



SPORT ROCKETRY

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AMERICAN ROCKET CHALLENGE 2023 COVERAGE





Altimeter is OK—Fly it!

Photo by Jim Wilkerson



American Rocketry Challenge 2023

The American Rocketry Challenge (we officially call it ARC now instead of TARC) is the NAR's premier STEM (science, technology, engineering, and math) program for young people and the largest rocket competition in the world. Over its 21 years it has drawn over 90,000 6th through 12th grade students to participate, in over 15,000 teams that have come from all 50 states plus D.C. and the U.S. Virgin Islands. Teams can be sponsored by a school or homeschool association, by a national youth organization (CAP, 4-H, Scouts, etc.), or by a local non-profit non-rocketry youth organization such as a church or science center. The 2023 program drew 798 teams from 45 states, a robust level of participation that

reflected a full recovery from the last few years of COVID constraints on group activities.

ARC is a "challenge" program, where student teams are given a specific set of flight mission performance objectives (a precise target altitude and flight duration carrying an egg payload) and design constraints. They then have to go through a student-only design-build-fly aerospace engineering process to meet these with their own original model rocket design. Teams do local practice flights and finally do up to three official "qualification" flights, which are scored by an independent local NAR observer and reported to ARC program headquarters. Over 450 of this year's 798

by Trip Barber NAR 4322
NAR ARC Manager

**Thomas Jefferson High School
of Alexandria, Va.**
Photo by Neil Michels.



Aerial view of ARC 2023 flying range.

Photo by John Langford.

teams submitted reports of local qualification flight attempts in 2023, and the 100 top-scoring of these teams were invited to the National Finals at Great Meadow Outdoor Center in The Plains, Virginia (45 miles west of Washington, D.C.) for

a head-to-head competition on May 20, 2023, to select the national champion.

The sustained success of ARC is a tribute to the dedication of the NAR volunteers nationwide who work locally with student teams to teach them rocketry, and to the strong financial support of the U.S. aerospace industry through the NAR's ARC co-sponsor, the Aerospace Industries Association (AIA). AIA is the trade organi-

zation that represents the interests of the whole U.S. aerospace industry in Washington. The AIA professional staff runs all of the registration, program administration, publicity, and corporate fund-raising that makes the program possible while NAR volunteers do the hands-on rocketry work with the students and runs the national Finals flying range. Each organization does what they are good at but works to a common purpose. It has been a successful partnership for 21 years, and is still going strong.

The contribution of rocketry to motivating the next generation of aerospace professionals was exceptionally evident at this year's Finals. At the Friday evening assembly for all the teams in preparation for Saturday's flying, veteran (now retired) NASA astronaut Dan Tani gave a slide show narrative of all the many model rocketry activities that he did growing up. And then Dr. Woody Hoburg spoke to the students from the International Space Station! Woody was a contestant in the ARC (TARC) program's Finals in its first year in 2003 while he was in high school (his team finished 10th) and then went on to Level 3 high-power rockets, to MIT for aerospace engineering through a PhD, and to service as a professor there until his selection as an astronaut. You can watch his message



Hackleburg, Ala., High School listens to the altimeter

Photo by Avis Cawley.

at <https://youtu.be/7TFXWo6-cog>. What we do “paying forward” through ARC and other NAR youth outreach programs is making a difference.

Success requires a year-long process of learning, building, then eventually lots of practice-flying, usually with failures along the way. Every successful ARC team has one or more dedicated adults—teachers, NAR rocketry mentors, and/or parents—

**RSO Ted Cochran
commands a launch.**

Photo by Glenn Feveryear.



**Oakton High School of
Vienna, Va., liftoff.**

Photo by Jim Wilkerson.



supporting that long and often challenging process. Each year we publicly recognize one teacher and one mentor at the Finals as representatives of all the hundreds who deserve this recognition. This year we called out Jeffrey Pan from California as the outstanding teacher and Andrew Heath from Alabama as the outstanding NAR mentor. You can read about their inspiring dedication to their students and teams in the accompanying text boxes.

**Embry-Riddle Aero
University exhibit.**

Photo by Glenn Feveryear.



The ARC 2023 Challenge

This year's challenge required teams to design, build, and fly a rocket to take one egg to a flight altitude of 850 feet and re-

Hardin Valley Academy
Knoxville, Tenn., (1st Place).

Photo by Glenn Feveryear.

cover it safely and unbroken within a window of between 42 and 45 seconds from liftoff to landing. The rockets were required

to separate into two non-attached sections for recovery, with each recovering safely by parachute. Duration times were measured only for the section that contained the egg payload and the barometric altimeter that

Liftoff photo
by David Bellhorn.



