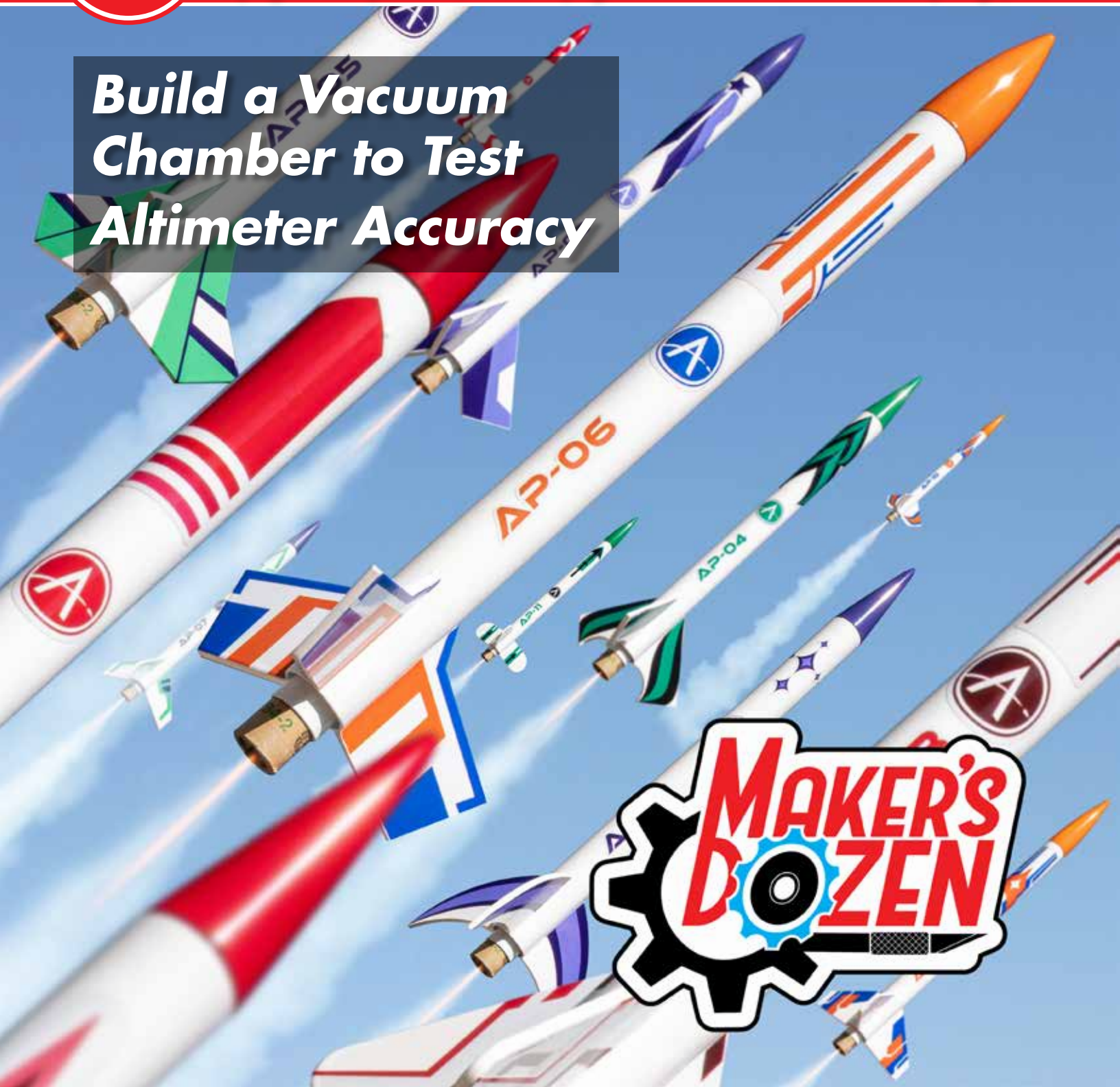
Issue 628 / June 18th, 2024

PEAK OF FLIGHT NEWSLETTER

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

Build a Vacuum Chamber to Test Altimeter Accuracy



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COVER PHOTO

Maker's Dozen

Thirteen similar sized rockets but with unique graphics, make up this bulk pack of rocket kits. It is perfect for schools and groups, because every student gets a special rocket, but nobody gets one that is bigger. This makes everyone feel that they got the best one!

