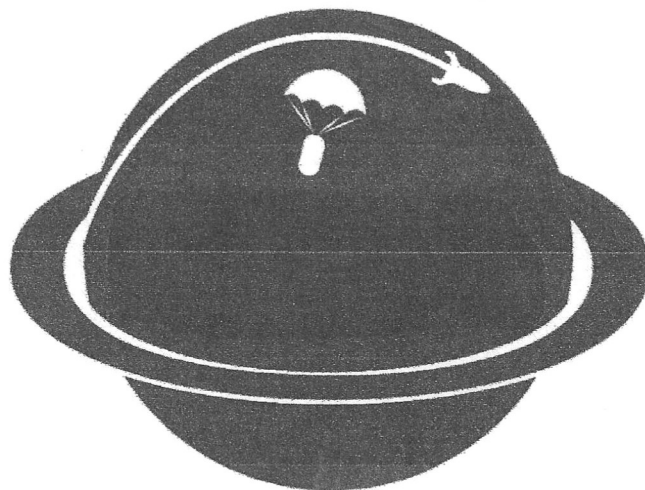


FDR

Final Design Review



Portugal



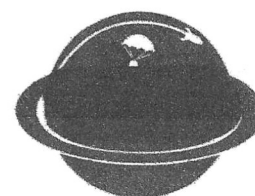


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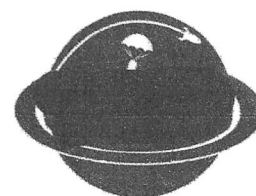


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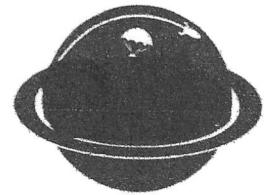


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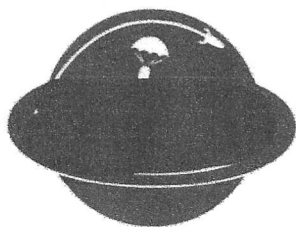
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Appendix 1



Technical Sheet n.01

RECOVERY SYSTEM TECHNICAL SHEET AND DESIGN REPORT

GENERAL INFORMATION:

Recovery system: Hemispherical 12 gore parachute

Calculation speed: 9,5m/s

Diameter: 0,25 meters

Spill hole: 0,08 meters (32% of diameter)

Wires: 0,29 meters

Particulars:

- Good aerodynamic efficiency despite some difficult construction.
- Made with Dacron® - fluorescent orange (fulfilling CanSat Portugal rules)
- Spill hole to improve stability and fine tune descending speed.
- Swivel to improve performance after opening.
- Special threat used in professional fishery for 100kg of traction force (CanSat requirement).
- Very strong strap used to connect swivel to upper CanSat lid providing traction resistance.

CALCULATIONS:

$$F_D = \frac{1}{2} \rho C_d A v^2$$

where:

F_D is the drag force

ρ is the air density (1.11 kg/m³)

C_d is the drag coefficient

A is the area of the parachute

v is the velocity through the air

$$FG = m g$$

where:

m is the mass of the CanSat

g is the acceleration of gravity = 9.81 m/s²

$$FG = FD \rightarrow A = (2 m g) / (\rho C_d v^2)$$

$$D = \sqrt{\frac{8 \cdot m \cdot g}{\pi \cdot \rho \cdot C_d \cdot v^2}} = 0.24m$$

Atmospheric Density (0.1 g/m³) profile at Lajes (2001-2010)

Level	Z(m)	N.obs.	Ave.	S.Dev.	Min.	Max.
1	113.	3122	12048.	159.	11542.	12534.
2	1000.	3123	11132.	157.	10666.	11592.
3	1500.	3124	10561.	154.	10141.	11221.
4	3000.	3121	8983.	97.	8684.	9483.
5	4500.	3117	7691.	85.	7442.	8304.
6	6000.	3115	6565.	70.	6304.	7178.
7	7500.	2815	5587.	58.	5309.	6070.
8	9000.	2075	4765.	122.	4434.	5452.
9	10500.	1211	4200.	279.	3575.	5111.
10	12000.	1137	3824.	360.	2853.	4781.
11	14000.	1116	3385.	391.	2138.	4358.
12	16000.	1100	2966.	386.	1679.	3951.

