Issue 659 / August 26th, 2025

PEAK OF FLIGHT NEWSLETTER

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

Find The Maximum Range Your Rocket Can Reach



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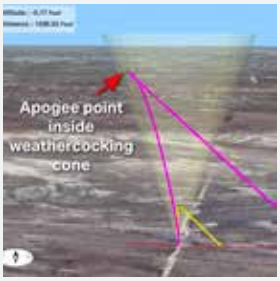
COVER PHOTO



The Euler's Revenge.

SThis was a plan that appeared in the March 13, 2023 issue to celebrate pi-day (3.14.2023). We're using this same rocket to honor Euler, who inspire the article in this issue.t

FEATURED ARTICLES



Selecting Motors for Clusters and Multi-Stage Rockets

by Tim Van Milligan

Since we can't use RockSim's Recommend Motor feature for clusters and multi-stage rockets, we need a simple process for picking motors. That is what this article is about.

Apogee Components, Inc.
4960 Northpark Dr.
Colorado Springs, CO 80918
1-719-535-9335
www.ApogeeRockets.com

About this Newsletter

You can subscribe to recieve this e-zine FREE at the Apogee Components website: www.ApogeeComponents.com, or by clicking the link here Newsletter Sign-Up

Editor-in-Chief: Tim Van Milligan
Managing Editor: Michelle Mason
Content Editor: Martin Jay McKee
Layout Design: Tim Van Milligan

The Apogee Slo-Mo rocket ready for take-off into a clear blue sky.



Would you like to see your launch photo featured in the *Peak-of-Flight* newsletter? Submit your photo at apogeerockets.com.

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Finding the Maximum Range Your Rocket Can Reach

By Tim Van Milligan

Introduction: A Thought Experiment Takes Flight

Imagine standing on a vast, open field, a sleek model rocket poised on its launch pad, the air humming with anticipation. You adjust the launch rod, tilting it just so, and wonder: What angle will send this rocket soaring to its maximum horizontal distance? It's a question that has intrigued scientists, engineers, and hobbyists for centuries—a classic thought experiment in projectile motion that pops up in school classrooms around the world. But in the world of model rocketry, turning this thought into reality isn't just about physics; it's about safety, simulation, and a dash of historical inspiration.

This article dives into that puzzle: finding the optimum launch angle for a model rocket to achieve its furthest range. We'll draw from the fascinating YouTube video *"Euler's Work on Ballistics"* (https://www.youtube.com/watch?v=MGN8ejqAbaQ), which explores the groundbreaking contributions of 18th-century mathematician Leonhard Euler to the science of projectiles. Euler (see Figure 1) , a prolific genius whose work spanned everything from fluid dynamics to number theory, laid the mathematical foundations for understanding how objects fly through the air—accounting for gravity, drag, and more. His insights, born from an era of cannons and warfare, feel remarkably relevant today, especially when applied to something as fun and accessible as model rocketry.

But here's the catch: In real life, experimenting with launch angles on a physical rocket can be downright dangerous. To truly optimize for distance, you'd need a "pure ballistic" flight, which might involve gluing the nose cone in place to prevent parachute deployment and ensure a streamlined trajectory. That violates core safety codes from organizations like the National Association of Rocketry (NAR) and Tripoli Rocketry Association, which mandate recovery systems to avoid uncontrolled descents that could injure people or damage property. Instead, we'll turn to safe, virtual simulations using RockSim software—a tool that lets us model rocket flights with precision, echoing Euler's own reliance on mathematical predictions over risky real-world trials.

