Parachute design for CanSat

V1.0

The parachute system of your CanSat might be one of the most critical parts of your mission. When you do not decelerate sufficiently, you do not have enough time for your measurements, and your system might break. This reader will help you design, build, and test the parachute system.

1 Introduction

A parachute is a device that generates drag to slow down a capsule. Parachutes have been an essential part of space exploration for small and large missions alike. For CanSat, parachutes are required to ensure your experiment survives landing and that you have sufficient flight time actually to do your experiment.

2 Requirements and interaction

To design something good enough, you first have to define good enough. This is done through a set of requirements. These come from your launch provider, launch site, and your own experiment.

To determine your internal requirements, you need to understand your mission and the interaction of the parachute system with the other subsystems. For instance, your experiment might need a particular time for measurements, or your structure can only handle a specific load. Write all these down to form a list of requirements.

The most important requirements are the landing velocity and decent time, but you can add your own here. Think as broad as possible!

Parachute system requirements

1. The landing velocity shall be ….. m/s
2. The descent time shall be ….. s
3.
4.
5.

3 Parachute sizing

For the sizing of the parachute area, we assume that:

- the parachute deploys directly after release from the rocket,
- it is small,
- the parachute only generates drag and no lift,
- and the can itself has a very low drag compared to the parachute.

If this is not the case, please visit our website for a more general parachute design guide.

3.1 Parachute area

With the assumptions above, we can balance the downwards and upwards forces. In this case these are the weight of the rocket/CanSat and the drag of the parachute:

$$m_{cansat} * g_0 = \frac{1}{2} * \rho * V_{landing}^2 * AC_d$$

Rewriting to solve for the area gives us:

$$AC_d = \frac{2 * m_{cansat} * g_0}{\rho * V_{landing}^2} [m^2]$$

For a first-order estimation, the air density at sea level can be assumed to be 1.225 kg/m^3 and the earth's gravitational acceleration can be considered to be 9.81 m/s^2. To help you solve this equation, you can use the following table:

	Parameter	Formula	Value	Unit
A	CanSat mass	Input		kg
B	Desired landing velocity	Input		m/s
C	Air density at sea level	Input	1.225	kg/m^3
D	Gravitational accelerator	Input	9.81	m/s^2
E	Weight	E = A*D		N
F	Dynamic pressure	F = 0.5*C*B*B		Pa
G	Drag area	E/F		m^2

Now you can translate this to the parachute area and diameter. The area depends on the drag coefficient. Generally speaking, you can say that a cross parachute has a Cd between 0.5 and 0.6, and a round parachute has a Cd of 0.6 and 0.75. However, this depends on your production, final design, and many more factors. We always recommend doing a drop test with your parachute to validate your system's drag area and drag coefficient.

3.2 Descent time

As the CanSats are (usually) deployed at the rocket's apogee, one can assume that it reaches terminal velocity nearly instantaneously. This means that the descent time can be determined using the highest altitude of the rocket (called apogee) and the descent velocity calculated earlier.

The descent time now becomes:

$$t = \frac{h_{apogee}}{V_{landing}}$$

Now there are two obvious options. Either one breaks the descent time requirement, or one does not. When the requirement is met there is no problem, but when the requirement is not met, you have the following options:

1. Decrease the size of the parachute
2. Increase the mass of the CanSat
3. Add a drogue parachute
4. Reef the main parachute

For a CanSat it is rarely recommended to add a drogue parachute or reefing for two reasons. The parachute of a CanSat is (when designed correctly) already so small it is near impossible to make a good parachute that is even smaller. Furthermore, this significantly increases the complexity of the mission.

This leaves two options, change the parachute size or change the mass of the CanSat. Here the team is faced with a real engineering challenge. The organisation has multiple requirements, such as a mass range, decent time, and size. Some might be easier to bend than others. For example, breaking a requirement from the launch site might lead to you not being allowed to fly. Breaking your own requirements might reduce the worth of your mission. It is up to the team to weight the effect of bending or breaking a requirements and which consequence to accept.

To help you with this process we have an excel sheet that you can use. In this sheet you can give your apogee prediction and your expected parachute Cd.