FEATURED ARTICLE

Build a Vacuum Chamber to Test Altimeter Accuracy

by Harold Larson

Ever wished you could test your altimeters, chute releases, and dual-deployment systems before launch? Well, now you can with this super simple, super affordable vacuum chamber! This article will walk you through building your own chamber using nothing more than PVC pipe, a syringe, and a water manometer. You'll learn how to simulate altitudes up to 3,150 feet and test your rocketry gear like a pro. Plus, you'll get tips on how to use this chamber to teach students about altimeter operation and how to avoid common pitfalls.

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The Apogee Draco Boost Glider being flown on an D12-5 motor at the National Sport Launch in Alamosa, Colorado 05/26/2024

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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www.ApogeeRockets.com

Build a Vacuum Chamber to Test Altimeter Accuracy

by Harold Larson

A number of rocketry products sense altitude by using pressure, and then converting a decrease in pressure to an increase in altitude. Chute releases, altimeters, and altimeters with dual-deploy outputs are examples. Wouldn't it be nice to have a vacuum chamber that can be used to simulate altitudes, and test these devices before flight?

It's easier than one might think. The picture in Figure 1 shows a vacuum chamber, based on a section of 4" PVC sewer line 16" long, closed with a 4" cap at the right end and a removeable 4" Oatey #33403 test plug at the left end (both available at Lowe's). Two windows were cut in the PVC pipe in order to observe such things as chute releases doing their thing, or apogee/main test lights connected to dual-deployment altimeters coming on. Clear plastic windows were cut from a jar of Kroger Animal Crackers, but whatever the source of clear plastic, it should be fairly rigid. Vacuum is provided by a 500-cc syringe, available on Amazon, and is connected to the PVC cap by a 1/8" hose barb tapped into the cap. Most of the plumbing is aquarium air-line tubing, and a single plastic tee is used to connect the top of the manometer to the syringe and to the chamber (more detailed construction pictures are below).

Vacuum is measured by a water manometer, with the atmospheric reservoir at lower right. Green food coloring along with a few drops of dish soap were added to the water for visibility. Naturally, other pressure indicators besides a water manometer could have been used, however it's hard to beat the price of a water manometer, and they very seldom get out of calibration!

In operation, the devices(s) to be tested are placed in the chamber, the test plug is closed up, and the 500-cc syringe is used to pull a partial vacuum on the chamber. This

Figure 1: The vacuum chamber tester to measure accuracy and to validate the performance of altimeters.

vacuum causes liquid to ascend the manometer leg, which is marked off in units of 50 feet of simulated altitude. The highest altitude that can be simulated is 3,150 feet, corresponding to 44" of water column.

So, where does 44" of water column come from? It comes from the "1976 Standard Atmosphere". An article about the standard atmosphere can be found in Wikipedia, and an online calculator can be found at **https://www.digitaldutch.com/atmoscalc/** where the user can enter altitudes and temperatures, and read the corresponding pressure. If Pascals are chosen as pressure units, then zero altitude is 101,325 Pascals, (at least, in Houston TX) and 3,150 feet is 90,310 Pa, for a change of 11,015 Pa. (If you live in Denver, your results will differ.) Pascals are not the usual atmospheric pressure units in the US, where inches of mercury are normally used and a standard atmosphere is 29.92 inches of mercury, but Pascals are a perfectly legitimate metric unit of pressure. Pascals can be converted directly into inches of water column, where 1" of water column is 248.8 Pa. Thus, a change from 0 to 3,150 feet involves a pressure change of 11,015 Pa, and 11,015/248.8 = 44.2". This example assumes that pressure varies linearly with altitude, which isn't quite the case. A number of points up to one mile are plotted below and fit to an equation, which was used to scale the manometer. It also assumes that the vapor pressure of water at room temperature very low, which also isn't quite true. Water's nonzero vapor pressure at room temperature makes a small difference, neglected here, and a manometer would not work at all if water were near its boiling point of 212F.

Construction

The vacuum chamber was constructed on a 1X6 wood base with plywood mounts, and with a braced section of 1X2 48" long as a support for the manometer tube. This support is marked in units of 50 feet of simulated altitude