To make this even more exciting, we'll tie in a custom rocket design called "Euler's Revenge," designed by our own product developer, Martin Jay McKee. You'll find the plans *Peak-of-Flight Newsletter #595* (https://www.apogeerockets.com/education/downloads/Newsletter595.pdf), and you can download the RockSim design file at: https://www.apogeerockets.com/downloads/rocksim_files/Eulers-Revenge.zip. This clever build honors Eu-



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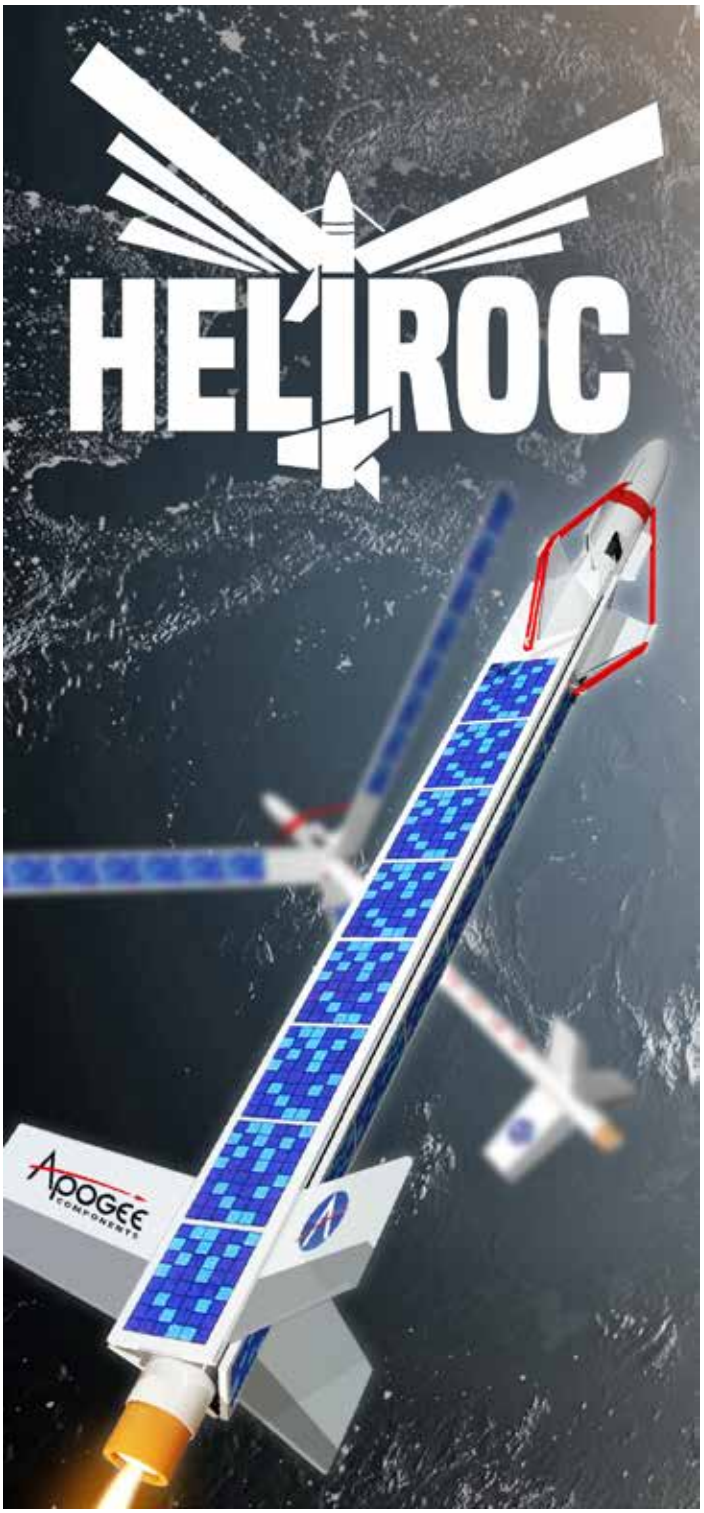
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ler's legacy, particularly his role in advancing the nomenclature and understanding of pi (π)—the mathematical constant central to circles, waves, and, yes, even rocket trajectories. (Euler's famous identity, e^{iπ} + 1 = 0, links pi with imaginary numbers, exponentials, and unity in a way that's often called the most beautiful equation in mathematics.) By simulating launches with this pi-themed rocket, we'll blend history, math, and hands-on hobbyism into a compelling exploration.

