Investigations into Gap-Stage BOOSTER RECOVERY

This article is based on the NARAM 38 R&D entry by Buzz Nau and Alberto de la Iglesia (Thrust You Can Trust team). The entry placed First in Team Division.

Background

Multi-staging has always added extra excitement to model rocketry. It is a method in which the velocity of one motor is imparted to the already existing velocity of another. This makes staging an excellent way to extend the altitude of a model rocket with little increase in complexity.

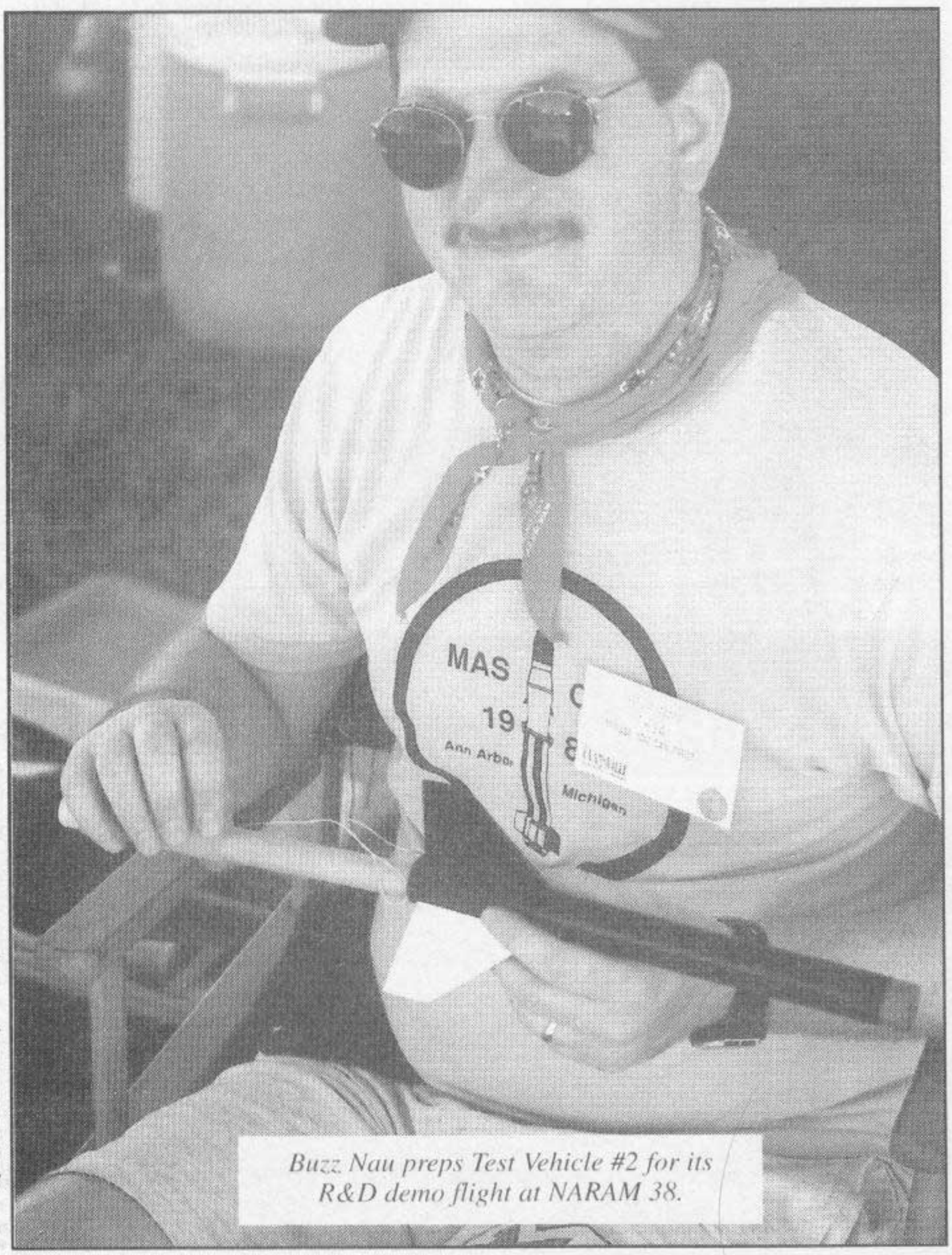
At the moment of staging, the forward wall of propellant in the booster motor ruptures, blowing hot gas and particles of burning propellant forward. It is the burning particles that actually ignite the upper stage motor. Any staging method must prevent the gasses from blowing the stages apart before the burning particles can ignite the upper stage.

