DBeta Manned Rocket: Step-by-Step Construction “Recipe”

Abstract

This manual outlines the various processes and procedures necessary to build a D-Beta Manned Atmospheric (Suborbital) Rocket. It is written in a series of “recipes” that delineate completely the necessary steps required to successfully fabricate a manned rocket from available materials including composite (fiberglass/epoxy), tubular steel and sheet aluminum.

Also included are the Bill of Materials (complete with FMV prices and vendor lists) of where you can get the materials to start building.

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Introduction

"So you want to build a Manned Rocket?"

A lot of Americans (and people all over the world) have a dream of going to space, becoming an astronaut or doing something important and adventurous. Examples of this impulse are enthusiasts who sky-jump, fly ultralights, hang-gliding, or non-professional aircraft pilots.

If you have this kit in your hands, it looks like you are wondering if you can build (and possibly, fly) a suborbital manned rocket. You are part of a group of select individuals that seek to realize a dream. This particular kit is not enough, in my opinion, to actually build one but it does contain enough information to bring you up to speed on the various techniques, skills, knowledge, issues that you will have to know in order to embark on such an endeavor.

Clarifying things...

Firstly, we need to cover all the things you need to understand about this kit so you are completely aware of its limitations. All of this information was discussed on the web site but I want to make sure we are all in agreement before continuing. This kit comes with a limited money-back guarantee, so if there are any concerns, misunderstandings or unmet expectations, NOW is the time to address them.

The big rub right now with the D-Beta design is that you can legally build it BUT you can't fly it. During the X-Prize the FAA determined that suborbital vehicles would be covered under experimental aircraft rules (with astronauts using a pilot's license). The D-Beta is not an experimental aircraft but a true experimental rocket...there is no civilian licensing available yet for vehicles of this type.

DBeta: NOT a true Spacecraft

NOTE: D-BETA ATMOSPHERIC ROCKET KIT

Secondly, in case there are any misunderstandings, this rocket will NOT go to space. It has a maximum altitude in its base version of 12,000 feet (50-60,000 feet in its PLUS version) which classifies it as atmospheric suborbital. It is similar to the capabilities of XCOR's Lynx vehicle being able to fly about half as high as their product[1].

Addendum: recent simulator data indicates that the Plus version might be capable of breaking the 125,000 Air Force definition of space in certain configurations, making the Dbeta PLUS airframe “spaceflight-capable”

About HAZMAT

Also, you will have to get your HAZMAT rating if you want to fabricate your own propellant grains and transport them.

About Sourcing Materials and Services

You will also find that your first hurdle in building this kit manned rocket is finding people and companies that will help you fabricate the vehicle. The materials you use will be easily sourced but UNDERSTAND that due to liability concerns, your average metal and other suppliers will not want to do business with you because of unfounded concerns that they are somehow doing something bad. As long as you don't talk to them about what you are using the materials for, its a simple matter of sourcing them and buying them.

The same goes for machining and fabricating. It's none of their concern what a specific part or component's final use is. So long as you don't run your mouth about what its being used for, you can find local businesses that you can get the difficult part of the fabrication process. As with kit aircraft building, you really have to watch what you say to who. Enough said.

Limitations of this Kit

This kit is missing several critical details that, unless you are an actual rocket scientist or experienced serious enthusiast, you cannot realistically build *directly* from these plans.

The foremost is the matter of physical motor geometry. I've purposefully checked the designs before hand to make sure they are approximately what they need to be (just in case someone tries to build especially the propulsion section), however on each of the drawings, you'll find the phrase “Not Certified for Build” on them.

You will notice you didn't have to sign any wavers before purchasing this particular kit. The reason for this is that phrase on a lot of the machine drawings. Using uncertified plans places the legal onus on you to make sure the design is safe and reliable.

There are kits available (with signed liability wavers attached) that are certified

1 Lynx and XCOR are registered trademarks of XCOR Inc.

for build, however this is not one of them. This starter kit is primarily designed for the interested individual enthusiast to acquaint themselves with the realities of suborbital vehicle construction. Its a comfortable first step for someone critically interested in what it realistically takes to build one of these vehicles.

Any certified kit will contain (among other things) a complete engineering workup on especially the power-plant used on how it is structurally sound, won't over-pressurize, anticipated failure modes, thermodynamic analysis and simulated performance characteristics. It should also require you to sign and return a waver of liability before they will hand it to you.

Features of this Kit

This kit contains a complete design for a true manned experimental rocket and covers all the main aspects of recovery, airframe design and construction and propulsion. It has been computer-simulated to be able to fly, however not physically tested as of the writing of this manual.