Why does this matter? In an age where STEM education emphasizes hands-on (or virtual) learning, topics like this bridge the gap between abstract theory and practical application. They touch on physics, mathematics, history, and even computer science, as we'll see. Whether you're a student tinkering in a garage, a teacher designing a lesson plan, or a hobbyist chasing that perfect flight, understanding optimal angles isn't just about distance—it's about unlocking the secrets of motion that Euler first illuminated. So, let's blast off into the past and see how his work propels us forward.



Figure 1: Leonhard Euler (1707-1783)



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Historical Context: Euler's Contributions to Ballistics

Leonhard Euler (1707-1783) wasn't just a mathematician; he was a revolutionary thinker whose work reshaped how we understand the physical world. Born in Switzerland and later working in Russia and Prussia, Euler produced over 800 publications in his lifetime, covering topics from calculus to astronomy. But it's his foray into ballistics—the study of projectiles like cannonballs and, by extension, rockets—that makes him a perfect muse for our model rocketry adventure. The YouTube video *"Euler's Work on Ballistics"* (https://www.youtube.com/watch?v=MGN8ejqAbaQ) provides a captivating deep dive into this aspect of his legacy, painting Euler as a bridge between theoretical math and practical warfare.

In the 18th century, Europe was embroiled in conflicts like the Seven Years' War (1756-1763), where artillery played a decisive role. Cannons were crude, their ranges unpredictable, relying on trial-and-error rather than science. Enter Euler, who, inspired by earlier pioneers like Galileo Galilei and Isaac Newton, sought to mathematicize the chaos. As the video explains, Euler's key contribution came in his 1753 treatise New Principles of Gunnery, an expansion of English engineer Benjamin Robins' work. Euler didn't just describe projectile paths; he derived differential equations to model them under real-world conditions.

At the heart of Euler's ballistics was the parabolic trajectory—the curved path an object follows under gravity alone. In an ideal vacuum (no air resistance), a projectile launched at velocity v and angle θ follows the range formula $R = (v^2 \sin(2\theta)) / g$, where g is gravity's acceleration (about 9.8 m/s^2). The video highlights how Euler proved the optimal angle for maximum range in this scenario is 45 degrees, an insight that simplified artillery aiming. But Euler went further, incorporating air resistance (drag), which complicates everything. Drag force, proportional to velocity squared and air density, bends the trajectory asymmetrically, making the descent steeper than the ascent. Euler's equations showed that for high-speed projectiles like cannonballs, the optimal angle drops below 45 degrees, often to around 30-40 degrees, to compensate for drag slowing the object more on the way up.

This wasn't abstract theory; it had real stakes. The video recounts how Euler collaborated with the Russian Academy of Sciences and military leaders, refining artillery tables for Emperor Frederick the Great of Prussia. His work on fluid dynamics (including the Euler equations for inviscid flow) directly informed ballistic models, predicting how air interacts with a projectile's shape. Imagine Euler, blind in one eye from overwork, scribbling equations by candlelight—these were the precursors to modern aerodynamics used in everything from bullets to spacecraft.

Euler formalized pi (π) in mathematics, crucial for understand-

ing rocket rotation and orbital mechanics. His solutions, like the Basel problem and Euler's identity, linked pi to complex analysis. Martin's "Euler's Revenge" model rocket pays tribute by incorporating pi-themed elements, acknowledging Euler's foundational math in trajectory optimization.



Figure 2

Historically, Euler's ballistics work democratized science. Before him, gunnery was an art; after, it was engineering. The video notes parallels to today's simulations—Euler's pen-and-paper models foreshadowed software like RockSim, where we can input drag coefficients and air density without firing a single shot. Yet, his era's dangers remind us of safety: Real ballistic tests often led to accidents, much like the risks in model rocketry if we ignore the safety codes.

