ARPL: RX1 Post-Operation Review

Objective: Post-flight analysis of ARPL-RX1

TO: Dr. Charles O'Neill
CC:
REF:

Date: 19 Feb 2018
Memo: ARPL: RFTC
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SUMMARY:
Christopher R. Simpson built a rocket to pass his Level 1 (L1) certification from the National Association of Rocketry (NAR). The rocket was a kit from Madcow Rocketry; the "Frenzy," [1]. The RX1 used an Aerotech H550ST-14A, "Super Thunder," motor with a total impulse of 71.9 lb-sec and a burn time of 0.57 sec. Construction of the rocket, flight, and recovery are reviewed to analyze and critique operations.

OVERVIEW:
I passed my L1 with a minor zipper on the aft main body tube. A zipper is when the body tube splits down the side like a "zipper." The most common cause is deployment of a parachute at high speeds. The shock cord splits the tube. Zippers, depending on the severity, are fixable, most often with a piece of tape. There is some doubt as to whether the zipper occurred during the flight or during recovery since the rocket was stranded in a tree. The rocket was recovered, is fixed, and ready to fly again.

Construction
Construction with a kit could have taken several hours. I chose to let the epoxy/paint dry overnight as I was building so construction took several days. I also had to apply a motor restraining device on-site because I failed to order it originally. I benefited from the rocket's natural stability because I did not purchase additional ballast. The Madcow kit made construction very easy. They provided a checklist to make sure I completed everything in order. The illustrations accompanying the checklist were very helpful. The pre-constructed parts cut down the time needed to make the rocket.

Table 1. Rocket construction and flight cost.

Category	Item	#	Item Cost	Shipping	Subtotal
Rocket					
	Madcow Rocketry Kit "Frenzy"	1	$147.95	$5.99	$153.94
	AeroPack 54(P) Retainer	1	$29.00	$0	$29.00
	AeroTech H550 Motor	1	$42.99	$0	$42.99
Travel					
	Gas	1	$30.00	$0.00	$0.00
Launch					
	Launch Cost	1	$5.00	$0	$0
				Total	**$225.93**

Phenolic does not like water. I would be concerned about flying the rocket in wetter conditions. It would fall apart easily if there was a hard landing or poor ejection timing.

- Easy to build.
- Lots of parts and everything needs to be built in order.

- If I build on my own I should make a checklist like Madcow Rocketry provided me.
- Should examine the rocket in OpenRocket or another simulation before purchasing.
- Need to find a source of ballast readily on hand to make sure the static stability margin is stable for the rocket.
- Laser-cut fins were surprisingly sturdy.
- The coupler/e-bay required continual sanding and application of baby powder to make sure it slid easily out of the aft body tube.

In the future:

- I will test the rocket in OpenRocket or some other simulator prior to purchase.
- I will have to buy my own main and drogue parachute.
- If I use phenolic again; I will use the Cube to cut my fins and body tubes.
- If I use fiberglass; I will use the water-jet to cut parts.

Flight

The launch vehicle flight occurred at 11:18 am CT. Powered flight lasted about 0.57 sec. The rocket continued to glide to apogee under 1700 ft. The altimeter was not turned on so the exact altitude is unknown. We know the altitude was under 1700 ft because the rocket stays under the cloud cover.

Weather conditions:

Weather was taken from KANB, the Anniston airport. KANB is a 30 min drive NW of the PMW site but can be traced in a direct line along the Talladega National Forest and its mountains. Conditions taken at KANB from 10:53 am to 11:53 am support what was seen on the field. Wind from the S, SW and occasional gusts. After my flight several tents were blown over.

Table 1. Weather conditions at KANB (near PMW) for 17 Feb 2018 [2].

Time (CST)	**Temp.**	**Dew Point**	**Humidity**	**Pressure**	**Visibility**	**Wind Dir**	**Wind Speed**	**Gust Speed**	**Precip**	**Conditions**
10:53 AM	64.0 °F	57.0 ° F	78%	30.12 in	10.0 mi	Calm	Calm	-	N/A	Overcast
11:43 AM	72.0 °F	61.0 ° F	68%	30.10 in	10.0 mi	SW	15.0 m ph	26.5 m ph	N/A	Mostly Cloudy
11:53 AM	73.0 °F	61.0 ° F	66%	30.09 in	10.0 mi	WSW	20.7 m ph	25.3 m ph	N/A	Partly Cloudy

