Issue 662 / October 7th, 2025

PEAK OF FLIGHT NEWSLETTER

Apogee Components, Inc. / ApogeeRockets.com / Colorado Springs, CO

Drag Coefficient of a Model Rocket Recovery Parachute

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COVER PHOTO

Super Loki Dart

A rendering of the A.S.P. Super Loki Dart being place on the launch pad.

FEATURED ARTICLES

Drag Coefficient of a Model Rocket Recovery Parachute

by Lt Col. Jordan Firth, USSF

How do you go about testing parachutes to measure their coefficient of drag? This article give you the steps needed.

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The Apogee Katana rocket leaves the launch pad at NSL in Alamosa, Colorado.

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The views expressed in this article, are those of the author and do not necessarily reflect the official policy or position of the United States Air Force Academy, the Department of the Air Force, the Department of Defense, or the US Government.

This project uses altitude data recorded during the launch and recovery of a model rocket to determine an empirical drag coefficient for the rocket's parachute. The observed drag coefficient closely matches the vendor's suggestion for a flat sheet parachute. The testing described in this paper can be used to determine empirical drag coefficients for any parachute with a drop test.

Nomenclature

A	area	m^2	h	altitude	m
c_d	drag coefficient		m	mass	kg
D	diameter	m	V	speed	m/s
g	gravitational acceleration	m/s^2			
ρ	air density	kg/m^3			

Objective and Approach

The objective of this project is to determine the drag coefficient of a 24" (610 mm) diameter nylon hexagonal flat sheet parachute, available from Apogee Components [1]. The drag coefficient value will be used to produce accurate rocket trajectory predictions in future projects. Drag coefficient is determined by analyzing flight data from several rocket launches.

Background

An unpowered rocket falling through the atmosphere is primarily subject to two forces: gravity and drag. The force of gravity depends on the object's distance from the center of the Earth [2].

$$F_{gravity} = \frac{\mu m_{rocket}}{R^2} \qquad (1)$$

where μ is Earth's gravitational constant and R is the object's distance for the center of the Earth. Model rockets stay relatively close to Earth's surface, so gravitational acceleration can be treated as constant, along with the force of gravity, $F_{gravity}$. This paper will use a value of $g=9.81\ m/s^2$.

The force of drag will vary with the rocket's speed [3].

Figure 1: By knowing the drag coefficient of your parachute, you can accurately determine its descent rate.

$$F_{drag} = \frac{1}{2}\rho V^2 c_d A \qquad (2)$$

The rocket's net acceleration is found with Newton's Second Law, simplified for constant mass since data is only being analyzed post-burnout.

$$a = \sum F/m = \left(F_{drag} - F_{gravity}\right)/m \qquad (3)$$

When released, speed is zero, so there is no drag force and the rocket will accelerate towards the Earth. Drag increases as speed increases. The force of drag will increase until it equals the force of gravity. At that point the rocket has reached an equilibrium. It will continue to fall, but it is no longer accelerating, so it will fall at a constant speed. This equilibrium speed, called terminal velocity, is the fastest speed an object will reach. Figure 1 shows the effect of a parachute on terminal velocity.

A rocket with a deployed parachute will have a slower terminal velocity than the same rocket without a parachute, because the parachute has a larger surface area. The lower speed allows for a safer landing and (hopefully) successful recovery of the rocket and its payload. This is the reason parachutes are used in model rocketry.

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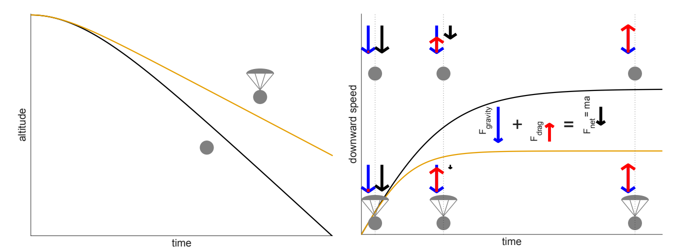

(a) altitude of an object falling through a fluid

(b) object reaches terminal velocity when $F_{drag} = -F_{gravity}$

Fig 1. Altitude and speed of an object falling through a fluid with drag. A parachute's large surface area causes an object to fall more slowly than the same object without a deployed parachute..

Assumptions

Air density is assumed to be constant throughout the experiment period (one hour) and altitude range (0 m–150 m AGL). Air pressure is used to determine the rocket's altitude during flight. Air pressure is assumed constant at least during a single flight—approximately 50 s.