The Science of Projectile Motion in Model Rocketry

With the historical stage set, let's ground this in the science that makes model rocketry so thrilling—and educational. Projectile motion is a staple of school curricula, appearing in physics classes as early as middle school and evolving into advanced topics by high school or college. It's the study of objects thrown or launched into the air, influenced primarily by gravity and initial velocity, with real-world twists like air resistance adding complexity. In the context of model rockets, this science isn't just theoretical; it's the key



to understanding why an optimal launch angle matters and how simulations can reveal it without endangering anyone.

At its core, projectile motion assumes an object follows a parabolic path. Launch something horizontally, and gravity pulls it down while inertia keeps it moving forward, creating that elegant curve. For angled launches, the motion breaks into components: vertical (affected by gravity) and horizontal (constant velocity, ignoring drag). The YouTube video emphasizes Euler's refinement of this: In a vacuum, the range R maximizes at 45 degrees because sin(2θ) peaks at θ=45° (sin(90°)=1). But rockets aren't in a vacuum; they're battling Earth's atmosphere.

Enter air resistance, or drag, which Euler modeled meticulously. Drag opposes motion, scaling with the square of velocity ($F_d = ½ \rho v^2 C_d A$, where ρ is air density, C_d is the drag coefficient, and A is cross-sectional area). For a rocket, this means the upward leg of the flight loses more energy to drag than the downward, skewing the optimal angle lower. Euler's calculations, as detailed in the video, showed that for cannonballs (similar to high-thrust rockets), angles around 35-40 degrees often yield the farthest range, balancing time in the air with horizontal speed.

Model rockets add layers: They have a powered ascent phase (thrust from the engine), a coasting phase (ballistic like Euler's projectiles), and descent (with recovery). Variables include engine type (e.g., impulse class A to G), rocket mass, rocket stability (measured in calibers), and environmental factors like wind or altitude. The "pure ballistic" experiment we mentioned—gluing the nose cone—aims to mimic a simple projectile by eliminating recovery drag, but it's unsafe. It could turn your rocket into a lawn dart, violating NAR Code #10 (Recovery Systems - https://www.nar.org/content.aspx?page_id=22&club_id=114127&module_id=669234)



Figure 3: Euler's Revenge (a free plan rocket) takes to the sky.

and risking injuries and bans from launch sites.

Ballistics shines in education, as we discussed earlier, thanks to its wide applicability. In physics, it's kinematics and dynamics; in math, trigonometry and optimization (e.g., differentiating the range equation to find max θ). History classes can explore Euler's Enlightenment-era impact, while computer science introduces simulation coding. Engineering ties in aerodynamics—rockets with low C_d (streamlined shapes) to fly farther, per Euler's drag insights.

"Euler's Revenge" is a unique mid-power Apogee design (e.g., 24mm diameter motors for C through F size engines) with pi-inspired features. The newsletter describes a body tube length multiple of π (e.g., 3.14 times the diameter), fins shaped like Euler's spiral (a logarithmic curve he studied), and even a payload bay for experiments echoing his pi series. Simulating it in RockSim lets us apply Euler's principles: Input the rocket's specs, vary angles, and see how pi-related dimensions affect stability and range.

In essence, the science here is about prediction and iteration—Euler's gift to us. By understanding these forces, we can simulate smarter, safer flights. Next, we'll dive into those simulations, focusing on the "Euler's Revenge" rocket to find its optimal angle.

Simulating the Optimal Angle with RockSim

Now that we've explored the historical and scientific foundations—thanks to Euler's pioneering equations and the insights from that enlightening YouTube video—let's roll up our sleeves and get practical. We'll turn to RockSim, the go-to software for



model rocketry simulations, to safely experiment with launch angles and find that sweet spot for maximum horizontal range. Remember, this is all virtual: No real rockets will be harmed (or made unsafe) in the process. I'll walk you through the steps I followed, using the "Euler's Revenge" design as our example. This pi-inspired rocket needed a small tweak for stability, but once dialed in, it became the perfect vehicle for testing Euler's ballistic predictions in a modern context.