SOURCE: IMPA – Portuguese Institute for Sea and Atmosphere

D is the parachute diameter in meters

m is the CanSat mass in kilograms (0,35)

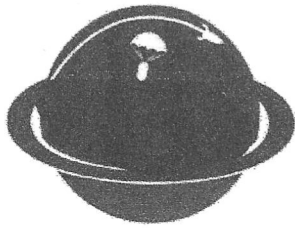
g is the acceleration of gravity = 9.8 m/s²

π is 3.14159265359

ρ is the density of air: 1.11 kg/m³

C_d is the drag coefficient of the chute, which is 1.5 for hemispherical

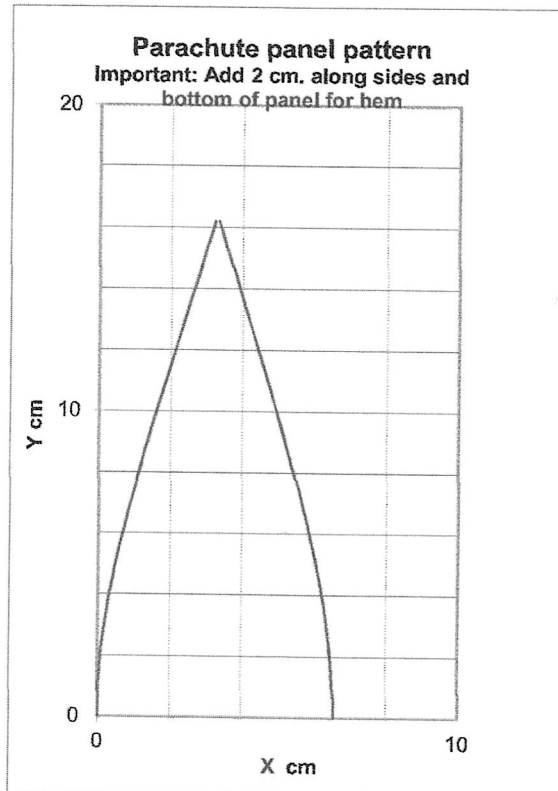
v is the required speed (9,5m/s)



Technical Sheet n.01

RECOVERY SYSTEM TECHNICAL SHEET AND DESIGN REPORT

GORE SIZING AND DRAWING:



Parachute Panel Scaled Coordinates 25cm diameter			
X	Y	X	Y
6.55	0.00	0.00	0.00
6.54	0.82	0.01	0.82
6.51	1.25	0.03	1.25
6.47	1.87	0.07	1.87
6.42	2.48	0.13	2.48
6.35	3.09	0.19	3.09
6.27	3.70	0.27	3.70
6.18	4.29	0.36	4.29
6.08	4.88	0.46	4.88
5.97	5.46	0.57	5.46
5.86	6.02	0.68	6.02
5.75	6.58	0.80	6.58
5.62	7.13	0.92	7.13
5.50	7.67	1.04	7.67
5.38	8.20	1.17	8.20
5.25	8.72	1.29	8.72
5.13	9.23	1.42	9.23
5.00	9.74	1.55	9.74
4.87	10.23	1.67	10.23
4.75	10.72	1.80	10.72
4.63	11.20	1.92	11.20
4.50	11.68	2.04	11.68
4.38	12.15	2.16	12.15
4.26	12.61	2.29	12.61
4.14	13.07	2.41	13.07
4.02	13.53	2.52	13.53
3.90	13.98	2.64	13.98
3.79	14.43	2.76	14.43
3.67	14.87	2.88	14.87
3.55	15.32	2.99	15.32
3.44	15.76	3.11	15.76
3.32	16.20	3.22	16.20