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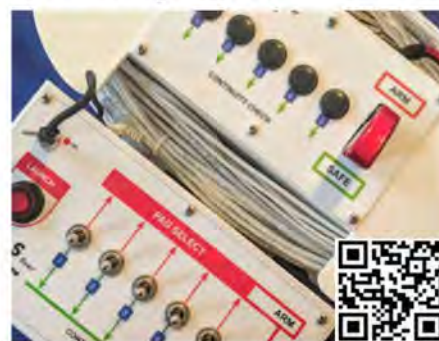
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**Thraptown, Ala., (2nd Place)
shows team spirit.**

Photo by Jim Wilkerson.

was used to determine flight altitude. As always, rockets had to be single-staged, weigh no more than 650 grams at liftoff, use no more than 80 N-sec of rocket motor total impulse, and be at least 65 centimeters in length.

Despite the many regional challenges

of bad weather that teams experienced during the first few months of 2023 leading up to the qualification flight deadline of April 3, especially on the West Coast, a combined best-two-of-three flight score of 35.0 or lower on local NAR-observed qualification flights was required this year to make the cut to get one of the 100 Finals invitations. This was more consistent with the average cutoff of the past decade than last year's cutoff of 47.58, which was

still affected by the constraints of COVID in many places on teams getting together to work and practice-fly. These 100 invited 2023 teams, coming from 27 states, had to raise the travel funds to attend the Finals and commit to attending within two weeks of their invitation, or yield their spot to one of the 20 alternates. This year we used no alternates; every team found a way to raise the money and get school permission to come to the Finals.



**Katrina Hill, AIA ARC
Program Manager.**

Photo by Glenn Feveryear.

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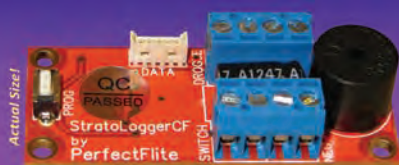
Photo by Alan Williams.

The ARC 2023 Finals

The Finals weekend began on Friday morning May 19 with the return of a long-standing and popular program event called "Rockets on the Hill," where the student teams got to display their rockets in a conference room at the U.S. Capitol and talk to members of Congress, Congressional staff, and other government officials. This had

not been possible for the previous several years due to heightened levels of security and/or COVID restrictions at the Capitol. This was followed by afternoon opportunities for student teams to either take a tour of Aurora Flight Sciences in Manassas or tour the aircraft and spacecraft collection at the Udvar Hazy Center of the Smithsonian National Air and Space Museum. All of these Friday activities were subscribed to full capacity and made for a memorable day for the teams.

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Matt Steele does check-in.

Photo by Glenn Feveryear.

For the NAR volunteers, Friday brought a different gathering opportunity, when 45 early-arriving NAR members spent the day out at Great Meadow setting up the equipment, banners, and signs needed to support the next day's flying. That evening, an additional 70 NAR volunteers joined them for a range crew training session in order to be

sure that everyone on the NAR team knew exactly what they needed to do the next day. These 115 NAR volunteers traveled at their own expense and worked hard for the weekend without flying any rockets of their own, just because they find the experience of supporting these motivated and excited students so rewarding. Of these NAR volunteers, 52 were helping for the 10th or more time and 19 of them have been part of the NAR team at every Finals since 2003, or every time but one. This depth of NAR experience and dedication is what makes the Finals run so smoothly. But in order to sustain the program and keep up with normal turnover, the NAR needs about 20 new people to volunteer for Finals range crew as first-time members each year—so there is lots of opportunity to join this “all star” team in May 2024.



Rocket Building Contest.

Photo by Avis Cawley.

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**Shelby Michigan Township
Junior High School.**

Photo by Neil Michels.

At the Finals each student team is pre-assigned days in advance a specific launch pad and a “launch window” time slot within which they must make their first flight. There are two NAR launch ranges at the Finals, one with 24 pads and the other with 18, that load and launch these flights sequentially in 45-minute “rounds.” One range was run by former NAR Presidents Ted Cochran and Mark Bundick, and the other by Estes Industries owner John Langford and Tom Lyon. First competition flight liftoff was at 8:30 AM on Saturday May 20, and over the next four hours all the teams made their first flights in five rounds. Fully qualified first flights were achieved by 86 of the 100 teams, with most of the unsuccessful flights being due to issues in getting

clean separation and safe recovery of both sections of their rockets.

