University of Minnesota Senior Design

Post-Flight Performance Report

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During the course of the Wisconsin Space Grant Rocket Design Competition, the rocket used by the University of Minnesota Twin Cities Senior Design team suffered a critical recovery failure. This failure was due to the lack of parachute bay separation which caused a lawn dart failure of the rocket into the nearby cluster of trees. A deployment event was witnessed from the ground during the period when the motor eject was expected some 16 seconds into the flight, but this did not cause deployment. Due to the high density of the growth in this region, searching for the impact site was extremely difficult and after some 6 hours of searching the surrounding regions of probable impact without success, the search was called off.

Given that there is no data on the actual fight performance of the rocket itself, this report will focus on potential sources of this failure and what steps could have been taken to minimize the risks of this failure. The first issue was the lack of electronic deployment which was extensively ground tested and would have accomplished separation. Given that the telemetry from the altimeter was in good running order and continuity to the E-matches was present, it is unlikely that the failure was electronic in nature, barring substantial issues with electronics during launch.

A more likely scenario was that the ejection charge was damaged during parachute packing. The charge holder was downward facing with the charge itself being held in with tape; therefore, if the tape was moved or damaged due to the rotational motion used on the nosecone and parachute during assembly, the charge could have leaked out or the wire to the E-matches could have been pulled out by this motion.

This particular failure mode could have been mitigated by the use of both of the charge holders present on the rocket. Only one was used, which was attached to the bulkhead within the nosecone. Two E-matches were present in this charge, but this is not true redundancy as issues with the charge itself could still be present. The second charge holder was located on the top bulkhead of the body tube and would have required a larger charge, but it proved effective in our previous test flight. Using both charges would have added a degree of redundancy that would greatly decrease the chances of failure occurring. Another measure that could have been taken was to include an additional altimeter to the rocket that would deploy the backup charge to add a layer of redundancy to the avionics systems.

The failure of the motor backup was a separate issue that resulted from a significant error in launch preparations. During testing, a charge originating from the body tube end of the parachute bay required roughly 2 grams of black powder to successfully and reliably deploy the parachute, while the charge on the motor is 1.3 grams. This issue was not noticed before flight due to the lack of proper motor eject testing which caused this issue to only be understood in retrospect. Simply adding to the charge at the end of the motor would have allowed for a rough, but effective, deployment and would have prevented the disaster that befell the rocket.

There were several motor failures that occurred during the competition but after analysis it appears unlikely that this was the source of failure for the rocket. The ejection charges were placed on the opposite side of the parachute from the motor. This arrangement isolated the charges which would have allowed deployment with a successful electronic eject even in the case of a full motor failure. The unsuccessful motor eject could have been due to a motor failure but given that the necessary charge requirements were not met it is quite likely that the motor functioned as intended.

As to the actual performance of the rocket and altitude control mechanism, there is not much that can be said with a great deal of certainty due to the lack of recoverable components. However, given the initial weather cocking of the rocket into the wind at a rather steep angle it is likely that the rocket undershot the 3000 feet altitude goal. In this situation, the air braking system would not have actuated at all and would have remained closed for the duration of the flight. The actual altitude reached would be purely conjecture but it is unlikely that the rocket was more than 100 feet off of the target given the results for high wind simulations.

If the rocket could have been recovered, there was the possibility of being able to better understand what had occurred and even recovering some data, although that would be unlikely. In the end, it is most likely that the launch preparation issues mentioned above were the source of the failure and could have been avoided with more thorough and careful setup.

For the rocket itself, there were minimal issues with the design by the end of production. The issues with the rocket were primarily in the form of manufacturability problems and assembly issues which took a while to work past. These delays kept the team from properly testing the rocket and air braking system. These issues should have been better dealt with during the design phase but the lack of manufacturing experience of the team made it difficult to catch all of the issues.

If test production of composites used in the rocket had begun during the design phase as opposed to the beginning of the build phase, many issues with the production schedule that prevented thorough test launches could have been avoided. The composites manufacturing was a valuable experience, but if we could have had a corporate sponsor manufacture these components, it would have been found then that the rocket production timeline would have been much improved. However, given that significant delays were due to the 3D printing sponsor, Stratasys, being unable to supply parts for a period of 2 weeks perhaps a greater reliance on outside help would have not been to the project's benefit.

If the rocket build had been completed sooner, the team would have been more experienced at the launch preparations. This additional experience could have allowed the issues encountered in the competition to be avoided. Addition test launches throughout the year with other rockets would also have been beneficial as the failure encounter is one of safe rocket procedures and not inherent to the custom rocket made for this competition. If the issues had

been experienced a few weeks before the competition it may have been possible to use our spare parts to fix up a rocket to participate even if a failure as bad as no separation had occurred. Overall, the failure of this rocket can be attributed to not enough testing and experience with launches of this type.