First things first, fire up RockSim and open the file for the "Euler's Revenge" rocket. If you haven't got it loaded yet, grab the design from Apogee Rockets' Newsletter #595—it's a fun build that pays homage to Euler's mathematical elegance, with dimensions nodding to pi and curves reminiscent of his spirals. Right away, I noticed the design could use a stability boost for a full ballistic flight. To prevent it from flipping wildly after apogee—like it did in my initial runs—I added a 40-gram mass to the nose cone. This shifts the center of gravity forward, keeping the rocket arrow-straight throughout its arc, even on the way down. Think of it as giving your virtual rocket the poise of a well-aimed cannonball from Euler's era: stable, predictable, and ready to "lawn dart" into the ground without tumbling. If your trajectory looks erratic (drag changes drastically with angle of attack), tweak the nose weight incrementally until you see that smooth, gentle parabolic path we all love.

With the rocket stabilized, load in a motor— I started with the Estes D12, a reliable choice for mid-power flights. To mimic a pure ballistic trajectory (similar to gluing on the nose cone, but without the real-world danger), set the motor delay to "Plugged." This blocks ejection, ensuring no parachute deploys. If you're in the Flight Events menu, you can also select "Never Deploy" for the recovery system. It's a safe way to model what Euler described: a projectile under gravity and drag, without interference.

Next, set your launch conditions to keep things controlled. I began with a launch guide angle of 10° from vertical— that's the rod tilted just a bit off straight up—and used a standard guide length (adjust if yours differs). Under simulation controls, tell RockSim to end calculations when the rocket hits the ground, so you capture the entire flight. Oh, and zero out the wind speed for these baseline runs; we'll add variables later to spice things up.

Hit that simulate button and watch the magic unfold in the 2D Flight Profile—or, if you've got RS-Pro, the immersive 3D Launch Visualizer. On my first go, the "Euler's Revenge" arched beautifully upward but then flipped post-apogee, tumbling like a leaf. That's when I knew more nose weight was key: It moved the CG forward, stabilizing the descent and ensuring consistent drag. Once you've got that nice ballistic curve—rising steadily, peaking, and diving steeper on the way down (just as Euler predicted due to air resistance)—you're ready to experiment with angles.

From here, it's all about iteration. Keep your setup the same but vary the launch guide angle from vertical in small steps—say, 5° increments from 10° up to 60°. Run a simulation for each, and jot down the maximum horizontal range from the results. If you just need quick numbers, the flight profile gives you the range instantly. For a visual treat, head to the plots menu and graph altitude versus