The Finals teams were challenged by being given slightly different flight performance goals than the ones they flew against in the qualification flights that got them to the Finals. Based on a coin toss at the Friday evening team briefing session, the first-round flight goal was 25 feet higher in altitude (875 feet) and one second higher in duration than the goals in qualification flights. The 42 top-performing teams from the first rounds of flights to this goal were then given the opportunity to make a second flight—to a goal that was 50 feet lower in altitude and two seconds less in duration than the first flight. Top places were then decided based on the sum of the two flight



**Rockets were required
to recovery in two
separate sections.**

Photo by Jim Wilkerson.

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St. John Paul High School of Huntsville, Ala. (3rd Place).

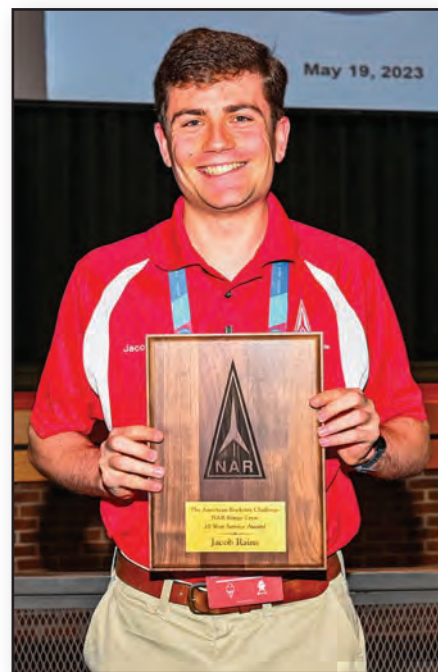
Photo by Glenn Feveryear.

scores, with the lowest numerical score winning (like in golf!). The weather on flight day, Saturday the 20th, started with a fog that was just high enough to support visibility and got clear and warmer as the day went on, with minimal wind. A front with heavy rain threatened but held off until the end of the day, when everyone was

off the field and in the awards and dinner tent.

When the 42 second competition flights were flown and scored, the winner of ARC 2023 and \$20,000 in prize money, plus \$1000 for their school, plus an additional “rookie team” prize of \$2500 as the best team from a school that was attending

a Finals for the first time, was one of the two teams from Hardin Valley Academy in Knoxville, Tennessee, with a two-flight score of 13.4. The other team from Hardin Valley also flew really well, finishing tenth. Second place (and \$15,000) went to the team from Tharptown High School in Russellville, Alabama, with a score of 14.8.



**Jacob Rains and
10-Year Service Plaque.**

Photo by Jim Wilkerson.

Outstanding NAR Mentor – Andrew Heath

Andrew Heath mentored teams from five schools in North-west Alabama in 2023. Four of those five teams attended the national Finals this year and two of them finished in the top ten. In the words of one of the teachers, “Andrew truly helps my students develop an understanding of rocketry concepts. He begins each year by teaching the newcomers the basics of rocketry. He answers their questions as they learn to use simulation programs and design their rockets. Andrew listens to their ideas and asks questions that make them think about the process of designing their rocket. He helps them troubleshoot and problem solve by making them think instead of just giving them answers and as a teacher, I love that!”

In the words of one of the students, “One of the most impressive things about Andrew is his ability to inspire and motivate our team. He always believes in us, even when we face setbacks or challenges, and encourages us to keep pushing forward. He instills in us a sense of pride and ownership over our work.” Andrew Heath led a Rocketry Challenge team as a high school student in 2016 and they won both nationals and internationals, now he’s “paying forward” for the next generation.

Outstanding Teacher Advisor – Jeffrey Pan

In the words of his students, “Mr. Pan is one of the most committed advisors we have ever known in the various sport, music, and science teams that each of us participated in at Whitney High School. For more than five years, he has devoted a great deal of time and effort in the rocketry team’s operation and helped to create an inclusive learning environment where members with different levels of rocketry knowledge and building skills can grow. He supports our captain to make our team activities organized and takes the responsibility of carrying all the equipment for our weekly workshop meetings or test launches. Mr. Pan makes the learning experience enjoyable and keeps members and families engaged through various team-building activities. Mr. Pan possesses humor and warmth that put team members at ease. He brings snacks to meetings to cheer up participants. He never forgets to emphasize how to safely carry out a launch. For more than five years, Mr. Pan has gone beyond providing the necessary supervision of our team. His contribution has been instrumental in the team’s history of ups and downs. He emboldens us to try different approaches to make rockets, encourages us to keep trying and never give up, and inspires us to continue our exploration.”

Hardin Valley did not use complex technology to win, they just flew a lot—over 30 practice flights, with data-taking that let them learn how to adjust things to get the exact performance that they wanted.