The parachute is assumed to be the only source of drag for the falling rocket. The rocket body, nose cone, and parachute lines create additional drag, but their area is much smaller than the parachute's area. Parachutes are assumed to deploy fully and to reach terminal velocity before the rocket returns to ground level. Exceptions are identified and excluded from analysis. The parachute is assumed to fall vertically through the wind column at landing.

The parachute is a regular hexagon. For the purposes of this project it is assumed to be round with a diameter matching the flat-to-flat normal distance.

Test Article and Test Equipment

The test article is a small rocket recovery parachute available from Apogee Components in Colorado Springs. The nylon parachute is hexagonal in shape and measures 24" (610 mm) from flat to flat. With the assumption that the parachute is roughly circular, parachute area is 0.292 m^2. Parachute mass is 16.9 g. The rocket is used for recovery of a USAFA-designed model rocket which is 630 mm long and 58 mm in diameter. The parachute is attached to the rocket with a tether consisting of 1 m kevlar string for flame resistance and 1 m elastic cord to absorb the shock of parachute deployment. The harness also incorporates a swivel to avoid tangling during recovery. The rocket and parachute are shown in Figure 5.

The rocket has a burnout mass of 396 g with an expended 24 mm Quest Q-Jet E26 motor. The nose cone contains an Arduino

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(a) rocket (b) parachute (c) parachute in flight

Fig 2. Rocket and parachute. Parachute photos courtesy Apogee Components.

microcontroller which logs accelerometer, gyroscope, and barometer data to an SD card at 4 Hz throughout flight. The barometer is a BME280 breakout board from adafruit.

Mathematical Technique

An equation relating terminal velocity to drag coefficient is presented in a NASA guide to model rockets [4].

$$c_d = \frac{2mg}{\rho A V_{terminal}^2} \tag{4}$$

Parachute area is found with Equation 5.

$$A = \pi \left(\frac{D}{2}\right)^2 \tag{5}$$

Vertical speed is found by differentiating altitude.

$$V = \frac{d}{dt}h \tag{6}$$

For this project the derivative is performed with matlab's gradient() function: output = gradient(input). This numerical function uses a single sided difference (Equation 7) at the ends of the input vector, and a central difference (Equation 8) for all other points.

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Fig. 3 Rocket launch.

While it is not described here, this function also scales results to match the step size of a variable-step time vector [5].

$$output(1) = input(2) - input(1) \tag{7}$$

$$output(j) = [input(j+1) - input(j-1)]/2 \tag{8}$$

Numerical differentiation produces noisy output, so the resulting speed was examined with a moving average.

Local air density is required, but finding it is significantly beyond the scope of this project. Instead atmospheric conditions were determined using calculators available at https://www.weather.gov/epz/wxcalc_stationpressure and https://www.calctool.org/atmospheric-thermodynamics/air-density. Weather observation data came from the US Air Force Academy airfield, which is approximately 160 m lower than and 6.5 km southeast of the launch location.

Experiment Setup and Execution

Several instances of an identical rocket were launched from Stillman Field at the US Air Force Academy on 2025-03-20 from 0800–0900 local. During the launch period, the Air Force Academy Airfield (KAFF) reported the conditions shown in Table 1 [6]. Launch site elevation is 2160 m. An air density of 1.02 kg/m^3 will be used throughout this report.

Table 1 KAFF METAR on 2025-03-20

	time	*1355*	*1455*	*Z*
reported	*barometer*	*30.12*	*30.11*	*in Hg*
	temperature	*16*	*25*	*°F*
	dew point	*5*	*10*	*°F*
derived	*launch site pressure*	*23.16*	*23.15*	*in Hg*
	launch site air density	*1.03*	*1.01*	kg/m^3

Rockets reached altitudes up to 160 m AGL. An onboard barometer was used to record altitude throughout the flight. The altitude history was differentiated to find the rocket's terminal velocity under parachute and the corresponding parachute drag coefficient.

All rockets were launched from the same location during the launch period. Launch is shown in Figure 3.

Theoretical Predictions

NASA's guide to model rockets proposes a drag coefficient of 1.75 for model rocket parachutes [4]. In the absence of a specification, the vendor suggests using a value of 0.75 [1]. Using Equation 4 with these proposed drag coefficients results in the predictions shown in Table 2.

Table 2 Predicted terminal velocity

source	*NASA*	*Apogee*	
c_d	*1.75*	*0.75*	
$V_{terminal}$	*3.86*	*5.90*	m/s

Experimental Results

Figure 4 shows 15 of 17 rocket launches. Two launches were excluded because they did not reach a sufficient altitude to fully deploy their parachutes. All rockets launched from the same location, but they landed at different elevations, which can be observed in Figure 4a. All rockets survived landing on the grassy field intact.