It is a serious kit however. It is designed to fly. Its not an exercise purely in creative thinking; we mean to put a person in space here in the next few years. We are in process of building a D-Beta prototype of our own, and as we make progress we'll be updating the kit with the lessons learned.

It contains checklists that as you are building it, you can check it off and check your progress over the weeks or months it takes to build.

You can build just the airframe if you desire (as in not fly it but have a rocket of your own). This is all about you, the enthusiast, what you want to do. You can build a scale model of the rocket motor and not fire it and walk away with the sense of accomplishment that you now know something that appeals to you, that is not commonly done.

Since Stanford Systems is a fellow enthusiast, feel free to contact us via email or though the main web site at any time to ask us questions if you need help. We are professionals but we are proud of our close friendships with our customers and are in process of figuring out a lot of the same things you are trying to. Use us as a resource to help you arrive at you dream destinations.

As you need to source the more sophisticated components, contact us and we can get you to the vendors and people you need to talk to get things done. For example, the flight computer for the D-Beta is available from Stanford Systems but it is bought outright (like how aircraft avionics are purchased) and there is some legal paperwork that needs to be filled out. The servos and other sophisticated parts are purchased from their specific vendor.

The only dumb question as they say, is the one that isn't asked. We believe this wholeheartedly here at Stanford Systems. Just email us and we will get back with you.

Dbeta Manned Rocket: Step-by-Step Construction “Recipe”

NOT CERTIFIED FOR BUILD YET!

Construction Recipe for Composite Nosecone Shell

Preparation

☐ Make “Parting Board”

☐ Make “Mold Support”

Shopping List:

☐ PVA, ☐ mold-release wax, ☐ sheets of fiberglass, ☐ 24-hour-set 2-part epoxy, ☐ Masonite board, ☐ soft plastic (or rubber) strips, ☐ plywood, ☐ dowel, ☐ auto-body filler, ☐ modeler's clay, ☐ primer paint, ☐ Polyurethane-based Glue, ☐ large, flat sheets of Styrofoam, ☐ Plywood and 2 x 2 studs for jigs, ☐ soap, ☐ rags,

☐ required fasteners

Tools required: ☐ hot-wire hand cutter, ☐ hot-wire table cutter, ☐ Potter's wheel, ☐ Utility knife, ☐ sand paper (course and fine, wet and dry), ☐ large precision compass, ☐ Sharpy marker, ☐ plastic mixing bowls/cups, ☐ foam brushes, ☐ fiberglass separation wedges, ☐ Electric Drill (and Bits), ☐ Exacto Knife (and blades),

☐ Dremel Tool (with accessories)

Construction of Plug (Positive)

- [ ] Print out full-size engineering prints of all required parts.
- [ ] Cut out Styrofoam circles with center registration hole (use dimensions from plans and layout with compass).
- [ ] Assemble plug blank by stacking circles with glue in between and wooden dowel down the center.
- [ ] Mount plug blank on turntable.
- [ ] Use tools and rough sandpaper to rough smooth the plug.
- [ ] Go over plug with finer and finer sandpaper.
- [ ] Coat entire plug with epoxy to seal it. Wait for it to fully cure.
- [ ] Look for pits and dents and fill with auto body filler.
- [ ] Fine sand the whole thing.
- [ ] Paint plug with primer paint.
- [ ] Wet sand plug.

Construction of Mold (negative)

First Half of Mold.

- [ ] Go over plug with mold-release wax (2 coats with buffing after each coat).
- [ ] Paint plug with PVA.
- [ ] Mount the plug in the Parting Board assembly.
- [ ] Fine-tune the board with a plane so fit is very close with plug.
- [ ] Use clay to fill any remaining gaps and make flush with board.
- [ ] Assemble collection of fiberglass and mix enough slow-cure epoxy to do mold half.
- [ ] Mix up small batch of epoxy with fibers (E&F).

- [ ] Use the E&F to work into corners.
- [ ] Paint plug with epoxy.
- [ ] Lay on sheets of fiberglass.
- [ ] Paint with epoxy keeping everything wet.
- [ ] Continue laying sheets and repainting with epoxy until ¼ thickness is achieved.
- [ ] Apply plastic strips (affixing with solvent or glue) in matrix to build up reinforcement blank.
- [ ] Apply fiberglass and epoxy over plastic strips to form reinforcement.
- [ ] At "leather" stage, cut off excess fiberglass/epoxy.
- [ ] Wait until full cure.
- [ ] Separate plug from mold-half with wedges and other tools.
- [ ] Inspect for any scratches or dings and repair (and wet sand after).