The top ten finishing teams split a significant fraction of the overall program prize pool of \$100,000. This pool also covered cash prizes for several other types of achievement, listed in the results box. In addition to these cash prizes, the 1st place ARC team got a free trip to Paris in mid-June courtesy of Raytheon Technologies to compete against the winning teams from the UK, France, and Japan by flying at the Paris Air Show. Hardin Valley finished fourth in this competition, losing their flight score due to an altimeter preparation error. Next year the winning team from the ARC Finals will get a trip to London, England, to compete at the Farnborough Air Show.

The top 25 teams were also awarded the opportunity by NASA to participate in the 2023-2024 NASA Student Launch program, a program (supported by the NAR) that gives university teams and these select ARC teams a rigorous year-long design-build-fly challenge involving a large high power rocket and a complex payload.

Thomas Jefferson High School team flies their NASA Student Launch HPR rocket.

Photo by Neil Michels.



Vocational STEAM Works of El Cajon, Calif.

Photo by Neil Michels.

The ARC Challenge for 2024

- Same dimension (650mm minimum length), weight (650 grams maximum liftoff), and motor power limits (80 N-sec) as always
- Altitude goal 820 feet for qualification (different for the Finals)
- Duration window 43-46 seconds
- One egg payload, any orientation
- Must use two different body diameters (no less than 6 inches of each): top part no larger than T-70 and the bottom part no smaller than 63.5mm (bigger than T-70 but a bit less than T-80)
- All parts must recover connected together under parachute
- Allowed altimeters: Perfectflite Pnut and Firefly; Jolly Logic Altimeter ONE or TWO (but not THREE)
- Finals on May 18, 2024, and qualification flight deadline April 8.



**Trip Barber's Stars & Stripes
HPR demo flight.**

Photo by Neil Michels.



**Men in Black from American Legion
Post 438, Sylvania, Ohio.**

Photo by Alan Williams.



**Onteora Central School
of Boiceville, N.Y.**

Photo by David Bellhorn.

ARC 2023 Special Competition Awards

Competition Category

Raytheon Most Innovative Approach to Mission
Boeing Team Spirit
Northrop-Grumman Best Finals Rocket Craftsmanship
Best Dressed Team

Rocket-Building Contest - Best Craftsmanship
Rocket-Building Contest - Most Creative Design

Presentation Competition

- 1 Sato Academy of Math and Science, Long Beach, CA
- 2 Copley High School (& Best Rookie Team), Copley, OH

Marketing Competition

- 1 Marquette High School, Chesterfield, MO

Copley High School, Copley, OH	\$500
Nazareth Academy High School, Philadelphia, PA	\$500
Notre Dame Academy, Los Angeles, CA	\$500
American Legion Post 438, Sylvania, OH	\$500
"Men in Black"	
Oak Park High School, Oak Park, CA	\$500
Camas High School, Camas, WA	\$500

Student Prize

\$3,000
\$2,000
\$3,000

This is a very demanding program that really challenges and grows the rocketry skills of the teams that participate. As part of this year's high-power rocketry demonstration at the ARC Finals, a team from Thomas Jefferson High School of Science and Technology in Alexandria, Virginia, that earned this opportunity at last year's Finals flew the very large rocket that they had just flown successfully a few weeks before at the NASA program Finals in Huntsville, Alabama.



CAP Squadron 64
La Verne, Calif.

Photo by David Bellhorn.

Other Finals Activities

In between the first set of 100 flights and the set of 42 second flights there was a pause while first flight results were tabulated and the teams that earned a second flight got their rockets ready and checked in. This pause, and another pause later in the day after the last ARC flights and before the award ceremony, provided an opportunity for the NAR to fly some large high-power rockets to demonstrate another aspect of the hobby to the students and spectators. Longtime NAR high-power flier Ben Russell runs this demonstration, and this year he lined up seventeen great flights including a Junior High Power certification flight by one of this year's ARC Finals competitors; a NASA Student Launch program high-power rocket flight by another group of this year's ARC competitors; several scale models including a big Saturn V flown by Tim Bookwalter; and a rocket with a deployable instrument payload



1st Baptist Church of
Manchester, Conn.

Photo by Jim Wilkerson.



Chris Kidwell tells
team their score.

Photo by Glenn Feveryear.



**East Aurora, N.Y.,
Free School District returns.**

Photo by Avis Cawley.

flown by a team in the CANSAT student program that is run by Navy space systems engineer Ivan Galys.

