

# Report A: Weight, weight distribution and self-righting momentum

## A01 Weight of components

Values in black were measured before assembly, values in red are estimates.

	#	weight/unit(g)	Weight (g)	
load-bearing structure + servo's			1450 g	
steppers			500 g	
nose cones	2	50	100 g	
			g	
			g	
bag0			83 g	
bag1			336 g	
bag2			368 g	
bag3			400 g	
			g	
bag5			284 g	
bag6			400 g	
				Total upper bags
bag7			300 g	
bag8			100 g	<b>2271</b>
platform	0	0	0 g	
edges in carbon 10mm	20	20	400 g	
bottombag1	1	166	166 g	

bottombag2	1	124	124 g	
bottombag3	1	110	110 g	
bottombag4	1	132	132 g	
bottombag5	1	112	112 g	
				Total bottom bags
bottombag6	1	162	162 g	
bottombag7	1	162	162 g	<b>968</b>
enlargement structure & widening bottom values bottombag 0 & 8				
			200 g	
			110 g	
ballast		0	0 g	
receiver	1	30	30 g	
electrical wiring	20 m	4	80 g	
arduino+motorshied	0	52	0 g	
rotors	0	50	0 g	
engines	0	100	0 g	
battery	0 <sup>s</sup> t	400	0 g	
			<b>6109 g</b>	

## A02 Measurement of total weight

31st of juli

The model is suspended on 2 dynamometers before being filled.

The measured version contains the heavy steppers, but not the arduino.

Total weight= 6,2 kg

## A03 Measuring self-righting momentum

*Sunday august 23rd*

### Experimental setup:

The model is filled with helium and supported on ropes, attached to the mounting points for the engines. These ropes are attached to the floor.

The model in this experiments has the microprocessors added and the servo for the front vertical hinge is removed. The rear servo is missing. No engines are fitted yet, but for use in the experiment +- 100 g ballast was fitted in the same location as the engines.

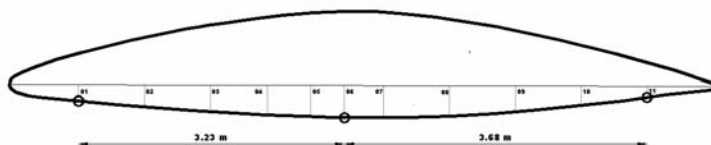
Temperature inside the hangar was not measured, but estimated at +30°C. The belly bags were partially filled to gain some extra lift. These are leaky and cause the model to loose +- 30g lift/hour. The model is trimmed to its low position, as this results in the least stable position (lowest centre of lift)



*Setup*

M6 bolts are used as ballast. These bolts weigh 8,4g/piece. Ballast can be added in the middle at section 6, in the tail at section 11

and in the front at section 1. The ballast is added in the bottom of the ship.



#### *Ballast placement points*

A camera is installed on a tripod to take a picture every 30 seconds.

Ballast is added until the model is balanced horizontally and no tension remains on the supporting ropes.

The ballast is then, one piece at a time, moved from the centre position to the front. This causes the front of the ship to pitch down. Pictures are taken at every increment to determine the corresponding pitch angle.

This operation is repeated for the tail ballast.

## Goal

The goal of this experiment is to measure the self-righting moment  $M$  of the airship model around its transversal axis.

The model has a low centre of gravity  $C_g$ . The weight  $G$  of the ship pulls the airship down. The ship is in equilibrium in the air because a second force, the lift  $L$  of the gas is working in opposite direction.

For the ship to be in equilibrium:

-L must be equally in size as  $G$ .

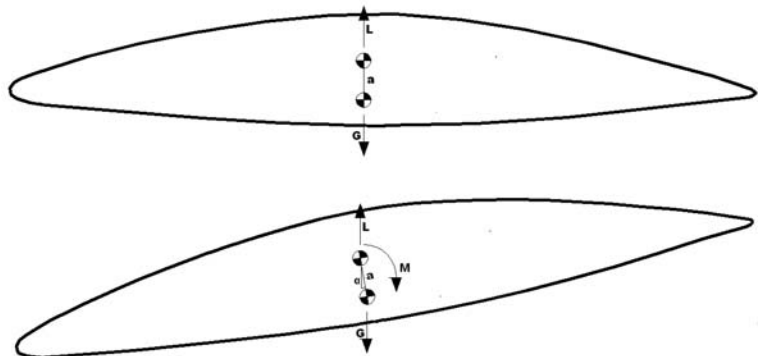
-the point of action  $C_l$  (centre of lift) of  $L$  must be located vertically above the centre of gravity  $C_g$ .

If the ship is pitched up or down, as shown in the figure below, this second condition will not be met. This will result in a self-righting moment  $M$ , analogous to the working of a float.

The value of  $M$  depends on:

- the distance  $a$  between  $C_g$  and  $C_l$ .