Second Half of Mold

- [ ] Enlarge Parting Board hole to accommodate the first mold half.
- [ ] Mount first mold half in Parting Board assembly, affix on underside.
- [ ] Check that wax and PVA are still good on plug, refurbish if not.
- [ ] Reinsert plug into first mold half, aligning with registration marks.
- [ ] Assemble collection of fiberglass and mix enough slow-cure epoxy to do mold half.
- [ ] Mix up small batch of epoxy with fibers (E&F).
- [ ] Use the E&F to work into corners.
- [ ] Paint plug with epoxy.
- [ ] Lay on sheets of fiberglass.

- [ ] Paint with epoxy keeping everything wet.
- [ ] Continue laying sheets and repainting with epoxy until ¼ thickness is achieved.
- [ ] Apply plastic strips (affixing with solvent or glue) in matrix to build up reinforcement blank.
- [ ] Apply fiberglass and epoxy over plastic strips to form reinforcement.
- [ ] At “leather” stage, cut off excess fiberglass/epoxy.
- [ ] Drill registration holes in both mold-halves.
- [ ] Wait until full cure.
- [ ] Separate the mold-halves with wedges and other tools.
- [ ] Separate plug from mold half.
- [ ] Inspect for any scratches or dings and repair (and wet sand after).

Mount Mold in Mold Support Assembly

- [ ] Wash off mold-halves
- [ ] Put mold-halves together.
- [ ] Insert removable fasteners into registration holes.
- [ ] Insert completed mold into mold support assembly.

Construction of a Nosecone Composite Shell (positive).

- [ ] Wax (apply, let “glaze-over”, buff, 2 coats) and apply PVA to inside of mold.
- [ ] Assemble collection of fiberglass and mix enough slow-cure epoxy to do positive.
- [ ] Paint inside of mold with epoxy.
- [ ] Lay in sheets of fiberglass.
- [ ] Paint with epoxy keeping everything wet.

☐ Continue laying sheets and repainting with epoxy until ¼ thickness is achieved.

☐ Apply plastic strips (affixing with solvent or glue) in matrix to build up reinforcement blank.

☐ Apply fiberglass and epoxy over plastic strips to form reinforcement.

☐ At “leather” stage, cut off excess fiberglass/epoxy from top of mold.

☐ Wait until full cure.

☐ Remove mold/positive from Mold Support Assembly.

☐ Remove fasteners from mold-halves.

☐ Separate mold-halves with wedge tool and plastic wedges.

☐ Remove Nosecone shell from mold half.

☐ Reassemble mold by reinserting fasteners and put back in support assembly for later.

☐ Clean mold.

Final Work on Nosecone Shell

☐ Layout upper cut circle to separate nosecone from nose cap.

☐ Work slowly with thin Dremel wheel to score completely around cone.

☐ Dig deeply and thru with cutting wheel.

☐ Sand (rough then fine) the cut edge.

☐ Lay out bottom cut circle to provide flush bottom

☐ Work slowly with thin Dremel wheel to score completely around cone.

☐ Dig deeply and thru with cutting wheel, discard excess.

☐ Sand (rough then fine) the cut edge.

Assembly of Complete Nosecone

Construction of Nosecone “Cage” and Pyro Tube

☐ Cut pieces of plate and tubular steel according to the plans.

☐ Layout holes to be drilled with fabrication patterns. Drill them on drill press.

☐ Fabricate 6 cage pillars by welding the appropriate pieces together.

☐ Take cage hoops and clamp the pillars to them. Weld them together.

☐ Take rolled aluminum sheet stock and form the internal pipe to the cage. Weld the seam; tolerances are not that important here.

☐ Fabricate the two plywood circles for the top and bottom of the nosecone by transferring the engineering print's features to the plywood.

☐ Cut out with jigsaw and sand to specification.

☐ Drill holes as squarely as possible and attach necessary fasteners and components (see “Recovery Systems” appendix for details here).

☐ Test the electrical continuity of the pyro system's electrodes. Wire the rest of the electrical internals of the recovery section.

☐ Bolt the nosecone cage and pipe to the lower piece of plywood.

☐ Bevel both circles with sander matching the profile of the INSIDE of the composite shell.

☐ Drill pilot holes with hand drill and sink screws through shell into plywood.

☐ Fill nosecone with medium-density polyurethane foam through holes drilled in upper circle.

Construction of Pyro Piston

☐ Fabricate according to specification. Tolerances not that important as all that is necessary is that the piston be slightly smaller than the pyro tube itself. Just weld together the various aluminum pieces according to the plans.

☐ Attach hardware (ie. stranded steel cable) to inside of pyro tube and the piston, connecting the parachute lug to the double eye-bolt on the piston to the parachute.