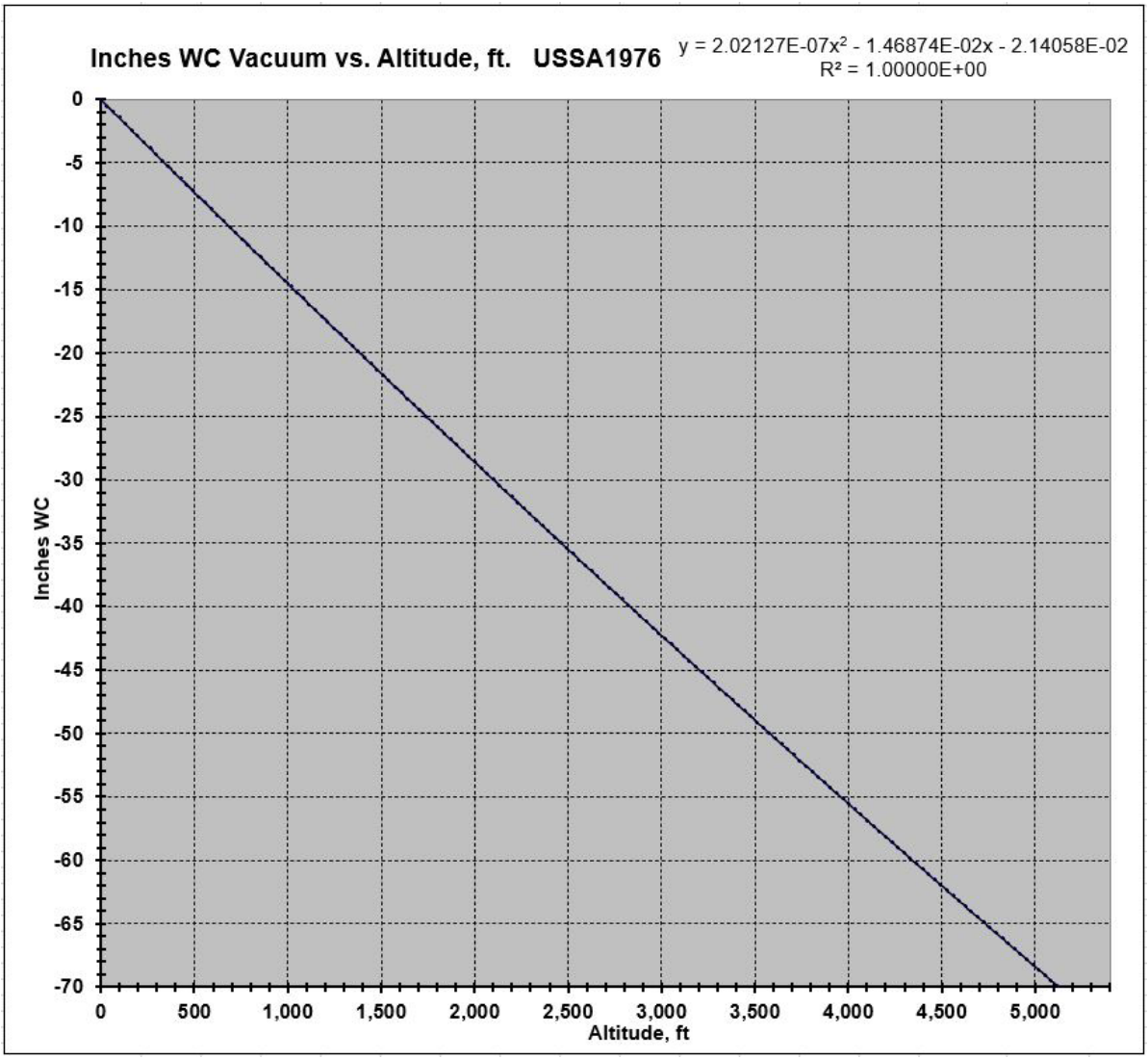


Figure 2: Chart showing the water column height versus the altitude in the vacuum chamber.

per the equation above, and labeled every 100 feet. The water reservoir should be large enough that water level does not drop appreciably as water is pulled up the manometer tube.

Figure 3: Connection of the hoses to the chamber an the syringe.

The top of the manometer (see figure 4) consists of a section of tubing from the syringe (on the right side) connected to a tee, to rigid tube that forms the manometer, and to a length of tubing that connects to the vacuum chamber (on the left side). Screw eyes are used to support the tubing every 1,000 feet of simulated altitude. The white background makes it easy to see the green water in the manometer tube. The clear, rigid tube is not a standard PetSmart item, and came from a salt-water aquarium shop.

Figure 4: Top of the manometer

The access port is an Oatey #33403 test plug that fits nicely in the end of a 4" PVC pipe (see figure 5). The plug is slipped into the pipe,

Figure 5: The Oatey end cap to close the vacuum chamber.

and the wing nut is turned to compress a rubber gasket, forcing it to seal to the walls of the pipe. It is important to keep the rubber gasket surfaces free of debris. With this arrangement, complete 3" E-bays can be tested, provided that their length is less than 16". 4" E-bays won't quite fit, as the switch ring is slightly larger than 4" in diameter.