There was more to the "Finals" competition in ARC 2023 than just the flying at Great Meadow on May 20. There were two other online events held before the Finals that provided an opportunity to learn and win for teams, independently of whether they attended the flying Finals: the Presentation Competition and the Marketing Competition. Both offered prizes of \$3000 for the winners and \$1500 for second place.

The Presentation Competition, described on the ARC website at www.rocketcontest.org/presentation-competition/ challenged teams to explain the technical details of their design-build-fly process for ARC in a maximum

of 20 slides with speaker notes. The top five based on preliminary judging against a set of specific criteria were then invited to do a live (online) 15-minute presentation followed by a 10-minute question and answer session with an NAR judging panel led by former NAR President Ted Cochran in early May, before the Finals. The winning entry was from Sato Academy of Math and Science in Long Beach, California, describing how they engineered an onboard computer-controlled air brake system to control flight altitude. Their 2023 winning presentation is posted at



ARC 2023 Flight Results

Place	Team Name	City	State	Flight 1 Score	Flight 2 Score	Total Score	Rocket Mass*	Rocket Length*	Motor	Student Prize	Award to School
1	Hardin Valley Academy - Team 1	Knoxville	TN	11.40	2.00	13.40	419	79	F39-9	\$20,000	\$1,000
2	Tharptown High School	Russellville	AL	13.80	1.00	14.80	437	69	F39-6	\$15,000	\$1,000
3	St. John Paul II Catholic High School - Team 2	Huntsville	AL	17.00	6.92	23.92	454	70	F44-8	\$12,500	\$1,000
4	AIAA Orange County Section	Irvine	CA	16.40	15.24	31.64	613	71	F59-5	\$10,000	\$1,000
5	Harmony Science Academy El Paso	El Paso	TX	15.84	16.04	31.88	454	65	F39-6	\$7,500	\$1,000
6	Richards R-V School District 5 - Team 1	West Plains	MO	3.00	31.00	34.00	446	71	F39-9	\$3,500	\$500
7	Master Arts Festival	Hawaiian Gardens	CA	23.00	15.00	38.00	580	83	F79-5	\$2,500	\$500
8	American Legion Post 438	Sylvania	OH	32.00	16.96	48.96	479	69	F39-6	\$2,500	\$500
9	Notre Dame Academy Schools of Los Angeles	Los Angeles	CA	37.20	12.00	49.20	545	69	F63-7	\$2,500	\$500
10	Hardin Valley Academy - Team 2	Knoxville	TN	11.24	39.36	50.60	421	71	F39-9	\$1,500	\$500
Best Rookie:											
	Hardin Valley Academy - Team 1	Knoxville	TN							\$2,500	\$0

*First flight mass in grams, length in cm

https://drive.google.com/file/d/1M90jrux1fIU4DEGp4ULCzZ1pDR_L_-0i/view and also at the bottom of the NAR website ARC page <https://www.nar.org/team-america/>.

The Marketing Competition, described on the ARC website at www.rocketcontest.org/marketing-competition/ challenged teams to create two-minute promotional videos to show their work and to help get others excited about rocketry, STEM, and aerospace. These were evaluated by a panel of aerospace industry professionals on the basis of strength of message, creativity, and video editing and technical skills, with bonus points for outreach efforts. The winning entry was from Marquette High School in Chesterfield, Missouri. You can watch their inspiring video on YouTube at: <https://youtu.be/vFjblk1QCJQ>.

The Road Ahead

At each year's Finals the challenge for the next year's ARC program is announced at the end of the award ceremony. The ARC 2024 challenge is described in the accompanying text box; the detailed rules and registration materials are available on the event website (www.rocketcontest.org). Registration opened in early June and will remain open until December 1, 2023.

This year's winners from Hardin Valley Academy were in only their second year of participation and were attending the Finals for the first time. There was no magic in their success, it was based on hard work that started early in the school year, included lots of practice flying (32 flights) with rigorous data-taking to establish relationships between

their rocket's characteristics and the weather and the resulting flight performance, and a understanding of these relationships. They are proof that any team—even first-year teams—can succeed if they go into this ARC program understanding that it is not as easy as it looks, if they start early in the program year, and if they have supportive adults behind them to help with logistics and an NAR mentor who can help them get their basic rocket skills right. We always need more NAR mentor volunteers who are willing to go work with ARC teams in their area. If you are interested in doing this, please contact Trip Barber at ahbarber@alum.mit.edu.

ARC continues to succeed because of the dedication of NAR volunteers who serve as mentor advisors for student teams; who volunteer as flight observers for teams' qualification flights; who run NAR section ranges; and who come to the Finals to be part of the NAR range crew. Thank you to all those in the NAR who support the premier program for sustaining our future.



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