☐ Test that all of the pieces function well together in that they slide correctly.

Construction of the Nose Cap

- [ ] Fabricate base of the cap by 3D printing it from the plans.

- [ ] Take the composite nose-cap shell and attach it to the base by drilling pilot holes and screwing it together.

- [ ] Again, fill this component with medium-density polyurethane (MDPU) and let cure.

- [ ] Install O-Rings and test for tightness on pyro tube. Cap needs to fit tightly enough so that it stays on during flight, but not so tight that the pyro can't blow it off during the recovery phase.

- [ ] Hammer the cap onto the nosecone with a rubber mallet.

Installation and Testing of Recovery System

- [ ] Affix recovery section to test fixture.

- [ ] Wire up test electronics to pyro connectors

- [ ] Install live pyro unit in nosecone.

- [ ] Slide pyro piston to bottom of pyro tube

- [ ] Connect cargo parachute to piston's hardware

- [ ] Pack parachute in tube according to manufacturer's instructions.

- [ ] Place drogue chute on top of packed parachute.

- [ ] Carefully hammer on nose-cap with rubber mallet.

- [ ] From safe distance arm and fire pyro system to see that everything works. It should blow off the nose-cap and push the entire parachute/drogue out of the nosecone for a successful test.

- [ ] Adjust the strength of the pyro unit so that does this reliably every time.

Note: reference John Coker's nosecone construction tutorial on Youtube.com at: https://www.youtube.com/watch?v=Lo_g1VOVAcg

Construction of Airframe

Preparation

☐ Source and obtain required metal stock to build frame.

Preparation of "Pillars"

☐ Measure tubular steel for six structural "pillars" and cut from available stock with chop saw with metal-cutting abrasive blade.

☐ Weld together where stock isn't long enough, reinforcing welds with appropriate plate stock.

☐ Use high-quality straight edge to insure straightness.

Preparation of Fabrication Patterns

☐ Print out 1:1 scale engineering drawings on wide-format printer or engineering plotter. (Today's printers are accurate enough that we will use these prints for the patterns from which to fabricate from.)

☐ Apply contact cement to back of engineering prints and top of heavy card stock. Wait for cement to dry.

☐ Mate the prints with the card stock on flat surface and smooth with a rubber roller.

☐ With exacto blade carefully make fabrication patterns by cutting them out of the prints.

☐ Apply epoxy or laminate to patterns so they are durable enough for use.

Standard for Pattern Use

☐ If we carefully cut the patterns along the thin lines of the print out, you will notice that if you use a standard Sharpy that if you grind/cut/work the metal to the point where the sharpy is no longer visible that your fabrication will be perfect.

Fabrication of Hoops

☐ Take appropriate amount of metal stock to a local metal fabricator and get them to fabricate the hoops for you. It requires a tubing bender and its worth the additional price for them to do it for you. Make sure that you specify that the hoops have to be in a relaxed state prior to weld (ie. that they are perfect circles without having to weld them together to be in spec). Get them to MIG/TIG weld the hoop ends so that you are left with a bunch of perfectly circular hoops.

Fabrication of Thin Hoops

☐ Take the appropriate amount of plate metal stock to the local metal fabricator and get them to make the thin hoops for you. Require them to make sure that the metal is in a relaxed condition as before, TIG/MIG welding the ends together so you are left with the required number of thin hoops you'll need. Take the thin hoop drill press jig (THDP jig) and put rivet holes at 2” intervals along the hoops

Construction of Top Cockpit Web

☐ Take Parachute Lug piece and machine it to specifications.

☐ Place completed lug in TCW plywood jig (for jig descriptions look in appendix under “jigs”. The use of jigs is critical to ensure straightness and squareness of the completed assembly).

☐ Test the jig against the appropriate hoops by sliding the hoops over the jig. Periodically do this check as you weld the web to make sure that everything is true to each other.

☐ With the Fabrication Patterns prepared earlier, cut and grind the needed metal pieces by transferring the pattern to the metal stock with a sharpy marker. A chop saw with angular adjustment will get the pieces to their approximate proportions and you can grind the arc with a good metal grinder.

☐ Sand edges to a good tolerance.

☐ Assemble the pieces in the appropriate jig and weld the web together continually checking to trueness.

Construction of Motor Mount Web

☐ Cut out the hardpoint piece and prepare it for insertion into the MMW jig.

☐ As before, use the fabrication patterns and a sharpie marker to prepare stock for cutting and grinding.

☐ Cut and grind and then sand.

☐ Place completed metal pieces in jig and weld as before continually checking for trueness.