The most common method of series staging is the "coupling system" in which the two motors are taped together. The tape prevents the stages from being blown apart by the gas pressure long enough for ignition to occur.

The downside of this arrangement is that the motors are close together and towards the very end of the rocket. To compensate for this reward shift in CG (center of gravity) the fin area on the lower stage is increased to improve stability but with a drag penalty.

With the advent of gap-staging as described in G. Harry Stine's *Handbook of Model Rocketry,* Revised 5th Edition, boosters were no longer constrained by short body lengths and large fin areas. Briefly, Stine's method involves venting the initial pressure from blow-through before ignition of the upper stage. This is accomplished by cutting holes in the booster airframe.

Since the motors do not need to be taped together, gap-staging allows for longer boosters and reduced fin area that equates to improved stability and less drag. In addition, this scheme allows constructing scale models of multi-staged vehicles without having to resort to weighty, space consuming, and



Buzz Nau preps Test Vehicle #2 for its R&D demo flight at NARAM 38.

sometimes complicated electronics.

The major problem with the longer, gap-staged boosters is that they are aerodynamically stable thereby streamlining down in an unsafe and damaging fashion after staging.

Purpose

The purpose of this project is to develop a simple and reliable recovery technique for gap-staged models that is internally contained and non-electrical. It is also desired that the technique not restrict the booster in dimension or fin shape so that it can be used for a broad range of applications.

During the investigation several reports and articles were found pertaining to booster recovery. Centuri Engineering's *TIR-123 Multi-Staging Principles* and Estes Industries' TR-2 *Multi-Staging* reports only detail boosters that are short and aerodynamically unstable and thus use tumble recovery.

The Centuri *Model Rocket Design Manual,* 2nd Ed. by Grant Boyd contains a section on Advanced Staging Techniques. However, the recovery techniques revealed were outside the requirements mentioned above by using completely external devices and glide recovery.

Robert Mullane's "Booster Recovery" R&D report, while containing techniques outside the guidelines above, did provide the key information on which this research project is based. In his report Mr. Mullane discarded the direct-ejection method of booster recovery (this method attempts to use the pressure produced by motor blow-through to eject the recovery device). Mr. Mullane's static tests showed that the pressure produced during the booster motor blow-through is insufficient to eject a recovery device.

However, booster motor blow-through is not the only source for pressurizing an ejection system. In theory, the ignition of the upper stage motor could provide the pressure needed to deploy an internally contained booster recovery system, even when blow-through pressure is vented.

Model Construction

Two models were developed to test two different booster recovery techniques. One would test ejecting a streamer out of a rearward facing vent tube. The other would test an ejectable pod design.

Test Vehicle One

Test Vehicle One, a BT-55 diameter model, tested ejecting a streamer from a vent tube that runs between the stuffer (motor) tube and the body tube. In theory, there would be enough of a gap with the streamer inserted in the vent tube to allow the venting of blow-through pressure. The greater pressure from the ignition of the upper stage would blow out the streamer as well as separate the stages.

The upper stage followed normal building and material procedures. The following describes special assembly steps for the booster construction (refer to Figure 1).

Two centering rings mount the stuffer tube inside the body tube. The forward one is solid, isolating the rest of the booster from the upper stage. The rear centering ring has a gap cut out to allow the vent tube an outlet. Just aft of the forward centering ring a hole was punched in the stuffer tube and a matching hole was made in the vent tube. The vent tube was pressed into an oval shape

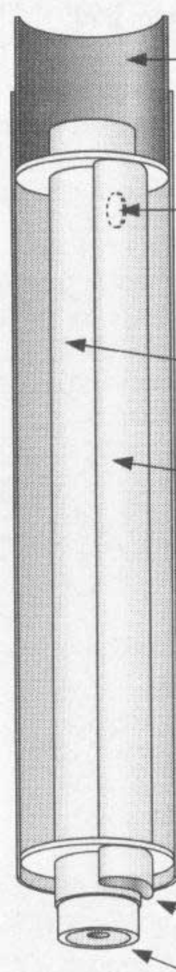


Figure 1. Test Vehicle #1 Cutaway view of booster stage

to fit properly between the stuffer and body tubes. The vent tube was glued in place with the vent holes aligned and sealed with CA.