Since the purpose of this report is to determine a drag coefficient from terminal velocity under parachute, it is helpful to align flight trajectories to landing time and altitude, as shown in Figure 4. The first launch shown to reach above 150 m (solid blue line) shows an exemplary launch, freefall during deployment delay, and then a slower fall with its parachute deployed. It also shows an altitude bump near apogee—the overpressure from the parachute deployment charge affected the barometric pressure sensor, which temporarily recorded a too-low altitude.

Landing speed is the slope of the descending altitude line. All

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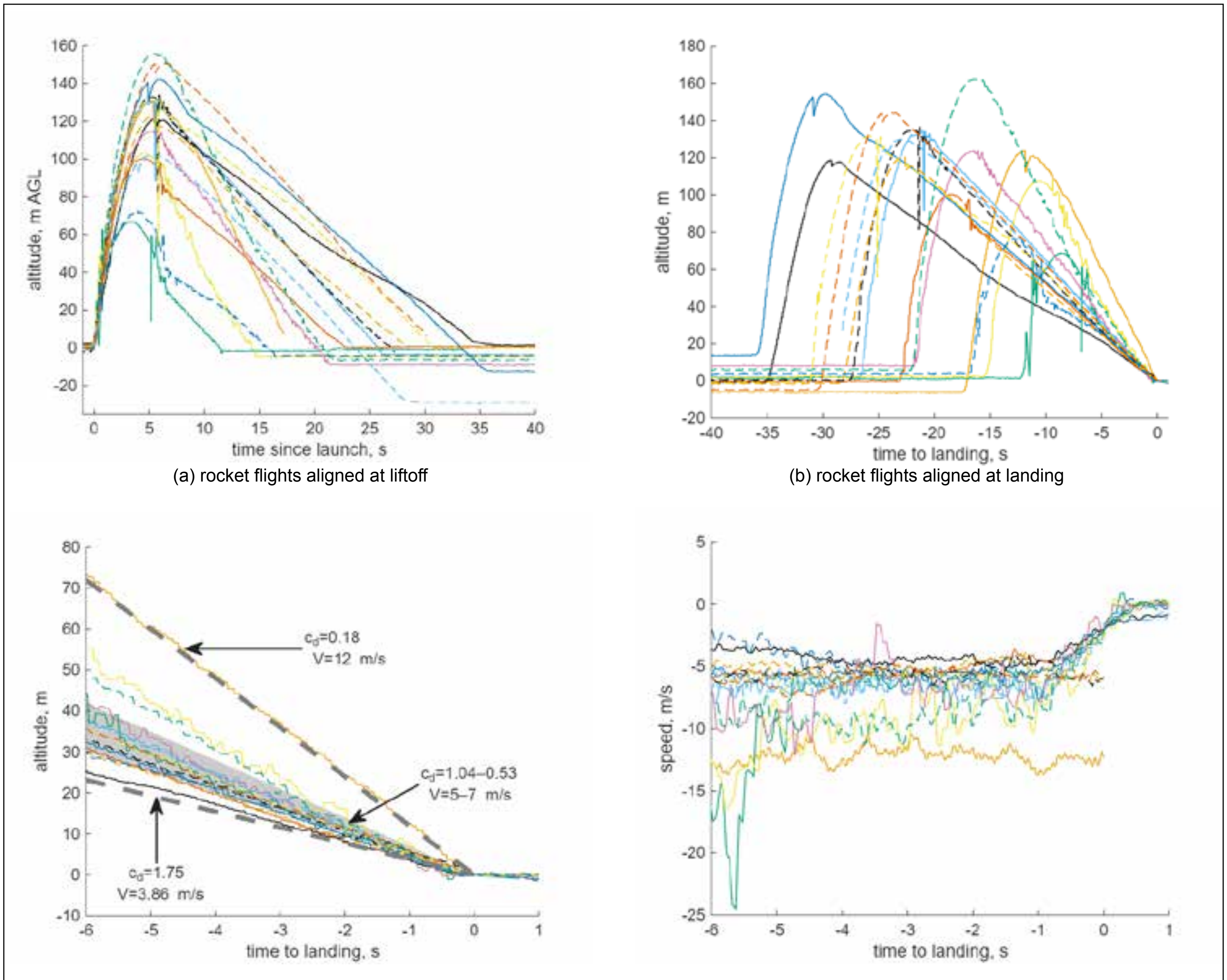

(a) rocket flights aligned at liftoff

(b) rocket flights aligned at landing

(c) rocket landings with speed and drag coeffiecient boundaries

(d) landing speeds

Fig. 4 Rocket trajectories and speeds

trajectories appear to have reached a constant terminal velocity before landing.