Landing velocity over body mass sensitivity analysis

velocity [m/s]	Body mass [kg]										
Parachute Area [m2]	0,25	0,26	0,27	0,28	0,29	0,3	0,31	0,32	0,33	0,34	Parachute diameter [m]
0,01	26,47	27,00	27,51	28,01	28,51	29,00	29,48	29,95	30,41	30,87	0,06
0,02	18,72	19,09	19,45	19,81	20,16	20,50	20,84	21,18	21,51	21,83	0,08
0,03	15,28	15,59	15,88	16,17	16,46	16,74	17,02	17,29	17,56	17,82	0,10
0,04	13,24	13,50	13,75	14,01	14,26	14,50	14,74	14,97	15,21	15,44	0,11
0,05	11,84	12,07	12,30	12,53	12,75	12,97	13,18	13,39	13,60	13,81	0,13
0,06	10,81	11,02	11,23	11,44	11,64	11,84	12,03	12,23	12,42	12,60	0,14
0,07	10,01	10,20	10,40	10,59	10,78	10,96	11,14	11,32	11,49	11,67	0,15
0,08	9,36	9,54	9,73	9,90	10,08	10,25	10,42	10,59	10,75	10,91	0,16
0,09	8,82	9,00	9,17	9,34	9,50	9,67	9,83	9,98	10,14	10,29	0,17
0,10	8,37	8,54	8,70	8,86	9,02	9,17	9,32	9,47	9,62	9,76	0,18
0,11	7,98	8,14	8,29	8,45	8,60	8,74	8,89	9,03	9,17	9,31	0,19
0,12	7,64	7,79	7,94	8,09	8,23	8,37	8,51	8,65	8,78	8,91	0,20
0,13	7,34	7,49	7,63	7,77	7,91	8,04	8,18	8,31	8,44	8,56	0,20
0,14	7,07	7,21	7,35	7,49	7,62	7,75	7,88	8,00	8,13	8,25	0,21
0,15	6,83	6,97	7,10	7,23	7,36	7,49	7,61	7,73	7,85	7,97	0,22
0,16	6,62	6,75	6,88	7,00	7,13	7,25	7,37	7,49	7,60	7,72	0,23
0,17	6,42	6,55	6,67	6,79	6,91	7,03	7,15	7,26	7,38	7,49	0,23
0,18	6,24	6,36	6,48	6,60	6,72	6,83	6,95	7,06	7,17	7,28	0,24
0,19	6,07	6,19	6,31	6,43	6,54	6,65	6,76	6,87	6,98	7,08	0,25
0,20	5,92	6,04	6,15	6,26	6,38	6,48	6,59	6,70	6,80	6,90	0,25

Descent time [s]									
37,78	37,04	36,35	35,70	35,08	34,49	33,92	33,39	32,88	32,39
53,42	52,39	51,41	50,48	49,60	48,77	47,98	47,22	46,50	45,81
65,43	64,16	62,96	61,83	60,75	59,73	58,76	57,83	56,95	56,11
75,55	74,09	72,70	71,39	70,15	68,97	67,85	66,78	65,76	64,79
84,47	82,83	81,28	79,82	78,43	77,11	75,86	74,66	73,52	72,43
92,53	90,74	89,04	87,44	85,92	84,47	83,10	81,79	80,54	79,35
99,95	98,01	96,18	94,44	92,80	91,24	89,76	88,34	86,99	85,71
106,85	104,78	102,82	100,96	99,21	97,54	95,95	94,44	93,00	91,62
113,33	111,13	109,05	107,09	105,23	103,46	101,77	100,17	98,64	97,18
119,46	117,14	114,95	112,88	110,92	109,05	107,28	105,59	103,98	102,44
125,29	122,86	120,56	118,39	116,33	114,38	112,52	110,74	109,05	107,44
130,86	128,32	125,92	123,65	121,50	119,46	117,52	115,67	113,90	112,21
136,21	133,56	131,07	128,70	126,47	124,34	122,32	120,39	118,55	116,80
141,35	138,60	136,01	133,56	131,24	129,03	126,94	124,94	123,03	121,21
146,31	143,47	140,79	138,25	135,85	133,56	131,39	129,32	127,35	125,46
151,11	148,17	145,40	142,78	140,30	137,94	135,70	133,56	131,52	129,57
155,76	152,73	149,88	147,18	144,62	142,19	139,88	137,67	135,57	133,56
160,27	157,16	154,22	151,45	148,81	146,31	143,93	141,66	139,50	137,43
164,67	161,47	158,45	155,60	152,89	150,32	147,88	145,55	143,32	141,20
168,94	165,66	162,57	159,64	156,86	154,22	151,72	149,33	147,05	144,87

As you can see, a heavy CanSat with a small parachute (top right) has a high decent velocity and thus a low flight time. But a heavy CanSat with a large parachute (bottom right) has a low decent velocity and thus a long flight time. Now say you have a requirement that your flight time is 90 seconds you can start removing options.