The kevlar shock line was secured to the vent/stuffer tube joint and a 2.5" x 25" streamer was used for the recovery device. The engine mount of the upper stage and the stuffer tube of the booster were designed so that the nozzle end of the upper stage motor socketed into the top of the booster's stuffer tube. This was to make sure the burning particles of the booster motor travelled straight to the upper- stage motor.

Pre-flight tests were conducted by inserting an expended motor in the stuffer and the streamer in the vent tube and attempting to blow out the streamer. This was unsuccessful at first because the air flowed through and around the streamer. This was solved by folding a one inch square piece of micafilm over the top of the streamer as it is inserted which acted as loose plug. While air still flowed around the streamer it no longer flowed through it. It was then possible to blow the streamer out and the model was considered ready for actual flight.

Test Vehicle Two

Test Vehicle Two, a BT-50 diameter model, was designed to test an ejectable pod method of recovery. In theory the ignition of the upper stage would blow the pod out of the booster as well as separate the stages.

The upper stage followed normal building and material procedures. The following describes assembly steps for the booster construction. The plans for Vehicle Two are presented in this issue.

The power-pod has two centering rings, one fore and one aft. The aft ring has a gap cut in it to act as a vent. The forward one is mounted ahead of the vent hole punched in the power pod tube.

When inserted into the booster the forward ring rests against the back of the tube coupler. The upper stage engine mount and the power pod are designed so that the nozzle end of the upper stage motor is socketed into the top of power pod, preventing the pod from traveling forward during boost.

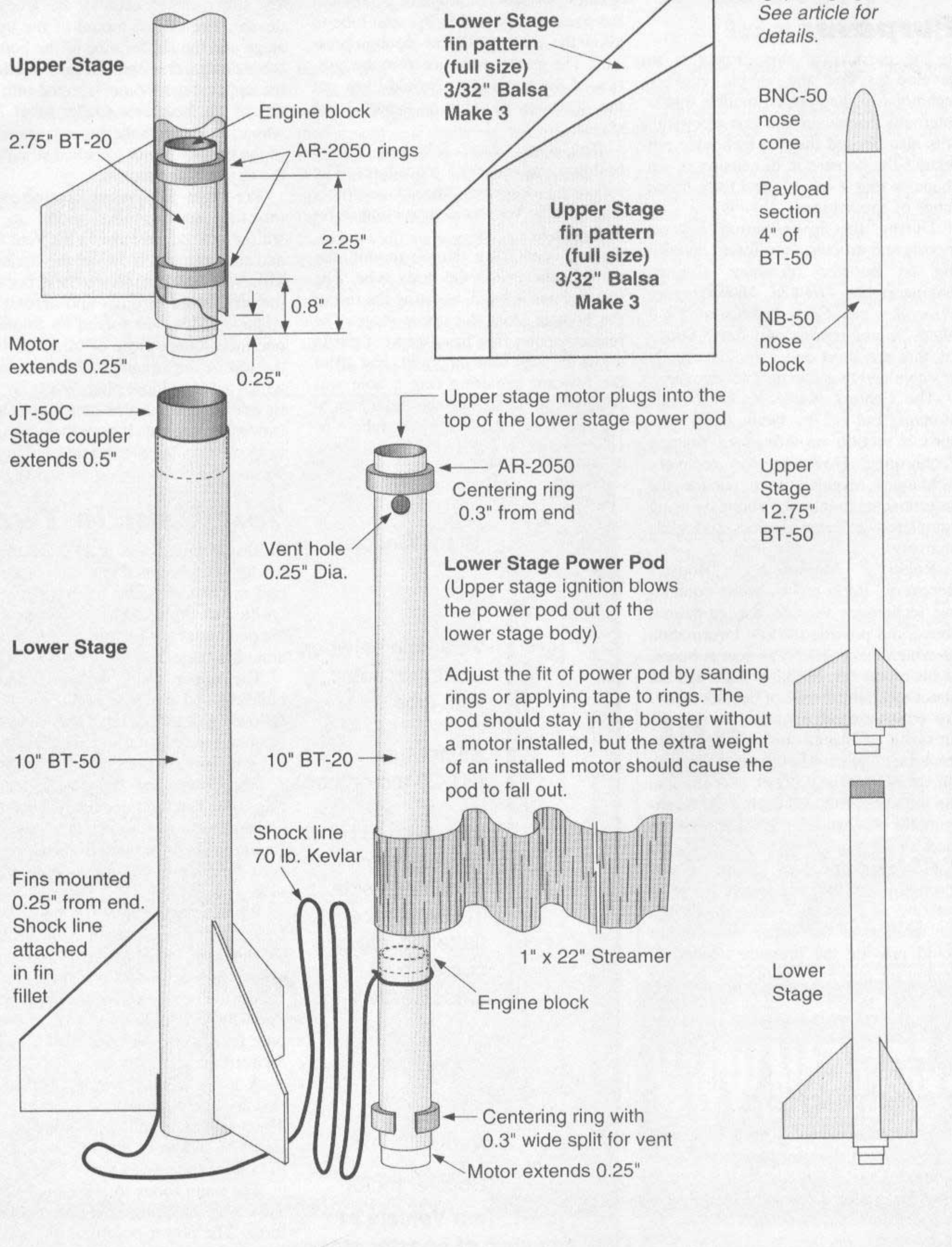
A 1" x 22" streamer is taped to the pod and wrapped around it for storage. The pod is secured to one of the booster fins by a length of kevlar shock line at the CG of the power-pod.