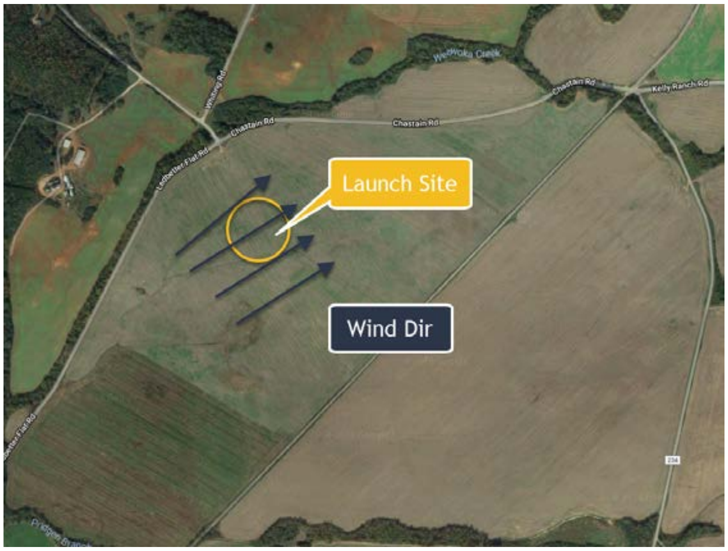

Fig. 1 Launch site and the wind direction

Prior to launch I had to attach the motor restraining device with epoxy on the motor tube. After waiting 2 hours for this to dry the H550 from Aerotech was installed. The H550 features a total impulse of 320 N-sec, a peak thrust of 150 lb and a burn time of 0.57 sec. I adjusted the delay time to from 14 sec to 8 sec as OpenRocket indicated that I would achieve apogee at 8.34 sec.

The checklist from my previous experience, NASA Student Launch, came in handy. Michael Gryder and I had constructed these checklists to make sure that on launch day the team prepped the rocket correctly. I modified the checklist slightly to meet the individual needs of the ARPL-RX1. I plan on using and modifying the checklist every time I fly a rocket.

Launch:

The motor clearly burns for 0.57 sec, as seen in the video of the launch [3]. The rocket experiences some roll instablility. Unfortunately, the cellphone video camera has too low fps capture rate to see the full roll. The shapes painted on the fins to distinguish individual fins was not visible from the cellphone video either. The GoPro HERO5 can provide 300fps at 720p resolution for $200. Other high-speed cameras can provide up to 1000fps for ~$1000 on average [4].

The motor had to be secured with a motor retention tool. This had to be secured at the launch site because I didn't think to order it prior to the launch. An adapter was used as well since the motor tube, 54 mm, was too large for the H550, 38 mm.

After burn, the vehicle glided to apogee. In the video there seems to be roll induced by the wind but at a much slower rate than during the burn phase of the launch. This bears investigation but requires a high-speed camera to be able to investigate fully.

In the future, the motor installation will be planned out and walked through prior to arrival on the launch site. This way the need for an adaptor or motor retainer can be recognized prior to arrival on the launch site. This will also give the experienced operator some heads-up on the unstable roll. The short burn time and high thrust were most likely the driving force behind the roll leaving the launch rod.

Recovery:

A motor ejection was used for recovery. No drogue; Only a main parachute was used for recovery. The main was deployed just after apogee. The original ejection was timed for 14 sec. Using a drill, 6 sec were removed to eject at 8 sec. OpenRocket had indicated that apogee would occur at 8.33 sec. Ejection occurred slightly after apogee, meaning that the rocket did not achieve the projected altitude of 1614 ft. This was most likely because of the high-winds out of the WSW.

The wind put the rocket just across the creek to the north of the launch site. With help from one of the prefects and his tool we were able to recover my rocket out of the tree. He and Karson both agreed that my rocket was re-flyable and therefore passed the requirements for my L1 attempt.

The altimeter in the rocket functions off the achieved altitude. For example, if the altimeter was set to deploy the main at 500 ft Above-Ground Level (AGL), at 500 ft AGL after apogee the altimeter would ignite the e-match attached to the black-powder cup. What if 500 AGL was never achieved? To guard against these issues a second altimeter is typically used. There may be some argument to use a reliable and precise IMU system to ensure deployment. If a drogue-main system is used; the main may still need to be deployed by an altimeter.

Conclusions/Critique

I benefitted greatly from using Karson Holmes to critique my design and question my decisions. His critique forced me to think critically. The next time I fly;

- The flight profile will be built in OpenRocket prior to construction.
- I will write a construction checklist prior to construction.
- I will send the flight profile/construction plan to Karson/another experienced engineer to critique my design.
- Based on their feedback I will correct the profile/construction plans.
- I will allot the same amount of time for construction (1 week).
- I will make sure to launch at a site where Chris Short is the vendor. His help and advice have often proved invaluable.

What went right:

- A kit was exceptionally useful to cutting down the time needed for construction.
- The flight was exceptional.
- The main event occurred when it was supposed to.
- The construction was easy.
- Using the resources/advice from Karson/ARA like the chute and adaptor helped make sure the flight went off without a hitch.

What went wrong:

- I landed in a tree.
- I didn't plan for ballast (I got lucky and didn't need it).
- I didn't simulate the flight in OpenRocket until the night before.
- I didn't ensure that the motor retainer I have fit the motor tube until the night before.
- Phenolic does not like water. It retained some water from when it was painted outside which may have contributed to the slight zipper.

REFERENCES:

[1] “4” Frenzy,” Madcow Rocketry, Product Number: K-3160, accessed: 20 Feb 2018. https://www.madcowrocketry.com/4-frenzy/

[2] “Weather History for KANB – February 2018,” Weather Underground, accessed: 5:42pm 19 Feb 2018. https://www.wunderground.com/history/airport/KANB/2018/2/17/DailyHistory.html

[3] Christopher Simpson, "ARPL – RX1 'First Flight'," YouTube, 20 Feb 2018. https://www.youtube.com/watch?v=Xqff5scf-00

[4] Ken Rockwell, "8 Best High Speed Cameras (Full HD Slow Motion Cameras)," High Speed Video Cameras, http://fpshighspeedcam.com/, accessed on 26 Feb 2018.