Length of cords calculation:

$$L = 2.25 * (D + S)$$

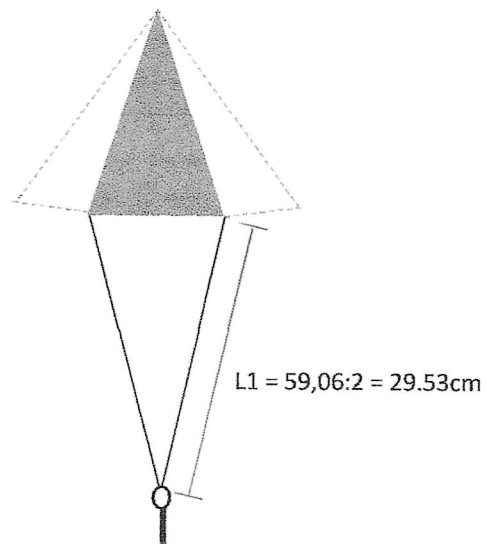
Where:

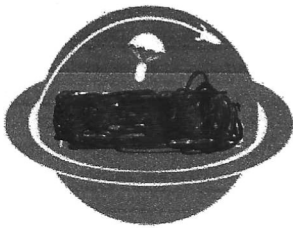
D = basic diameter of parachute

S = stitching length (length of cord sewn to the canopy, should be between 5% and 10% of the basic parachute diameter. Less percentage length is required for smaller parachutes, more for larger).

$$L = 2.25 * (25 + 1.25) = 59 \text{ cm (6 cords with this length).}$$

L=59,06cm (each cord is connected to the two vertex of the base of the gores)





Technical Sheet n.01

RECOVERY SYSTEM TECHNICAL SHEET AND DESIGN REPORT

PARACHUTE TEST:

FIRST MODEL:

Ø25cm with no spill hole ; Dacron® tissue (fluorescent orange)

Results for 3 attempts at 28.7 meters high:

Average descending time – 3.69 seconds

Average velocity: 7.77m/s

SECOND MODEL:

Ø25cm with a 5cm spill hole ; Dacron® tissue (fluorescent orange)

Results for 3 attempts at 28.7 meters high:

Average descending time – 3.62 seconds

Velocity: 7.91m/s

THIRD MODEL:

Ø25cm with 8cm spill hole; Dacron® tissue (fluorescent orange)

Results for 3 attempts at 28.7 meters high:

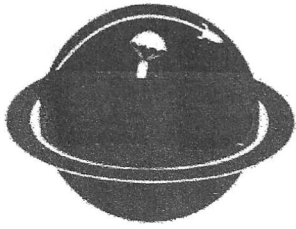
Mean descending time – 3.12 sec.

Velocity: 9.2m/s

CONCLUSIONS:

Our final parachute model gives us a 9.2m/s perfectly inside CanSat rules (8 to 11 m/s) however we might have higher. Despite we chose to use a local air density value we have to consider that the competition launch will occur in a local with a different atmosphere composition (in terms of humidity for instance) and the altitude will be also higher. And we know that air density is lower at higher altitudes leading to higher descending speeds. For this reasons we think that speed compliance is achieved.

In terms of mechanical traction compliance we couldn't test our final model made with the Dacron material but we made a test using an equal parachute built with the same type of sewing (thread and stitch), size, cords (size, length and and thread) and connection accessories. This test was successful since our testing model raised two 50Kg calibrated weights. We conclude that our parachute built with the same characteristics and a very higher resistant material will have similar behavior.



Technical Sheet n.04

BATTERY TESTS

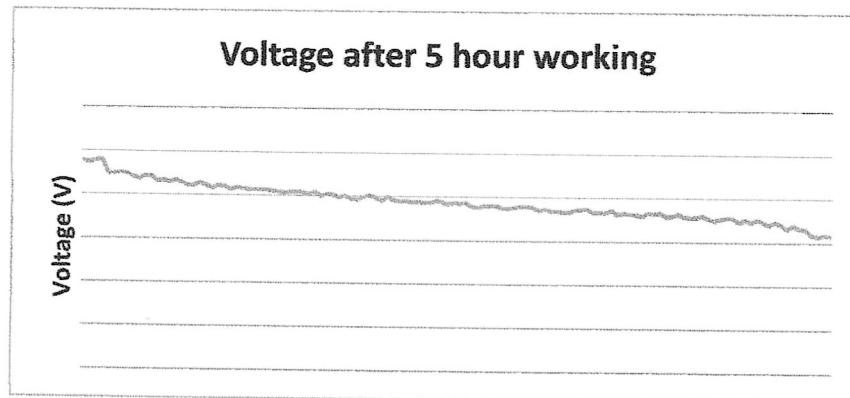
GENERAL PROCEDURE:

1st test: one 9V battery – after 2,5 hours system shutdown

2nd test: 2 LiPo 3,4V 980mAh batteries (serial connection) – after 5 hours system still working

Initial voltage drop: system start ("coup de fouet") 3 to 10%

Slight voltage recover (typical)



$$U_0 = 7,4V \quad U_i = 7,65V \quad U_f = 6,4V \quad \Delta U = 1,25V$$

$$\%(voltage) = \frac{\Delta U}{U_i} = 83\%$$

The power consumption is like the following table:

Module	Power characteristics				Usage ratio
	Voltage	Current	Power	Source	
Microcontroller	7,4V	30mA	222mW	Datasheet	100%
RF transceiver	5V	30mA	150mW	Datasheet	100%
GPS module	5V	25mA	125mW	Datasheet	100%
Pressure and temperature module	5V	10mA	0,0135mW	Datasheet	100%
Light to frequency converters + multiplexer	5V	40mA	200mW	Datasheet	100%
Battery voltage divider	-	-	negligeble	Estimation	100%
Total consumption	= 135mA		Needed voltage		5V
Power available	1100mAh		Battery supply		7,4V
Autonomy	8.15 hours				

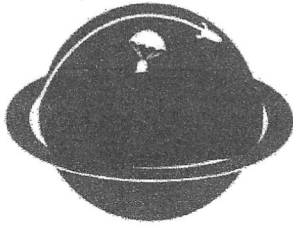
$$t = \frac{Q}{I} \Leftrightarrow t = \frac{1100}{135} = 8,15h$$

CONCLUSION:

After 5 hour of full work we still have 83% of voltage.

Theoretically we have 8 hours of continuous power.

Compliance verified for 4 hours (CanSat requirement)!



Technical Sheet n.05

ACCELERATION TEST

GENERAL INFORMATION:

System used:

- 3 phase electric motor vertical mounted
- Metallic arm with strong tweezers on end
- Electronic speed drive for velocity control
- Optical detector, Arduino board

CALCULATIONS:

First we have calculated the relation between drive frequency and CanSat rotation frequency using an optical detector connected to an Arduino board . This relation was determined to be:

1Hz CanSat \rightarrow 2.5Hz drive

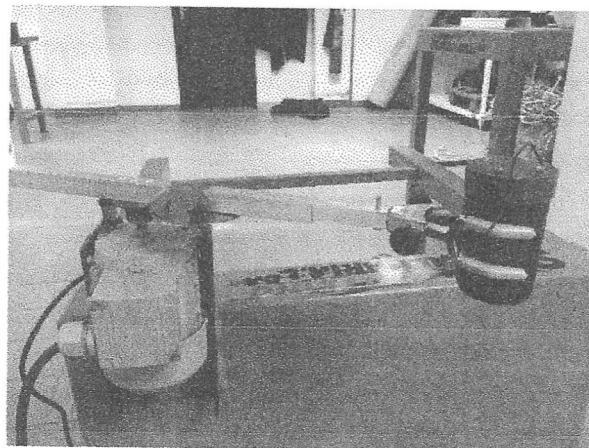
$$a = 20g \Leftrightarrow a = 20 \cdot 9.8 = 196m \cdot s^2$$

$$f = \sqrt{\frac{2 \cdot a}{4 \cdot \pi^2}} = 3.15Hz$$

Using the frequency relation above we calculate the speed drive regulation of 7.9Hz to a 20g acceleration.

We did the test with 8Hz that represents 20.63g acceleration!!! During this test, the CanSat still emitting data all time.

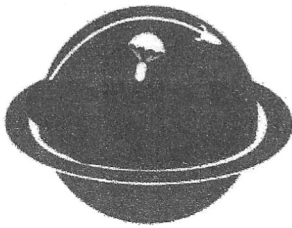
Test video in: <https://youtu.be/gWEkl-nyv7Y>



CONCLUSION:

Our CanSat passed the critical test of 20g acceleration (CanSat requirement).