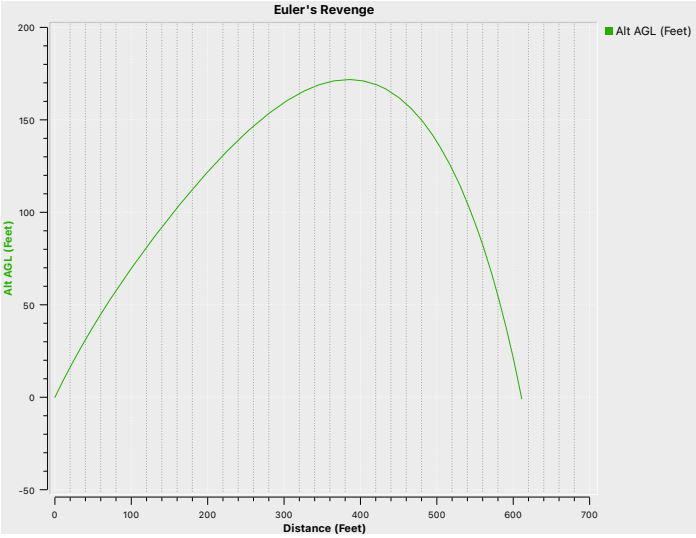
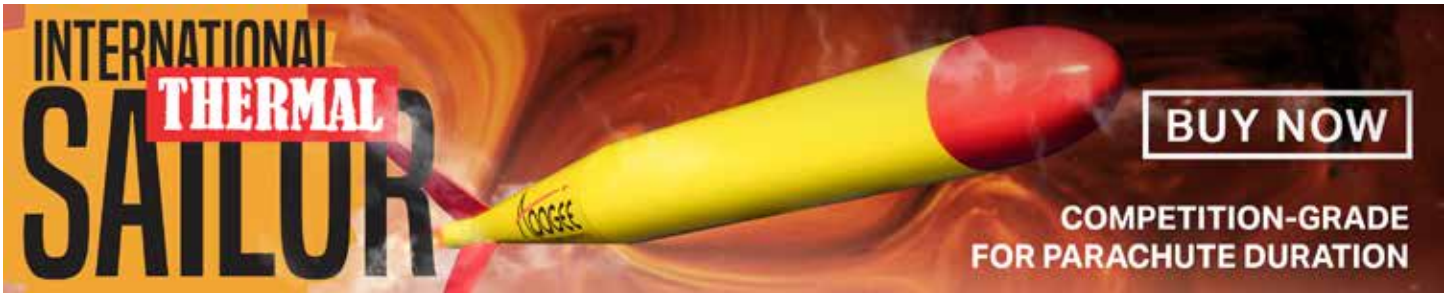


Figure 4 - You can plot the altitude vs Range graph of your simulation from inside RockSim



range (or time), like in Figure 4. It's a simple way to see the trajectory's shape right inside RockSim.

But if you're like me and want to compare multiple runs at a glance—spotting trends across angles—export the data for some spreadsheet wizardry. Go to File, Export Data, and save as CSV. Pop it into Excel or Google Sheets, then plot range versus launch angle to create a chart like Figure 5, showing the "Euler's Revenge" with the Estes D12 at various tilts. The full how-to is in Peak-of-Flight Newsletter #544 (https://www.apogeerockets.com/Peak-of-Flight/Newsletter544), complete with a handy video on Google Sheets (check it out at https://youtu.be/nI5kKz5HDck). In my results, the optimal angle hovered around 50-55° from vertical, which flips to 35-40° from the horizon—eerily close to Euler's drag-adjusted predictions from the video. And yes, that steeper

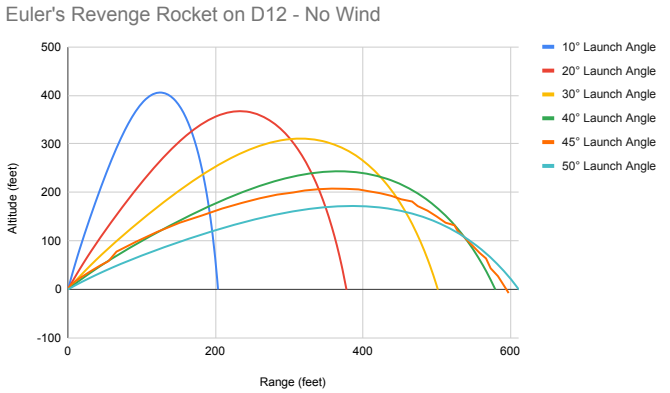


Figure 5 - A Chart showing the range of the Euler's Revenge rocket plan when launched ballistacally at different launch angles using the Estes D12 motor.

descent? Spot on with his models.