-the pitch angle  $\alpha$



## Measurements

**Run 1** was a trial run

### **Run 2**

Negative pitch, ballast is moved from centre to front

Number of bolts as centre ballast: 12



*Start position*



01



03



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09

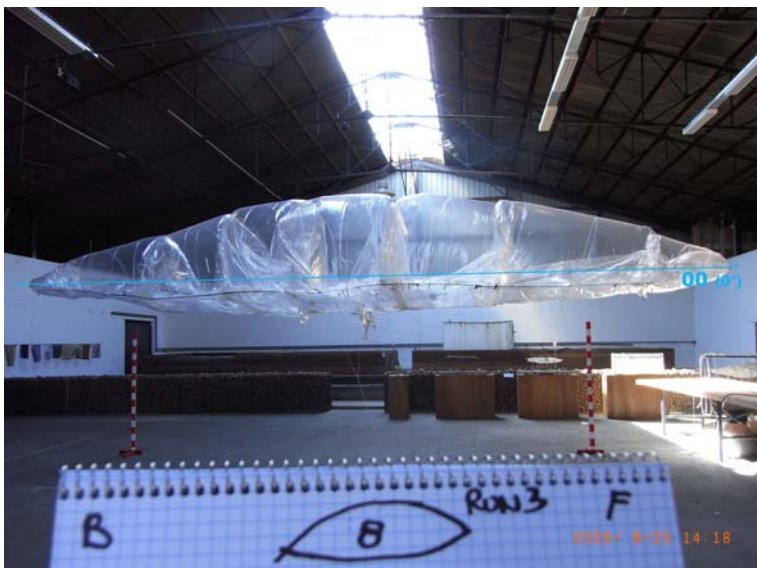


11

<b>Pitch down</b>			
<b># of bolts moved to front</b>	<b>B'(N)</b>	<b><math>\alpha</math> (°)</b>	
<b>1</b>	0		-2
<b>2</b>	0,168		-3
<b>3</b>	0,252		-3
<b>4</b>	0,336		
<b>5</b>	0,42		
<b>6</b>	0,504		-7
<b>7</b>	0,588		
<b>8</b>	0,672		
<b>9</b>	0,756		-13
<b>10</b>	0,84		-13
<b>11</b>	0,924		-13

### Run 3

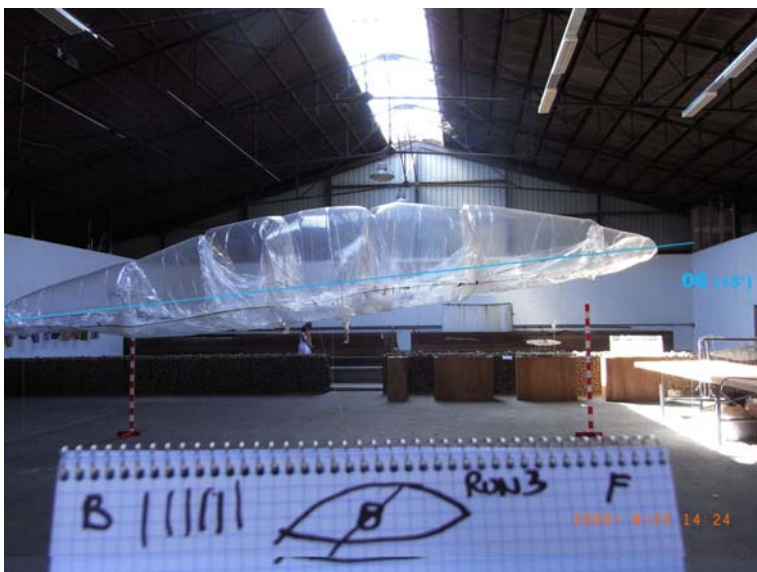
Positive pitch, ballast moved to tail, section 11  
Run 3 was executed with 4 pieces of ballast less.



00



03



06



07

Pitch up		
# of bolts moved to back	B'(N)	$\alpha$ (°)
1	0	
2	0,168	
3	0,252	3
4	0,336	
5	0,42	
6	0,504	5
7	0,588	7
8	0,672	

### Calculations

For the ship to be in equilibrium, the rotational momentum caused by the ballast, must in each case be counteracted by the self-righting momentum M

$$M' = -M$$

or

$$B' \cdot a_1 \cdot \cos \alpha = G \cdot a \cdot \sin \alpha$$

with  $a_1=3,23\text{m}$  for the front ballast point

In this equation the only unknown is  $a$ , the distance between CG and CL, which can be determined.

Run2:

Pitch down					Value for a (m)
	B'(N)	a2(m)	sin α	M' (Nm)	
1	0,084	3,23	-0,0349	0,27	-0,13
2	0,168		-0,05234	0,54	-0,17
3	0,252		-0,05234	0,81	-0,25
4	0,336		0	1,09	
5	0,42		-0,10453	1,35	-0,21
6	0,504		-0,12187	1,62	-0,22
7	0,588		-0,12187	1,89	-0,25
8	0,672		0	2,17	
9	0,756		-0,22495	2,38	-0,17
10	0,84		-0,22495	2,64	-0,19
11	0,924		-0,22495	2,91	-0,21
<b>aav=</b>					<b>-0,20</b>

Run3:

Pitch up					Value for a (m)
	B'(N)	a2(m)	sin α	M' (Nm)	
1	0,084	3,68	0	0,31	
2	0,168		0	0,62	
3	0,252		0,052336	0,93	0,29
4	0,336		0,069756	1,24	0,29

5	0,42	0,069756	1,55	0,36 0,35 0,29  <b>0,32</b>
6	0,504	0,087156	1,85	
7	0,588	0,121869	2,16	
8	0,672	0	2,47	

$a_{av} =$

## Conclusions

This test should be repeated with better accuracy before the measured values can be used as benchmark in further experiments. Run2 and run3 should ideally return identical results, but differ by 60%.

The experiment setup is good, and can be executed with one man in one hour.

See remarks below for improvements.

## Remarks and suggested improvements

-the model tended to rotate away from the camera due to a slight draft. This was corrected manually, but could be prevented by placing the model against 2 vertical struts.

-doing the test again with more ballast should yield a larger pitch angle and a more accurate result. Adding more ballast will however lower the Cg. To compensate for this the servos could be temporarily removed for the test.

-using the camera/noteblock setup the experiment can be done quite fast. Run1, Run2 & run3 were completed in little over one hour with one man.

-the larger version for a in run3 could be explained if the CG is located behind the suspension point and the weight of the rope cannot be neglected and/or tension on the rope was not completely removed. A lighter rope should be used in the next run, and it should be counterweighted with small ballast items to check the load on this rope.