Construction of Motor Mounts

☐ Place required pieces into the MMH jig

☐ Weld the Motor Mounts together continually checking for trueness.

Start Assembling Airframe

☐ Build the main plywood Airframe Jig and place the completed pillars into it

☐ Insert the top Cockpit Web into it on one end, and...

☐ Insert the Motor Mount Web on the other end.

☐ Check for trueness. Use tack welding once trueness is ensured.

☐ Cut hoops with chop saw as accurately as possible and weld them into the airframe as required.

☐ Fabricate the “shim” pieces by starting with thin plate and sanding them down to the required roundness.

☐ Once the airframe “cage” is fully fabricated, start adding the thin hoops. Remember that the thin hoops fit OVER the pillars, riding on the shim pieces.

☐ You can glue the shims to the airframe (and the thin hoops) temporarily with auto-body filler.

Construction of the Fin Mounts

☐ Take the appropriate lengths of U-Channel and measure and cut on a chop saw.
Sand with electrical hand sander.

☐ Transfer the fin mount pattern to the metal and drill holes with the drill press

☐ Tack weld nuts to backside of channel.

☐ Weld the completed 3 assemblies to the airframe.

Construction of Fins

☐ Transfer fin patterns to plywood stock with sharpie marker.

☐ Cut out by hand with jig saw.

☐ True up the cuts with an electric sander.

☐ Place fin into its mount and use the holes in the channel as guides to drill through with hand drill.

☐ Round over leading edge with round-over bit in router.

☐ **S**and three fins, starting coarse and ending up fine.

☐ Paint fins with epoxy and let cure.

☐ Sand epoxy and apply primer in preparation for whatever final paint job you want on the rocket.

Construction of Servo Mounts

☐ Weld the additional two tubular steel pieces to the top of the airframe.

☐ Fabricate the servo mounts as specified in the plans. Cut, bend, weld and drill out of plate steel; tack weld nuts.

☐ Check that the servos can be mounted on the servo mounts before welding to airframe

☐ Drill the servo shaft pass-though holes in the airframe, welding on the strengthening washers once drilled.

☐ Servo placement is critical so test multiple times that the servo mounts are EXACTLY perpendicular to each other and axially true.

☐ Weld the four servo mounts to the airframe.

☐ Attach the actual servo units to the mounts and test for trueness.

☐ Power them up and see that their axles are free from obstructions and rotate freely.

Construction of Cockpit and Hatch Frame

☐ Layout and fabricate plywood circles that the pilot will sit on. Sand and prime.
Insert finished circles into airframe.

☐ Continue cutting, sanding and welding airframe pieces to the cockpit section. First the hoops, check for trueness and then weld in the thin hoops.

☐ Prepare the upholstered chair pieces and screw them into the plywood bulkhead circles. Remove them for installation later so they are not damaged by the welding going on.

☐ CNC plasma-cut the hatch frame components (we CNC these pieces because tight fit is critical here).

☐ Fabricate Hatch itself by cutting out of sheet aluminum and then rolling it to correct diameter.

☐ Weld in the hatch frame pieces and keep the hatch pieces for later when we build the hatch.

Construction of Steering Fins

☐ 3D print fins from a high-tensile-strength aerospace-grade filament material from plans.

☐ Machine servo axles to octagonal cross-section

☐ Tap bolt holes in fins

☐ Insert headless hardened bolts into holes.

☐ Attach to servo axle and tightened bolts.

☐ Test complete system mechanically and electrically.

☐ Remove fins and store for later.

Hatch Construction

☐ Take the remaining pieces that were cut from the cockpit and use them for the hatch re-enforcement.

☐ Have local metal fabricator roll the sheet aluminum for the hatch to approx diameter of 36”.

☐ Weld the steel pieces together in the HC plywood jig, continually testing the plasma-cut internal and external hatch frame pieces for trueness (ie, so they fit tightly but not so tightly that the hatch sticks) against the main airframe.

☐ Cut the four holes for the view-ports into the hatch.

☐ Separately fabricate the view-ports from the aluminum and plastic pieces according to the plans. The cockpit isn't pressurized so just put them together as well as possible. *Alternative:* 3D print viewports from Triton filament and rivet on hatch with thin metal washers or drilled thin metal strips

☐ Hand drill rivet holes through the view-ports into the hatch, and rivet into place.

☐ Drill holes in hatch to bolt on the internal latches.

☐ Affix latch hardware to hatch and airframe testing that they mate correctly and can be actuated.

☐ Exhaustively test that they operate as intended, that they will hold fast during flight but will release quickly.

Construction of Aluminum Skin

☐ After ALL airframe fabrication, wiring and such things are completed, you can attach the aluminum skin.