Once you've nailed the basics and generated those charts, the real fun begins: tweaking variables to see how they bend the trajectory and shift the max range. Start simple—swap motors. I reran everything with a Quest D22 instead of the D12, and the range jumped noticeably further, as shown in Figure XYY. Why? Well, the D22 packs more total impulse (19.24 N-s versus the D12's 16.839 N-s)—it's like giving your rocket a bigger fuel tank for extra push. But is that the whole story, or does the quicker burn time (higher thrust) play a role? I didn't simulate enough angles to pinpoint each motor's exact optimum, but here's the insight: Burn duration can nudge the ideal angle, all else equal. Test it yourself—compare long-burn versus short-burn motors with similar impulse, and watch how the curves change.

Don't stop there; RockSim lets you layer in real-world complex-

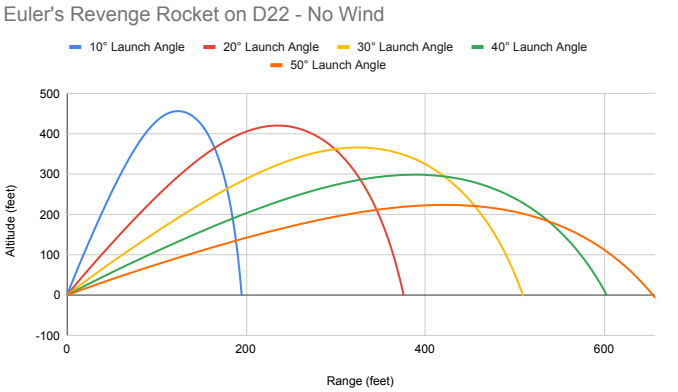
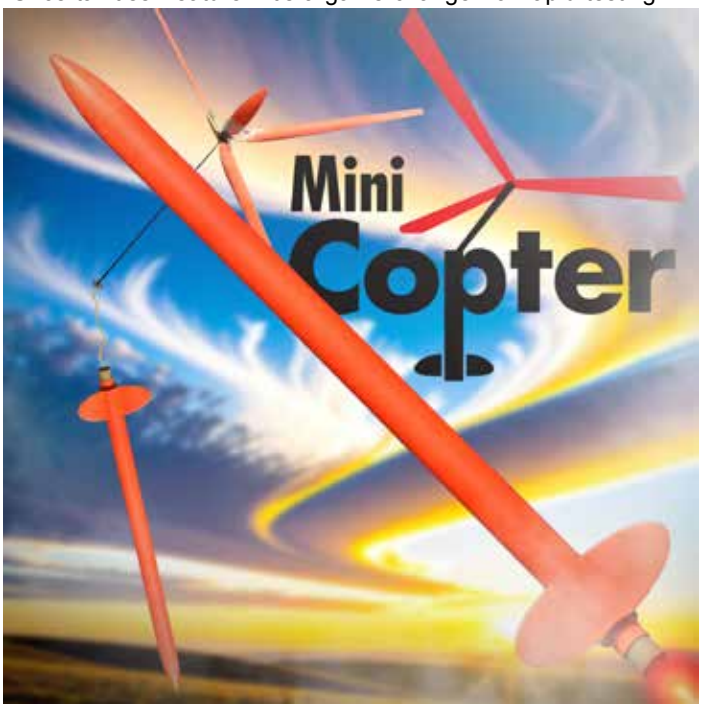


Figure 6 - The same rocket, but with a D22 rocket motor.

ities that echo Euler's comprehensive equations. Try adding a tailwind to push your rocket farther, or launch into a headwind to see resistance in action. Vary the coefficient of drag to simulate sleeker designs, or adjust air density and temperature for high-altitude scenarios. Play with launcher guide length, extend the body tube for better stability, or enlarge the fins. In RS-Pro, you can even cant the fins to add spin, fly through crosswinds, or reposition fins along the tube—each tweak revealing how small changes amplify distance or alter the optimal angle.