The main focus in prepping Vehicle Two was ensuring that the pod was loose. The power-pod tightness was set

R&D Staging Test Vehicle #2

Design by Evan "Buzz" Nau and Alberto de la Iglesia

Reliable recovery method for models using "gap-staging." See article for details.



so that with the pod inserted without a motor it would stay in but, with a motor installed the pod should fall out. Lightly sanding the centering rings was all that was required to achieve this fit. See the Vehicle Two plans.

Experimental Program

Each test vehicle was flown six times. All flights were conducted with C6-0 and B4-6 motors. The C6-0 was selected because it would loft the booster higher and allow longer durations to observe the recovery characteristics. The B4-6 are used in the upper stage because the larger nozzle would increase staging reliability. All flights were performed on June 22 and July 13, 1996. The test flights were successful except for two deployment problems, detailed below.

Test Vehicle One Flight #3: The streamer deployed but curled around the corner where the shock line was attached, resulting in a fast descent. This is not an uncommon occurrence with streamers mounted this way. It was an oversight from the beginning of testing. All further test flights were flown with the streamer mounted on the center of the short edge, identical to the way we mount our competition streamers.

Test Vehicle Two Flight #1: The pod failed to eject fully due to the shock line snagging on the streamer. The streamer had been wrapped around the pod and then the line laid over it. The streamer either loosened up after prepping or during ejection. On all following flights the shock line was laid flat against the pod and the streamer wrapped over it. The problem never recurred after incorporating this change.

Conclusion

Both test vehicles completed the test program successfully with each having a slightly marred recovery. In both cases the problem was identified and remedied. Also, neither problem was the result of a flaw in the method of recovery being tested.

No special parts or assembly techniques are required and each model should be able to be built and flown by anyone who has already flown staged models successfully.

Throughout the testing it became apparent that the ejectable pod was the easiest to build and prep. It has fewer components and assembly steps. Prepping the booster merely involves inserting a motor, wrapping the streamer, and inserting the pod. It is actually easier to prep than the coupling system of taping the motors. The main item requiring post flight testing was pod tightness. Occasionally the pod needed to be run in and out of the booster a few times to clean out motor residue.

While the vent tube approach on Vehicle One worked successfully it is often tedious to roll the streamer to the correct fit. There is also the added step of inserting the streamer with a micafilm square plug to guarantee streamer ejection. Refinement of this system is possible.

Suggestions For Further Research

Further research could be directed at applying these recovery methods to different booster sizes to test scalability. Investigating the use of parachutes in place of streamers could also be useful in the recovery of larger boosters. Recovery devices located in the interstage area that are pulled out by the upper stage have been researched in the past, however this technique has met problems. It is possible that this area has

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NAR Capital Campaign Takes Off!

Congratulations to Bruce Lerner, NAR 63586, Belaire, MD, for being the first NAR member to contribute to the NAR's Capital Campaign. Bruce was the first Gemini Level Supporter in addition to the first member overall to contribute.

Longtime NAR member, National Champion, and NARAM-37 Contest Director Dan Wolf was close on Bruce's heels as the second contributor. In less than two weeks, we've already raised $474 dollars toward the $100,000 goal. Thanks to these NAR members for their generous contributions!

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