Figure 4c shows a closer view of the landing trajectories. Most of the rockets landed at a speed of 5 m/s–7 m/s, indicated by a gray shaded region. One rocket clearly fell faster, and two fell faster until their parachutes fully deployed just before landing.

The figure also shows the trajectory a rocket would follow if the parachute had a drag coefficient of 1.75 as provided by NASA [4]. Figure 4d shows the landing speed of each rocket flight. The numerically-differentiated altitude data is very noisy, so this figure show speed averaged over 50 samples (12.5 s), which causes the (artificial) trend toward zero speed beginning approximately 1 s before landing.

Using Equation 4, the observed terminal velocities correspond

Table 3 Drag Coefficients

terminal velocity	*3.86*	*5*	*5.90*	*6*	*7*	*12*	*m/s*
drag coefficient	*1.75*	*1.04*	*0.75*	*0.72*	*0.53*	*0.18*	
prediction	*NASA*		*Apogee*				

to the drag coefficients shown in Table 3. The drag coefficient of 0.18 (speed of 12 m/s) is misleading. In reality the parachute did not deploy, so the parachute area is much smaller than the nominal deployed area. Therefore the observed drag coefficients can be confidently declared to fall between 0.53 and 1.04.

Discussion

The rocket trajectories showed a wide range of performance—much wider than expected simply from motor manufacturing variance. All rockets were functionally identical, with identical motors. This observation is worth further study, but is beyond the scope of this investigation into a specific parachute's drag coefficient.

The parachutes deployed in 14 of 15 rocket flights. Two of the successful deployments occurred late—shortly before landing—but when fully deployed they ultimately achieved a landing speed within range of normal deployments.

Conclusion and Recommendations

Three to five of the rockets launched for this project had poor launches and/or parachute deployments. When launching a rocket with Apogee's 24" printed nylon parachute, the rocketeer must assemble the rocket and pack the parachute carefully to ensure that it deploys correctly.

The consistency of this project's results provide confidence that the drag coefficient of the parachute used in this project is approximately 0.72, which represents a generally suitable value for trajectory modeling. A rocket designer can choose to use a more conservative value to address particular concerns—$c_d = 0.53$ if the primary concern is damage from a too-hard ground impact, or $c_d = 1.04$ if the primary concern is flying away in windy conditions. The most conservative approach would be to validate the design with both drag coefficients. A rocket designer should also ensure that the parachute is ejected at a sufficient altitude to ensure full deployment before impact with the ground.

The drag coefficient determined in this project is remarkably close to the vendor's recommendation. It is also quite different from NASA's suggestion for model rocket parachutes. Multiple other sources list the drag coefficient for a flat sheet parachute as 0.75. It is not clear where the value of 1.75 came from. Different parachute types have different drag coefficients—it is possible that NASA's assumptions about parachute type don't apply to this parachute, or it may just be a typo.

A similar approach using post-burnout ascent data could be used to determine the drag coefficient of the pre-deployment rocket body. Twice-differentiated barometer data would be too noisy, but acceleration could be taken from accelerometer data instead.