Speaking of RS-Pro, if you're chasing efficiency, dive into its "Uncertainties" feature—it's a game-changer for rapid testing. In-





stead of manually tweaking angles one by one, set up a batch: Start with a base launch angle of 45° from vertical, allow ±15° variation, and run 100 simulations. The software randomly adjusts and crunches the numbers in seconds, spitting out a landing zone plot like Figure 7. This visual maps every impact point, highlighting the farthest range (in my example, at 56.06° from vertical). Click any spot for a summary of what changed—pure efficiency, letting you focus on analysis rather than setup.



Figure 7: A landing zone plot that was generated after varying the launch angle using RS-Pro's uncertainty feature. Here we ran 100 consecutive simulations and all that was varied was the launch elevation angle. By clicking on a landing point, a summary screen pops up to let you know what changed during the launch to allow the rocket to land at this specific point. Here the furthest point was reached by angling the launch rod 56.06°

Through all this, you're not just crunching numbers; you're embodying Euler's spirit—using math and simulation to predict without peril. These virtual flights with "Euler's Revenge" bring his 18th-century ballistics into the 21st century, showing how drag lowers the optimal angle and steepens the fall. By the time you've run a few experiments, you'll have your own data-driven insights, ready to tie back into the bigger picture of rocketry design.

Conclusion: From Euler's Equations to Your Launch Field

From an 18th-century mathematical puzzle to a 21st-century virtual launch, our journey to find the optimal launch angle has come full circle. We began with a simple question—how to launch a rocket for maximum distance—and found ourselves walking in the footsteps of the great Leonhard Euler. His foundational work on ballistics, which accounted for the pesky realities of air resistance,

showed us that the perfect 45-degree angle is just the beginning of the story. By translating his historical insights into modern practice with RockSim, we safely and accurately simulated the "Euler's Revenge" rocket, proving that for real-world objects, a shallower angle often wins the day.

This exploration—blending history, mathematics, and hands-on simulation—is the very essence of taking your rocketry skills to the next level. It's about moving beyond the launch and into the why of the flight path. This is precisely the capability that Apogee Components strives to foster within the rocketry community. The "Euler's Revenge" plan, the detailed newsletters, and the powerful RockSim software are not just products; they are tools designed to deepen your understanding and increase your success. Apogee is committed to empowering you with knowledge, turning every build into a learning opportunity and every launch into an experiment.

So, what's your next step? Visit the Apogee Components website to discover a universe of resources waiting for you. Explore the kits, delve into the educational articles, and consider how tools like RockSim can transform your approach to the hobby. And when you do, tell your rocketry buddies. Let them know how Apogee Components is making your experience more rewarding by providing the information and components you need to not only fly higher, but smarter.

Keep launching, keep learning, and may your flights always reach new heights—in both altitude and understanding.

About the Author

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who enjoys helping fellow rocketeers. He is Level 3 high-power certified, an experienced educator, and the founder of Apogee Components. Formerly involved in the Delta II rocket program, Tim holds a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University and has worked toward an M.S. in Space Technology. He is also the author of *Model Rocket Design and Construction* and *69 Simple Science Fair Projects with Model Rockets: Aeronautics,* and publisher of the *Peak-of-Flight newsletter.*



Fly Safe. Fly True.





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Article Submission Guidelines

SUBMITTING ARTICLES TO APOGEE

We are always looking for quality articles to publish in the *Peak-of-Flight* newsletter. Please submit the "idea" first before you write your article. It will need to be approved first.

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.

ORIGINALITY

All articles submitted to Peak-of-Flight must not run in another publication before inclusion in the *POF* newsletter, but it may be based on another work such as a prior article, R&D report, etc. After we have published and paid for an article, you are free to submit them to other publications.

RATES

Apogee Components offers **$300** for a quality-written article over 2,000 words in length. Payment is pro-rated for shorter articles.

WHERE WILL IT APPEAR?

These articles will mainly be published in our free newsletter, *Peak-of-Flight*. Occasionally some of the higher-quality articles could potentially appear in one of Tim Van Milligan's books that he publishes from time to time.





Apogee Components, Inc.
4960 Northpark Dr.
Colorado Springs, CO 80918
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