Testing and Use

Once the chamber is constructed, and the inevitable vacuum leaks plugged, it's time to put the chamber to the test. A Perfectflite Pnut recording altimeter was placed in the chamber, taken to a simulated 3,000 feet, and lowered in 500-foot steps to zero altitude by manipulating the 500-cc syringe. The resulting "altitude" plot is very different from a normal Pnut ascent/descent plot, but does confirm that the chamber is doing a good job simulating altitudes. Pnut altimeters are barometric-only and do not contain accelerometers, and are triggered to log data after a barometric ascent to 160 feet. If your altimeter is triggered by acceleration, this won't work for you. I haven't come up with a way to simulate both acceleration and barometric altitude in a single unit!

This chamber has been useful in teaching students entering the "American Rocketry Challenge" how their altimeters

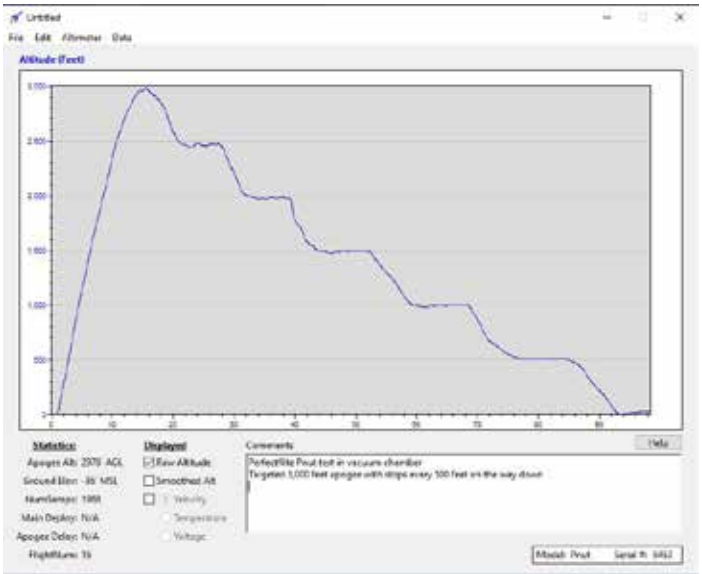


Figure 6: Data recorded from a Perfectflite Pnut altimeter. The steps in the graph were created by varying the volume of air in the syringe and watching the water level in the manometer and holding it for a few seconds.

work, and how to use them. On altimeter day, I bring the chamber to class, and have the students power up their altimeters, listening for the initial altitude and battery voltage beeps, then 25 seconds of silence, then the "ready" beeps. The altimeter is then put in the chamber, and the students try to hit the current ARC altitude target (which will be 790 feet in 2024-25) using the syringe. Knowing in advance what the "ready" beeps sound like has saved a few launches from lost data.

The notion that a moving piston can cause pressure changes also explains why it's not good to manipulate the nose cone of an ARC rocket once the altimeter is giving its "ready" beeps, or why it's not good if the eggs and their packaging can slide fore and aft like a piston in the payload section. Finally, the chamber is large enough that a complete ARC egg capsule with altimeter can usually be placed inside and tested when fully assembled and nose cone taped on, as it would be when ready to launch. Occasionally, the students forget to drill air holes in the side of the egg capsule, or accidentally block the air holes with egg-packing material. I make them figure out why their beeped altitudes are too low!

The American Rocketry Challenge recently dropped the Perfectflite APRA altimeter, which is no longer in production, and added the Jolly Logic Altimeter 1 and 2 (but not

Altimeter 3) as official altimeters. This raises the question of whether the current altimeters are consistent with the old APRA unit, or with each other. It's an easy question to answer by putting an APRA, a Pnut, a Firefly, and a Jolly Logic Altimeter 1 in the chamber together, simulating various altitudes spanning the range of ARC target altitudes, and observing how the results beeped, blinked, or displayed as text compare with each other. Agreement is excellent (as shown in Figure 7), indicating that it doesn't matter which altimeter is used (it matters a lot more that whichever altimeter is chosen is used correctly). In particular, the average of the Perfectflite values is quite close to the Altimeter 1 results. Placing several Pnut altimeters in the chamber together results in synchronized beeping that has to be heard to be appreciated!