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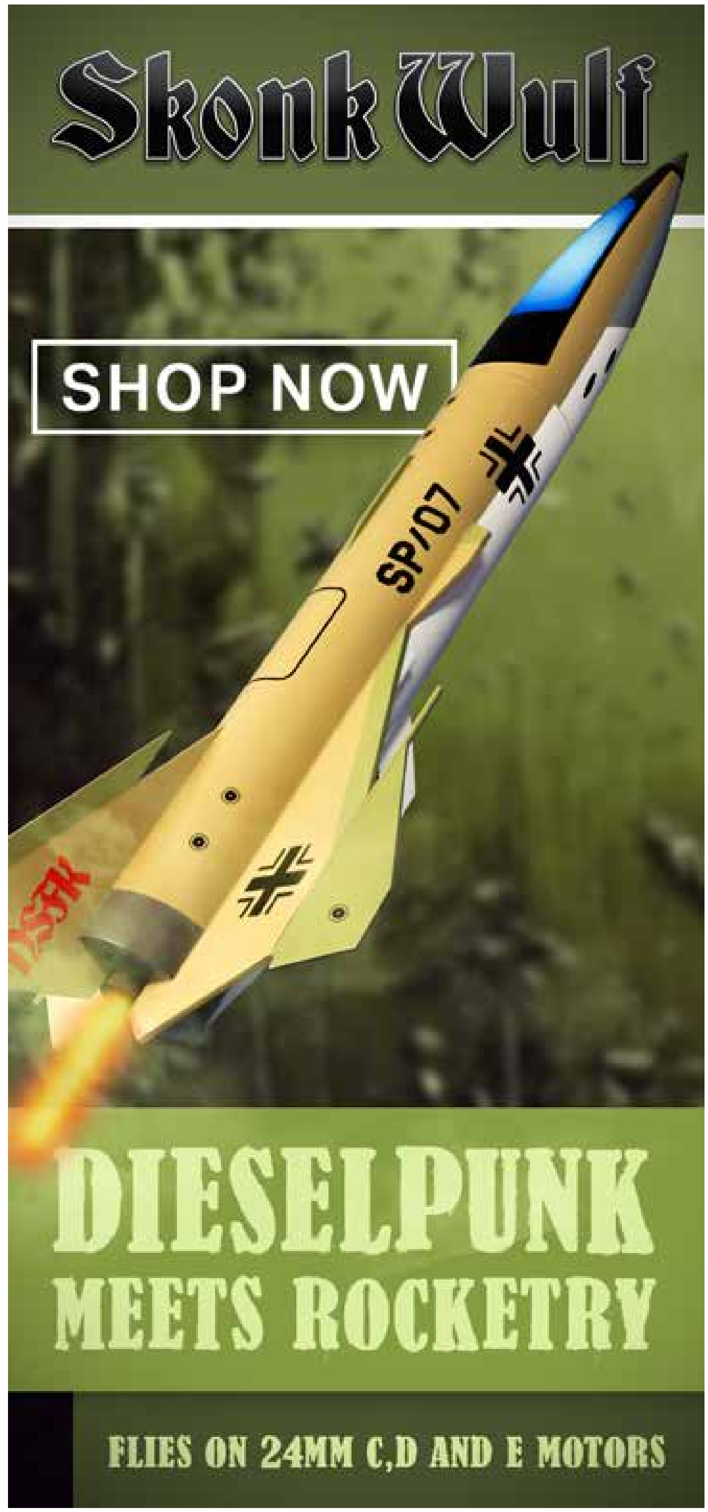

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When you have an idea for an article you'd like to submit, please use our contact form at **https://www.apogeerockets.com/Contact**. After review, we will be able to tell you if your article idea will be appropriate for our publication.

Always include your name, address, and contact information with all submissions. Including best contact information allows us to conduct correspondence faster. If you have questions about the current disposition of a submission, contact the editor via email or phone.

CONTENT WE ARE LOOKING FOR

We prefer articles that have at least one photo or diagram for every 500 words of text. Total article length should be between 2000-4000 words and no shorter than 1750 words. Articles of a "how-to" nature are preferred (though other types of articles will be considered) and can be on any rocketry topic: design, construction, manufacture, decoration, contest organization, etc. Both model rocket and high-power rocket articles are accepted.

CONTENT WE ARE NOT LOOKING FOR

We don't publish articles like "launch reports." They are nice to read, but if you don't learn anything new from them, then they can get boring pretty quick... Example: "Bob flew a blue rocket on a H120 motor for his certification flight." As mentioned above, we're looking for articles that have an educational component to them, which is why we like "how-to" articles.

You can see what articles and topics we've published before at: **https://www.apogeerockets.com/Peak-of-Flight?pof_list=archives&m=education**. You might use this list to give you an idea or two for your topic.

Here are some of the common articles that we reject all the time, because we've published on these topics before:

- How to get a L1, L2, or L3 Cert
- Building cheap rockets and equipment (pads & controllers)
- How to 3D print parts, or a Rocket Kit
- How to Build a cheap Rocket Kit
- Getting Back Into Rocketry After a Long Hiatus

ARTICLE & IMAGES SUBMISSION

Articles may be submitted by emailing them to the editor. Article text can be provided in any standard word processor format, or as plain-text. Graphics should be sent in either a vector format (Adobe Illustrator, SVG, etc.) or a raster format (such as jpg or png) with a width of at least 600 pixels for single column images or 1200 pixels for two-column images. It is preferable for images to be simple enough to be readable in a two-column layout, but special layouts can be used.

Send the images separately via email as well as show where they go by placing them in the word processor document.

ACCEPTANCE

Submitted articles will be evaluated against a rubric (available here on our website). All articles will be evaluated and the results will be sent to the author. In the evaluation process, our goal is to ensure the quality of the content in *Peak-of-Flight*, but we want to publish your article! Resubmission of articles that do not meet the required standard are heavily encouraged.

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