Landing velocity over body mass sensitivity analysis

Parachute Area [m2]	velocity [m/s] / Body mass [kg]: 0,25	0,26	0,27	0,28	0,29	0,3	0,31	0,32	0,33	0,34	Parachute diameter [m]
0,01	26,47	27,00	27,51	28,01	28,51	29,00	29,48	29,95	30,41	30,87	0,06
0,02	18,72	19,09	19,45	19,81	20,16	20,50	20,84	21,18	21,51	21,83	0,08
0,03	15,28	15,59	15,88	16,17	16,46	16,74	17,02	17,29	17,56	17,82	0,10
0,04	13,24	13,50	13,75	14,01	14,26	14,50	14,74	14,97	15,21	15,44	0,11
0,05	11,84	12,07	12,30	12,53	12,75	12,97	13,18	13,39	13,60	13,81	0,13
0,06	10,81	11,02	11,23	11,44	11,64	11,84	12,03	12,23	12,42	12,60	0,14
0,07	10,01	10,20	10,40	10,59	10,78	10,96	11,14	11,32	11,49	11,67	0,15
0,08	9,36	9,54	9,73	9,90	10,08	10,25	10,42	10,59	10,75	10,91	0,16
0,09	8,82	9,00	9,17	9,34	9,50	9,67	9,83	9,98	10,14	10,29	0,17
0,10	8,37	8,54	8,70	8,86	9,02	9,17	9,32	9,47	9,62	9,76	0,18
0,11	7,98	8,14	8,29	8,45	8,60	8,74	8,89	9,03	9,17	9,31	0,19
0,12	7,64	7,79	7,94	8,09	8,23	8,37	8,51	8,65	8,78	8,91	0,20
0,13	7,34	7,49	7,63	7,77	7,91	8,04	8,18	8,31	8,44	8,56	0,20
0,14	7,07	7,21	7,35	7,49	7,62	7,75	7,88	8,00	8,13	8,25	0,21
0,15	6,83	6,97	7,10	7,23	7,36	7,49	7,61	7,73	7,85	7,97	0,22
0,16	6,62	6,75	6,88	7,00	7,13	7,25	7,37	7,49	7,60	7,72	0,23
0,17	6,42	6,55	6,67	6,79	6,91	7,03	7,15	7,26	7,38	7,49	0,23
0,18	6,24	6,36	6,48	6,60	6,72	6,83	6,95	7,06	7,17	7,28	0,24
0,19	6,07	6,19	6,31	6,43	6,54	6,65	6,76	6,87	6,98	7,08	0,25
0,20	5,92	6,04	6,15	6,26	6,38	6,48	6,59	6,70	6,80	6,90	0,25

Parachute Area [m2]	Descent time [s]									
0,01	37,78	37,04	36,35	35,70	35,08	34,49	33,92	33,39	32,88	32,39
0,02	53,42	52,39	51,41	50,48	49,60	48,77	47,98	47,22	46,50	45,81
0,03	65,43	64,16	62,96	61,83	60,75	59,73	58,76	57,83	56,95	56,11
0,04	75,55	74,09	72,70	71,39	70,15	68,97	67,85	66,78	65,76	64,79
0,05	84,47	82,83	81,28	79,82	78,43	77,11	75,86	74,66	73,52	72,43
0,06	92,53	90,74	89,04	87,44	85,92	84,47	83,10	81,79	80,54	79,35
0,07	99,95	98,01	96,18	94,44	92,80	91,24	89,76	88,34	86,99	85,71
0,08	106,85	104,78	102,82	100,96	99,21	97,54	95,95	94,44	93,00	91,62
0,09	113,33	111,13	109,05	107,09	105,23	103,46	101,77	100,17	98,64	97,18
0,10	119,46	117,14	114,95	112,88	110,92	109,05	107,28	105,59	103,98	102,44
0,11	125,29	122,86	120,56	118,39	116,33	114,38	112,52	110,74	109,05	107,44
0,12	130,86	128,32	125,92	123,65	121,50	119,46	117,52	115,67	113,90	112,21
0,13	136,21	133,56	131,07	128,70	126,47	124,34	122,32	120,39	118,55	116,80
0,14	141,35	138,60	136,01	133,56	131,24	129,03	126,94	124,94	123,03	121,21
0,15	146,31	143,47	140,79	138,25	135,85	133,56	131,39	129,32	127,35	125,46
0,16	151,11	148,17	145,40	142,78	140,30	137,94	135,70	133,56	131,52	129,57
0,17	155,76	152,73	149,88	147,18	144,62	142,19	139,88	137,67	135,57	133,56
0,18	160,27	157,16	154,22	151,45	148,81	146,31	143,93	141,66	139,50	137,43
0,19	164,67	161,47	158,45	155,60	152,89	150,32	147,88	145,55	143,32	141,20
0,20	168,94	165,66	162,57	159,64	156,86	154,22	151,72	149,33	147,05	144,87

When you have met your most important requirements, those of the launch provider and/or launch site, it is up to the team to determine the right parachute area and mass.