Simulated	Altimeter Readings					
Altitude	APRA	P-Nut	Firefly	Altimeter 1	Average of	PF-Alt 1
Feet	2016	2011	2014	2022	Perfectflites	Delta
500	496	497	495	496	496	0
600	608	608	607	611	608	-3
700	708	710	708	710	709	-1
800	798	800	799	801	799	-2
900	900	903	904	901	902	1
1,000	1,005	1,007	1,004	1,007	1,005	-2
1,100	1,095	1,098	1,094	1,101	1,096	-5
1,200	1,195	1,199	1,196	1,200	1,197	-3

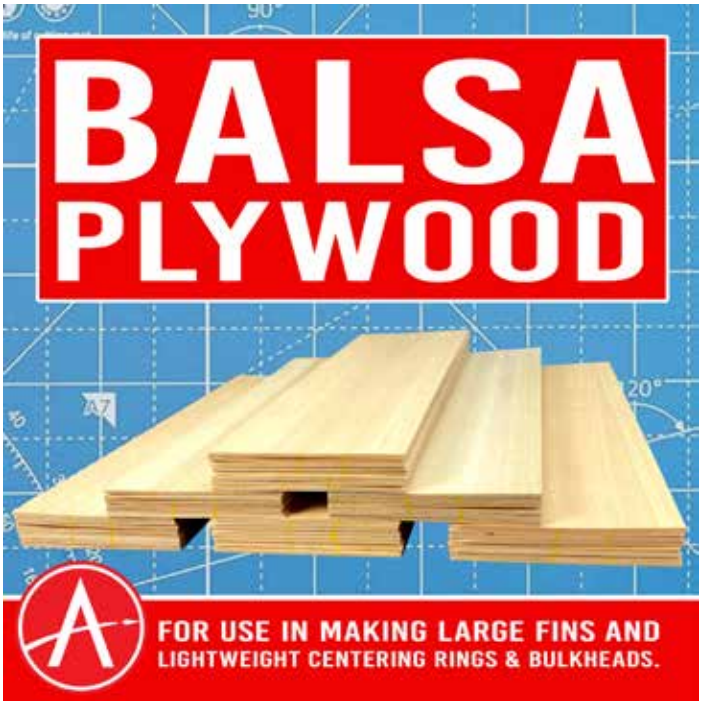
Figure 7: Results of simulated altitude in the test chamber (as verified by the manometer, versus the altitudes read by the various altimeters.

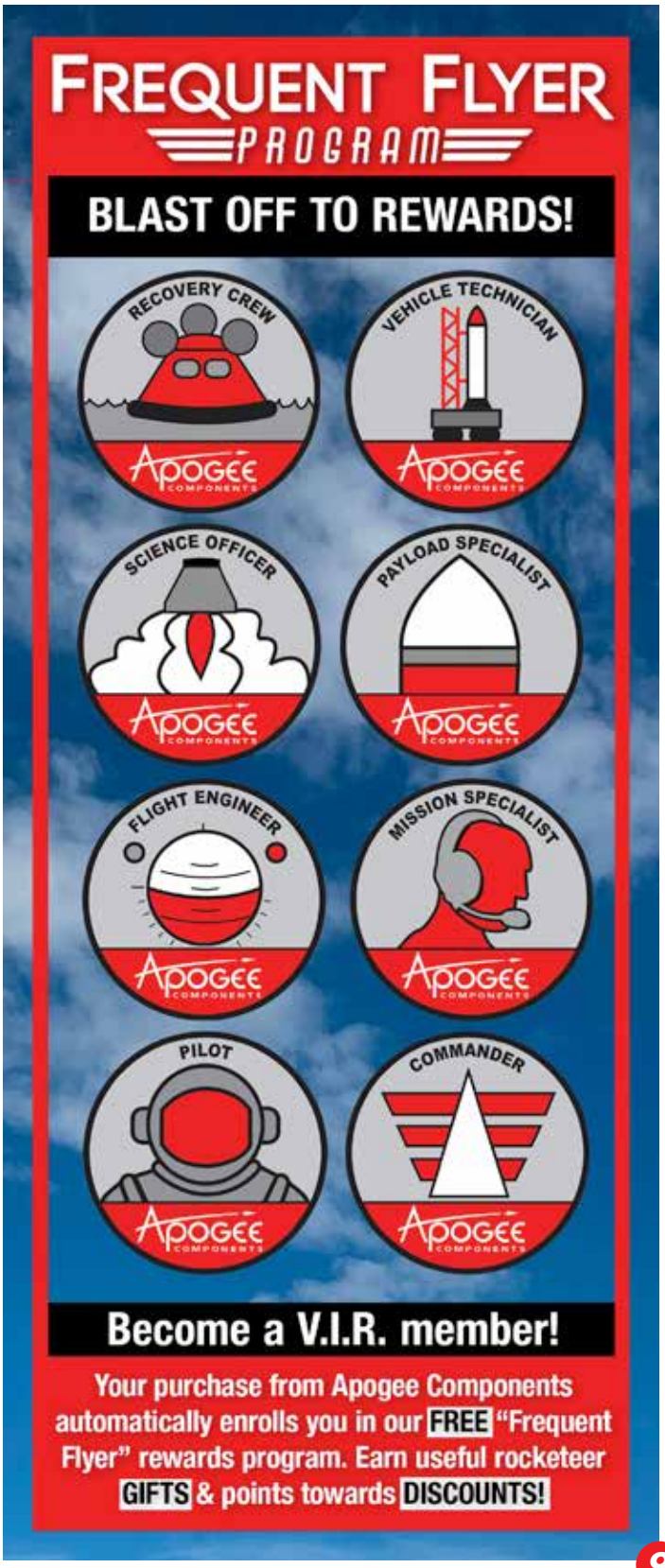
The Jolly Logic chute release is a device that releases parachutes to unfurl at target altitudes from 100 to 1,000 feet, in steps of 100 feet, as set by the user before launch. After apogee, and after the chute is (hopefully) ejected, the altimeter waits until the target altitude is reached on the way down, then releases a rubber band that is preventing the chute from unfurling. It's easy to test operation in the vacuum chamber; just fold the chute and restrain it with the chute release as for flight, place it in the chamber, simulate apogee, then simulate a slow descent by pushing air back into the chamber with the syringe. At the target altitude, the chute release releases the chute, with an audible hum

