.810	3.216	0.480
Ivanov	0.975	0.097	156	150	-0.317	-0.244	0.550	0.447	0.620

Team	$\mathbf{g}(P_{\max}, W_{wing})$	$0.1\frac{\sum Q}{\lvert\delta_Q\rvert}$	$0.05\left[\frac{P_{30}}{\delta_{30}} + \frac{P_{30}}{\theta_{30}}\right]$	$-10W_{wing}$	$-10\frac{W_{glue}}{W_{wing}}$	$S_{performance}$
Julian & Trevor	67.71	3.15	4.80	-9.60	-0.39	65.67
Albatross	58.39	2.87	4.98	-9.95	-1.20	55.09
Ivanov	147.79	3.79	5.15	-9.75	-0.99	145.98

Wingbox Challenge Results

Team	$f(P_{max}, P_{pred}, 0.1)$	$f(\delta_Q, \delta_{Q\_pred}, 0.1)$	$f(\delta_{30}, \delta_{30\_pred}, 0.1)$	$S_{analysis}$
Julian & Trevor	0.519	0.668	0.310	18.03
Albatross	0.162	0.752	0.748	16.37
Ivanov	0.039	0.299	0.230	26.70

Team	*Design Philosophy* (5)	*Analysis Details* (20)	*Itemized weights*(10)	*CAD* (10)	*Summary of activities* (5)	S_{report} (max 50)
Julian & Trevor	3	13	9	8	5	38
Albatross	4	17	10	10	5	46
Ivanov	4	15	9	8	5	41

Results

Team	$S_{performance}$	$S_{analysis}$	S_{report}	$Total\ Score$	$Place$
Julian & Trevor	65.67	18.03	38	121.7	**2**
Albatross	55.09	16.37	46	117.5	**3**
Ivanov	145.98	26.70	41	213.7	**1**