3.3 Parachute load

When the CanSat is released from the rocket the parachute suddenly inflates leading to a high deceleration load. For CanSat your parachute is so small you can assume an instantaneous opening. That means you can determine the opening load using the following equation

$$F_{opening} = \left(\frac{1}{2}\,\rho\, v_{deploy}^{2}\right) CdA * 2$$

In this equation, you multiply the dynamic pressure at deployment or inflation with your parachute's drag area, which you have determined in the previous step. The factor 2 at the end is to correct for dynamic behaviour during inflation. When the canopy inflates, it overstretches slightly. This elastic deformation temporarily increases the parachute area leading to a force higher than expected. You can fill in the table below to find an estimation of the loads on your parachute. Note that the velocity is not the landing velocity (parameter B), but a velocity given by the launch provider. Also note that the air density is not the air density at sea level, but lower as you are at apogee.

	Parameter	Formula	Value	Unit
J	Velocity at deployment	Input		m/s
K	Rho at deployment	Input	1.112 [for 1000 m]	kg/m^3
L	Dynamic pressure	L = 0.5*K**J*J		Pa
M	F opening	M = 2*L*G		

Now you can start the design. Keep in mind that when designing for the inflation load you take a safety factor onto of the predicted load. Which load is the right one for you is up to you and your team to decide! We would recommend a safety factor of 1.5 to 2. The lower the safety factor the lower the system mass and the higher the risk of a failure in flight. The higher the safety factor the heavier the CanSat will be.

4 Landing and retrieval

For a CanSat mission there is (usually) no landing system. This means that the terminal velocity you have selected should be low enough for your system to survive. However, the mission is not over after landing. The CanSat are retrieved after flight by the launch site, launch provider or yourself. Given an apogee of 1000 meters, it is very possible that your CanSat lands several kilometres away and that retrieval might take some time. Furthermore, the CanSat can land on any surface, including forest and high grass. Keep this in mind when choosing your parachute colour and the colour of your CanSat. For example, a green CanSat might be hard to find in a forest, but it might be easy to find in the snow when flying in the north of Norway.

To help the retrieval crew find your CanSat you can also include a beeper or light to help locate the can. You can also send a GPS location to your ground station. Remember that you might lose line of sight before landing and that your last known location is not your landing location. However, having a starting point is already of great help to the retrieval crew.

5 Testing

There are many tests you can and have to do on your CanSat. This includes the deceleration and landing system. For this purpose we recommend you build a dedicated test unit such that, if the CanSat breaks, you do not break your flight model.

Whenever you do a test make sure you think about your test objectives and why you test. Also think about what you expect to happen and what you want to observe. This helps you determine which sensors and cameras you might need and determine if the test was a success.

5.1 Drop test

During a drop test you drop your CanSat model from a height to determine the stability of the parachute and the descent rate. Before the test it is important to know the height of the building/crane, the mass of your CanSat, and the actual size of the parachute. You drop the vehicle and you measure the flight time using a stopwatch. Then using the same equations mentioned earlier to determine the actual CdA.

$$V_{landing} = \frac{h_{building}}{t_{flight}} \; [m/s]$$

$$C_d A = \frac{2 * m_{cansat} * g_0}{\rho * V_{landing}^2} \, [m^2]$$

Using the actual CdA you can redo the flight calculations to determine whether you still meet the requirements.

During the free fall you might observe a strong oscillation or parachute drift. When this occurs your parachute is a bit unstable. This most likely means that there are some problems with the production. It is up to the team to decide if this is a problem.

5.2 Impact test

The can will drop to the ground with a predetermined velocity. When you can land on a soft surface, this will be different when your CanSat lands on a concrete road. We recommend doing a drop test on a hard surface to see if your CanSat can survive this impact. We also recommend doing an impact test higher than the velocity you expect, as you never know what will happen in flight.

5.3 Static load test

It is difficult to test the parachute inflation on the ground without having a wind tunnel available. However, you can apply the expected load (parameter M in the table on page 4) on your CanSat with the parachute using a weight. We recommend hanging your suspension lines on a bar or hook and placing an equivalent mass on the bottom of your CanSat. It is important to test your parachute wires and the attachment point with the CanSat as this also has to take up the load of inflation.