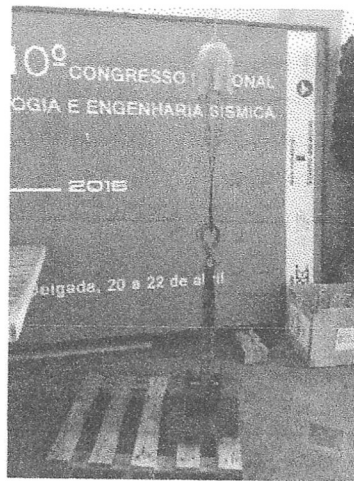


Technical Sheet n.06

TRACTION FORCE TEST

GENERAL INFORMATION:

For this purpose, we used the setup identified in the image bellow, which consisted on the suspension of the parachute by means of a ball placed inside it, connected to a cable, which in turn was attached to a mobile crane inside LREC's facilities.



Existing wires in the lower end of the recovery system were, in turn, connected to two standard weights (50 kg each) provided by [REDACTED]. The rise of the mobile crane allowed to suspension of the system with a slightly higher tensile force than the required 100kg (standard weights + mass of the strap that connected the weights to the recovery system).

EXPERIMENTAL PROCEDURE:

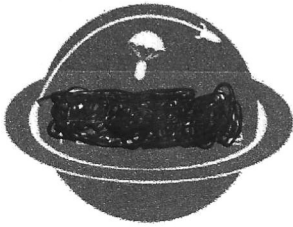
The experimental procedure included a mass suspension – slightly above 100kg - according to the setup shown in the previous paragraph, over a period of 10 minutes.

Test video in: <https://youtu.be/u41K5FTh1MI>

RESULTS:

Two experiments were carried out on 05.18.2016, in which the following was observed:

- Test 1 - The first trial was stopped a little before reaching the two minute mark due to the breakage of the cables linking the spherical ball to the crane. The recovery system per se did not suffer any damage, and therefore another test could be performed after the improvement that connection's strength (test 2);



Technical Sheet n.06

TRACTION FORCE TEST

- **Test 2** - In this test , the load was suspended about 20 cm above the ground for a period of time (timed with a chronometer) of 10 minutes. We have not recorded any incidents during the test run (e.g. sounds which pointed to rupture of the parachute and / or coupling system).

CONCLUSION:

Given the above it is considered that the proposed recovery system meets the tensile strength requirements specified under the CanSat competition - 100 kgf , or 1000 N.



Assunto:

RE: Ensaio de tração - sistema de recuperação CanSat

Following your request for collaboration and the testing conditions presented in our proposal, we present the following report on the tensile tests performed at the recovery system (parachute) for determining its compliance with the CanSat competition requirements, particularly if it has a tensile resistance of 100Kgf (1000N) for a period of at least 10 minutes.

Setup

For this purpose, we used the setup identified in Fig. 1, which consisted on the suspension of the parachute by means of a ball placed inside it, connected to a cable, which in turn was attached to a mobile crane inside LREC's facilities. Existing wires in the lower end of the recovery system were, in turn, connected to two standard weights (50 kg each) provided by INOVA. The rise of the mobile crane allowed to suspension of the system with a slightly higher tensile force than the required 100kg (standard weights + mass of the strap that connected the weights to the recovery system).



Fig. 1 – Experimental setup.

Experimental procedure

The experimental procedure included a mass suspension – slightly above 100kg - according to the setup shown in the previous paragraph, over a period of 10 minutes.

Results

Two experiments were carried out on 05.18.2016, in which the following was observed:

- Test 1 - The first trial was stopped a little before reaching the two minute mark due to the breakage of the cables linking the spherical ball to the crane. The recovery system per se did not suffer any damage, and therefore another test could be performed after the improvement that connection's strength (test 2);
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Conclusions

Given the above it is considered that the proposed recovery system meets the tensile strength requirements specified under the CanSat competition - 100 kgf , or 1000 N.