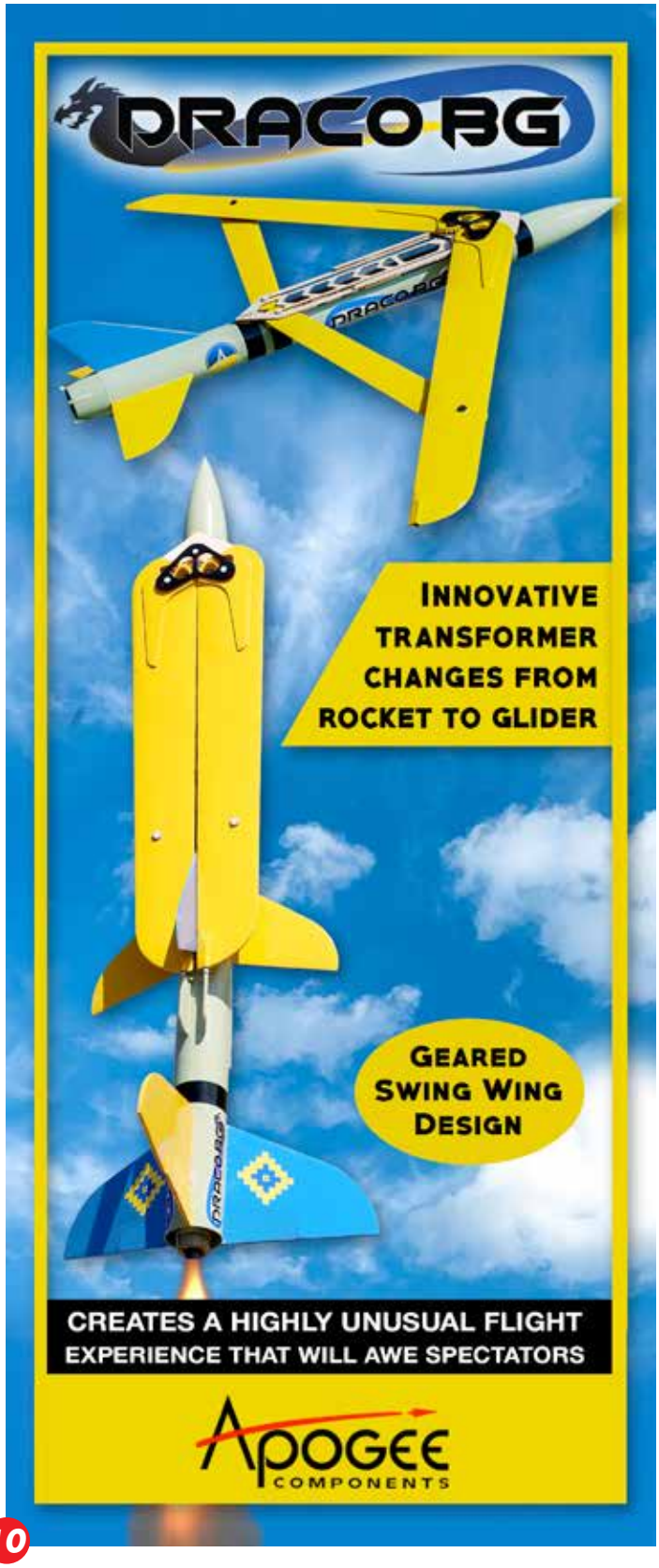
from the internal servo as it releases.