☐ Source sheet aluminum and take to local metal fabricator to have rolled to appropriate diameter (approx 36”).

☐ Starting at the rear, apply sections of skin to the airframe affixing them with adhesive.
Reach around inside of the airframe with a hand drill and drill through rivet holes in the thin hoops through the skin section.

☐ Install a few rivets for registration purposes and complete drilling the holes.

☐ Install remaining rivets once all the holes are drilled.

☐ Work from rear to front with as large of skin sections as possible.

☐ For holes and the hatch, cut the sheet aluminum with cutter as closely to the item as possible.

☐ Test that all moving structures have sufficient clearance with which to move unobstructed.

☐ When skin is installed, weld adjacent sections together horizontally (NOT vertically).

- [ ] Sand and prime.

Construction of Propulsion Section "Recipe"

Preparation

"Shopping List"

Construction of Upper Bulkhead

- [ ] Take plans to machine shop, and have support vanes chop saw cut out of steel plate.
- [ ] Take plans to machine shop and have them shop saw cut the hardpoint.
- [ ] Take plans to machine shop and have the upper bulkhead component turned.
- [ ] Weld Hardpoint to the Upper Bulkhead component.
- [ ] Weld Support Vanes to the Hardpoint and Upper Bulkhead component.
- [ ] Once cooled, Drill and tap affixment bolt holes.
- [ ] Verify fabrication against specifications.
- [ ] Install O-Rings.
- [ ] Test for fit on Motor Casing and bolt in place.
- [ ] Remove completed Upper Bulkhead from Casing for later use.

Construction of Lower Bulkhead

- [ ] Take plans to machine shop and have them fabricate the lower Support Vanes by chop saw cutting steel plate.
- [ ] Take plans to machine shop and have them turn the Lower Bulkhead component.
- [ ] Take plans to machine shop and have them turn the Nozzle Bell component.
- [ ] Take plans to machine shop and have them fabricate the Slug Holder by

chop saw or band saw cutting seamless steel pipe to part specification.

- [ ] Stick weld the Nozzle Bell component to the Slug Holder.
- [ ] Weld the Slug Holder to the Lower Bulkhead component.
- [ ] Weld the lower Support Vanes to the Slug Holder and Lower Bulkhead component.
- [ ] Once cooled, drill and tap the various affixment bolt holes.
- [ ] Fabricate the Slug Retaining Ring (SRR) out of sheet steel.
- [ ] Verify all parts against specification at this point.
- [ ] Cast an Ablative Ceramic Slug
- [ ] Install Slug into Slug Holder.
- [ ] Install Slug Retaining Ring (SRR) by attaching with appropriate machine screws.
- [ ] Install O-Rings.
- [ ] Test fit Lower Bulkhead against Casing by installing and bolting in place.
- [ ] Remove Lower Bulkhead and store for later use.

Construction of Casing

- [ ] Take plans to Metal Vendor and get appropriate length and diameters of seamless steel pipe cut by industrial band-saw.
- [ ] Inspect casing for any flaws and sand and clean to usable finish.
- [ ] Drill affixment bolt holes to match bulkheads.
- [ ] PRESSURIZATION TEST: Pressure test casing with pressurizing assembly (Nitrous Oxide or Carbon Dioxide are at about the same operating pressure so use these) by installing upper and lower Bulkheads WITH O-Rings installed, stopping up the lower assembly with a plug/valve combo and slowly bring up to operating pressure.
- [ ] Remove Bulkheads after successful test.

Construction of Grain Casting Fixtures

- [ ] Construct Casting Fixtures from plans
- [ ] Install casting metal pipe in fixture
- [ ] Test fit an EPDM liner into pipe to verify that supplies meet specifications, and remove.

Fabrication of Ablating Ceramic Slug

- [ ] Construct the Slug Casting Fixture from plans
- [ ] Install casting metal Pipe in fixture as well as bottom Nozzle Profile Core.
- [ ] Apply appropriate Release Agent (usually Lithium Grease) liberally to inside of Fixture as well as the top Nozzle Profile Core and top of fixture.
- [ ] Mix ceramic material with water to specified proportions, also mixing in any other ingredients. Visually inspect for excessive bubbling or other obvious problems.
- [ ] Pour liquid ceramic into Fixture.
- [ ] Install upper Nozzle Profile Core, top of Casting Fixture and affix top with bolts.
- [ ] Let Slug fully cure before taking apart Fixture and removing the finished Slug. It might take a little coaxing, but hit with a rubber or wooden hammer until the required piece separates from its mold.
- [ ] Visually inspect for any defects like voids, soft spots, cracks. Only use if it meets muster.
- [ ] Slugs are brittle so store in a plastic 5-gallon bucket for later use, with crumpled butcher paper at the bottom, sides and top. Anti-static spray isn't necessary as they aren't flamible.