Be careful during vacuum testing to “ascend” smoothly, and be careful when packing the chute to arrange things so that the chute release pin can pull straight out of the release mechanism…you don’t want it to be at an angle, which interferes with the release. A possible failure mode is for the rocket to launch, but fly to an altitude below the chute release setting. What happens then? Testing, as well as the instruction manual, both show that the chute release will release anyway once it senses apogee, even if the apogee is lower than the chute release setting. It must have been quite a programming exercise to program the chute release to sense altitudes and ignore the spike in pressure data associated with ejection.

Finally, dual-deployment altimeters can be checked to ensure that they fire the drogue output at apogee, and the main output at the selected altitude, as intended. In the Figure 8, a Stratologger CF has been placed on a temporary mount, connected to a 7.4V cell and a switch, and Christmas lights have been connected to the drogue and main outputs. When doing the test, it’s important to simulate a smoothly increasing altitude using the syringe, and observe the drogue light flashing at apogee and the main flashing at the selected altitude. It’s helpful to select different color lights for drogue and main outputs.







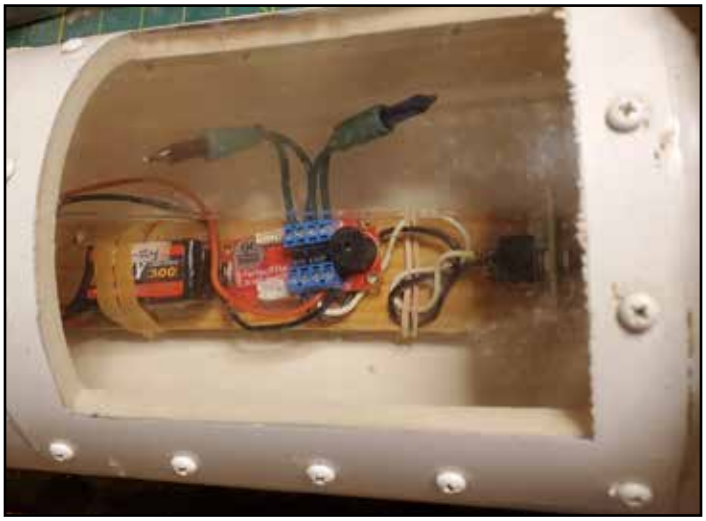


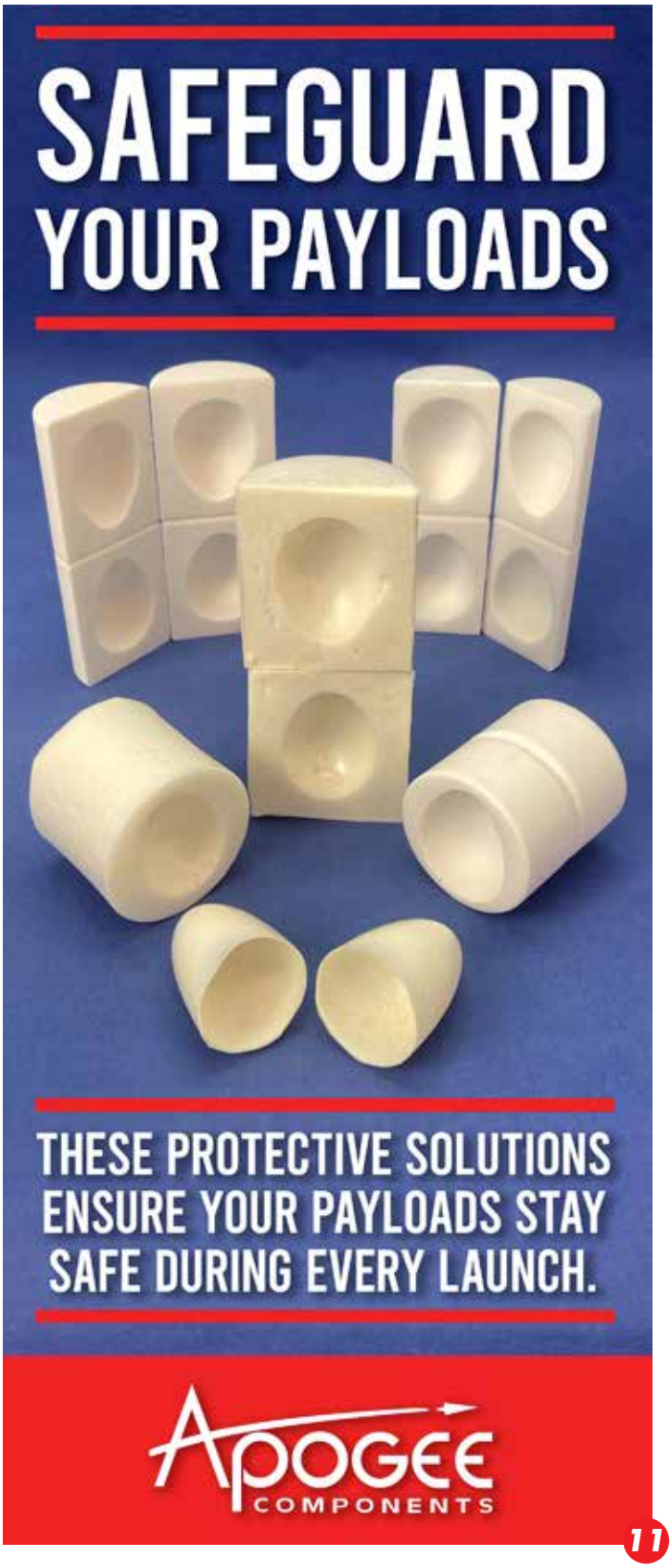
Figure 8: A dual-deployment altimeter is testing in the vacuum chamber. Instead of using igniters, christmas tree lights indicate when the deployment charges would fire off.

In summary, construction of a vacuum test chamber is not overly difficult. The size of the chamber is somewhat arbitrary, and other sizes can be chosen. Since the ideal gas law states that P*V=n*R*T, and since atmospheric air is reasonably close to being an ideal gas, if the chamber was half the present volume, it would be possible to simulate roughly double the present altitude limit (provided that the manometer leg is also enlarged). Chamber size was

chosen to simulate the atmosphere at least up to 2,500 feet, which is the altitude limit of NASA Houston Rocket Club's present launch site. The chamber at 16" long and 4" in diameter has a volume of 3,290 cc. If this volume is increased to 3,790 cc using a 500-cc syringe, internal pressure drops from 101,325 Pa to 88,000 Pa, which corresponds to 3,850 feet if the entire volume of the 500-cc syringe is used and there are no air leaks.

About The Author:

Donald Larson is a 74 year old, retired engineer, still working 1 day/week for the old company, living in Houston TX, married (47 years), and flying with the NASA-Houston Rocket Club and with Tripoli Houston Rocket Club. He's therefore into his second childhood, unsupervised by his parents this time around! Donald is a mentor of TARC/ARC with local teams since year 1 when the target was 1,500 feet and 2 stages (everyone used D12-0 boosters that year, and hoped that the upper stage lit). He's supported Seabrook Intermediate school with ARC, as perhaps half of the students have parents with NASA so there's considerable interest. The photo shows Donald about to launch a Defender (sorry, not from Apogee), getting some practice with dual-deploy ahead of mentoring the Seabrook SLI team.



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 nice 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 more common articles that we reject all the time, because we've published on these topics before:

- How to get a L1 Cert
- How to get an L2 or L3 Cert
- Building cheap rockets
- How to 3D print parts
- Building Low Cost Launch Equipment (pads and controllers)
- Getting Back Into Rocketry After a Long Hiatus
- How to Build a Rocket Kit
- How to Build a Computer (too technical)

ARTICLE & IMAGES SUBMISSION

Articles may be submitted by emailing them to the editor. Article text can be provided in any standard word processor format (MS Word, Libre Office, etc.) or as plain-text. Graphics, meanwhile, should be provided 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 a width of 1200 pixels for two-column images. If possible, it is generally preferable for images to be simple enough to be readable in a two-column layout, but special layouts can use the whole page width if required.

Send the images separately via email as well as showing 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 have been run in another publication before inclusion in the *Peak-of-Flight* newsletter, but it may be based on another work such as a prior article, R&D report, project 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.

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