Fabrication of Propellant Grains

- [ ] Set up casting fixture, without EPDM liner, but WITH center Teflon rod.
- [ ] Rub the entire inside of the fixture with Release Agent including center rod (see specifications for type of agent, usually Lithium Grease).
- [ ] Mix small batch of pure R45 resin with PAPI hardener.

☐ Pour the liquid into bottom of fixture (without the liner installed) to form inhibitor layer. Either self-level or manually level it so it will be the specified thickness when cured.

☐ Wait for inhibitor to cure halfway. You CAN'T WAIT until full cure or it won't chemically bond to the propellant. Not cured enough and the dropping propellant will move it around. Wait for the “pre-leather” phase where it's hard and tacky then proceed quickly to the next step.

☐ Install the EPDM liner from your supplies. (Remember to NOT put release agent on the inside of the liner...its a common mistake...the liner is part of the finished grain.)

☐ Measure and mix atomized aluminum powder with R45 resin with mixer. (We do this first to stabilize the aluminum fuel by taking away its ambient oxygen.)

☐ Measure and mix Ammonium Perchlorate oxidizer and mix into fuel/resin mixture.

☐ At appropriate point, add the R45 hardener (usually PAPI) at the manufacturer suggested ratios and continue mixing.

☐ Pour into casting fixture with installed liner and inhibitor at the bottom. Level so there is enough room at the top to pour the other inhibitor.

☐ Wait until half-cured (so we can chemically bond the inhibitor to the top of the partially cured propellant).

☐ Quickly mix and pour a pure R45/hardener mixture into the top of the fixture forming the upper inhibitor layer.

☐ Place the top of the casting fixture on the top of the casing pipe and bolt into place.

☐ Leave alone until the whole grain is cured (usually about 24 hours after pouring final layer).

☐ Once grain is cured, disassemble the casting fixture.

☐ Carefully extract the finished propellant grain from the casting pipe. Remember that the EPDM liner IS PART of the grain, the metal pipe IS NOT. With some coaxing it should come loose.

☐ Carefully but quickly visually inspect them for obvious defects like voids, cracks, discolorations or other problems. (Quality Control)

☐ Prepare a plastic 5-gallon bucket with anti-static spray (ASS).

☐ Carefully place the finished grain onto the bottom of the bucket, and put the lid on with a minimum of vibration. (Remember that finished propellant grains are HAZMAT so move, store and transport grains according to law at all times.)

☐ Clean and completely disassemble casting fixture, storing clean parts for later use.
Repeat procedure 5 times (or build 5 casting fixtures for simultaneous usage) to build 6 grains. Requires all 5 grains to launch rocket.

Assembling the Rocket Motor
Preparation

☐ Collect all parts and supplies necessary to assemble the rocket motor. Check against parts manifest to see that you have all the parts/components necessary BEFORE HAND to successfully assemble the motor.

☐ Install the Upper Bulkhead in the Motor Casing first. It is assumed that you have already installed its O-Rings and applied the suggested lubricant to the circumference of it.

☐ Attach the upper EPDM Bulkhead Liner and the hi-rel Ignition System to the Upper Bulkhead. (It's easier to install this way than trying to install it from the other end of the casing.)

☐ Slide it into the Motor Casing (threading the Ignition System's cable so it pops out the other side of the casing) and bolt it in place with the appropriate fasteners. Use an O-Ring compressor tool if you need to. Use a calibrated Torque Wrench and tighten the affixment bolts to specification. Visually inspect.

☐ Remove the Propellant Grains from their buckets, quickly visually inspect them for defect, and CAREFULLY slide them into the Motor Casing, threading the cable through the center of each Grain. Insure that they fix snugly together and are firmly pressed against the upper Bulkhead.

☐ Completely assemble the Lower Bulkhead by installing its O-Rings and lubrication, installing the Ablative Ceramic Slug, retained by its fastened Slug Retaining Ring AND the lower EPDM bulkhead liner attached to the front of the Bulkhead.

☐ Slide it into the Motor Casing, threading the Ignition Cable through the Nozzle. If you selected the correct thickness of EPDM bulkhead liner, there should be about 0.25” of firmness that you will have to push the lower Bulkhead into place. Use an O-Ring compression tool if necessary. Visually inspect.

- [ ] Compress the lower Bulkhead into the Motor Casting and quickly attach the affixment bolts. Use a calibrated Torque Wrench and tighten the bolts to specification. Visually inspect.

- [ ] The motor is now LIVE and ready for firing. Treat the assembled motor with CAUTION.

Static Testing

- [ ] See that all switches and settings on the Test Stand are in the specified state for pre-fire.

- [ ] Run through the Test Stand's pre-fire safety procedure. Only proceed with a successful procedure.

- [ ] After assembling the live Rocket Motor, you can place it in an inverted position on the specified Test Stand so it fires with its flame going upward so the thrust is counteracted by the ground.

- [ ] Remove the Safety Plug on the end of the Ignition Cable and plug it quickly into the Test Stand's Firing Electronics.

- [ ] The Rocket Motor is now ready for static testing.

Installation of Rocket Motor into Airframe

- [ ] At the launch site, completely assemble the rocket motor as per specification AND take the rest of the rocket through the pre-launch setup procedures.

- [ ] Slide the live Rocket Motor into the Airframe horizontally, sliding any protruding affixment bolt heads past the pads on the internal Motor Mounts.

- [ ] Insure that the Rocket Motor's Hardpoint is correctly mated with the Airframe's corresponding Hardpoint.

- [ ] Secure the Rocket Motor within the Airframe by bolting on the Motor Retention Clips around the bottom of the motor to the bottom of the Airframe.

- [ ] The Motor is now installed.

- [ ] (Complete the appropriate checklist for pre-launch procedures not covered here).

Flight Computer Installation "Recipe"

Gather all flight computer, electronic hardware, wiring and devices that the rocket requires
All permanent wiring should have been strung during the airframe construction phase and be inside of the skin
All OEM additions should be riveted to the inside of the aluminum skin NOT the steel pillars (holes can weaken the structural integrity of them).

Preparation

☐ Recharge the Battery Unit to full previous to installation

☐ <u>Make absolutely sure that there is NO live pyro unit installed in the recovery section</u>

☐ <u>Make absolutely sure that there is no physical linkage between the avionics systems and the propulsion section of the rocket.</u>

Installation of Flight Computer

☐ The Flight Computer has a semi-circular rack-mountable shape to it. With the rack-mount blank, use it's mounting holes as guides hand drilling the matching holes to the appropriate set of pillars.

☐ Remember to not use greater than a 1/4" hole to mount components as this might weaken the airframe.

☐ The Battery Unit is the lowest, followed by the Flight Computer Unit, followed by 2 Relay Units. Screw the units into place. Always consult the Flight Computer's installation manual for specific instructions on how to do this.

☐ Using the FCU's (and other) manuals, wire the units up to each other and the various sensor/actuator/devices that it needs to connect to.

Testing the Flight Computer

☐ Test that all switches are in the off (or appropriate) states (especially the *ground diagnostics* switch, which should be set to DIANGONSTIC).

☐ Once all wiring has been connected according to specification, power on the complete system.

☐ If a *thin visual client* is installed you should see the operating system loading and finally the guidance software being executed.

☐ Follow the instructions that come up.

☐ If any errors are encountered document these and check with the manufacturer about solutions.

☐ At the appropriate moment the FCU will request you connect the Flight Planner Unit; since your system is in diagnostics mode, you will notice a difference in the flight planning software that its set up more for testing than loading an actual flight plan.

☐ Follow the FPU's instructions and document any errors or notes that you think are important.

☐ Open and follow the checklist in the *DBeta Flight Computer's Diagnostics Manual*.

☐ At the end of a successful power-up test, power down the system according to the manufacturer's instructions.

Bill of Materials
for DBeta Manned Rocket

Vendor Part#	*Vendor*	*Part Description*	*Price*	*Quantity*	*Total Price*	*(weight)*
50-1656	Performance Bike	**Ergon GP1 Neo Grips** Bike Handle Grips	$24.99	1 set	$24.99	
80027	Northwestern Tool	**Latch-Action Toggle Clamps (2000lb)**		4		
CES-66-5018	Vetco	**Toggle Switch Guard / Cover - Translucent Red**	$2.49			

Full Vendor Information
for Dbeta Manned Rocket

Vendor Name	***Full Vendor (or Distributor) Information***
Northwestern Tool	ISMG Machinery & Tooling Agency John Szot 16835 Algonquin Street #420 Huntington Beach, CA 92649 Office: 714-846-2700 Cell: 714-913-5664 Fax: 888-839-6434 johns@ismgagency.com http://www.northwesterntools.com/toggle-clamps/latch-action-toggle-clamps-2000lb
Performance Bike	http://www.performancebike.com/bikes/Product_10052_10551_1158826_-1_400211__400211