Orbiter Developer Notes for the DH-1 RLV from "The Rocket Company" by Patrick J.G. Stiennon and David M. Hoerr (Illustrations by Doug Birkholz)

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1. Introduction

"The Rocket Company" is a 2005 book by Patrick J.G. Stiennon and David M. Hoerr, with illustrations by Doug Birkholz. The book is a fictional but technically detailed and technically accurate case study of the development by a private startup company of a two-stage reusable launch vehicle (RLV) called the DH-1. The premise is that the book is a historical review (from some years in the future) of the founding of the company and the development and application of its launch vehicles and spacecraft, written by a journalist who was given full access to the project from the start. The fiction device allows the authors to invent a well-funded startup company (AM&M) and to define characters such as the founder/visionary John Forsyth, the chief engineer Tom Rabbet, and others. They also invent fictional events related to the development, engineering, testing, troubleshooting, commercial introduction, sales, future versions, etc. of the DH-1.

Although there are characters, there is no attempt to develop much of a "back story" for them – there are no office romances or even industrial espionage (just as well). But the use of a fiction-like narrative structure does make the book less structured and more readable than (say) a business plan or an engineering study, which in many respects it otherwise is. The only downside of this approach is that the technical details of interest to someone developing an Orbiter add-on to simulate the DH-1 are buried in the text (except for one table that summarizes major technical details, on page 251). The book also uses English units (feet/second etc.) instead of metric. Unlike most novels, the book has an index, which is useful for locating technical details. It has some graphics too.

These add-on development notes are intended to document the work done primarily by Andy McSorley in creating a "proof of concept" add-on based on relatively simple meshes, Vinka's spacecraft and multistage DLL's and information from the book. The prototype works: you can fly this DH-1 to orbit in Orbiter using essentially the book's launch profile. Bruce Irving's main contribution was in reading the book, noting the DH-1's potential as an interesting add-on for Orbiter, collecting some information, recruiting Andy, and writing these notes. Our hope is that one or more of the talented and versatile Orbiter add-on developers will see the potential here and create a more complete add-on. If you do, please give credit in your "readme file" or other add-on documents especially to the authors of the book, the illustrator Doug Birkholz, and to Andy for getting the prototype together and into space. I think the book and the concept of the DH-1 are both fascinating and I hope that an Orbiter add-on will spread awareness of and interest in this approach.

2. Summary of the DH-1 Concept and Flight Profile

The book explains the motivation for the overall flight profile and the many engineering decisions in detail, and I won't try to summarize all that here except to say that there are economic and safety justifications made for having the vehicle be completely re-usable, for having both the first and second stages return to the launch site, and for having both stages be manned by a pilot/astronaut.

The included spread sheet has the numbers for masses, ISP's, dimensions, etc. so only selected numbers will be repeated here.

Flight Profile – The basic concept is essentially a "boosted SSTO" where the first stage booster is used to place the second stage at high altitude above the launch site, but not to impart significant horizontal velocity. This is to allow the first stage to return to the launch site, slowed down in descent by drogue chutes and landed vertically using either rockets (prototype) or jet engines (production). The jet engines allow longer powered descent which gives greater cross-range capability for wind tolerance. Although an autopilot would be used to control the ascent and descent, including gimbaled thrust control to keep the vehicle over the launch site, and control of the descent and preparation for vertical hover landing, the first-stage human pilot is there for safety and backup. Note that the launch thrust-to-weight ratio is about 1.6 because of this unusual flight profile. The basic profile has main engine cutoff at 100,000 feet (30,480 m), but lower-thrust sustainer engines are used to burn the last 5% of fuel and partially counter gravitational deceleration, allowing the DH-1 to reach 200,000 ft (60,960 m) where staging occurs. After separation, the unpowered first stage reaches a final height of 350,000 ft (106,680 m) before beginning its descent.

This profile also requires that the second stage provide essentially all of the horizontal delta-V required to achieve orbit. This is achievable in the book's DH-1 design with a payload of about 5000 lbs. (2200 kg), which is in addition to the second stage pilot and pilot support (i.e., the pilot, life support, ejection seat, etc. are considered part of the vehicle empty weight).

After separation the second stage engines fire, ideally applying all thrust horizontally until orbit is achieved, although testing of the initial Orbiter prototype required a slightly different profile (see launch profile notes in spreadsheet).

Payloads are deployed by the second stage pilot/astronaut after depressurizing the combined crew/payload compartment. The space-suited pilot essentially pushes the payload out the door, though in some cases, a trapeze-like mechanism is used to assist in this, in cases where the satellite must be unfolded or configured before deployment.

The conical orbital stage has a heat shield on blunt end which is explained in chapter 10. After the high temperature phase of reentry, drogue chutes are deployed to slow the descent, and finally a parasail is used to allow a controlled landing on a runway. The vehicle is carried horizontally by the parasail and deploys simple landing skids for landing.

3. Suggestions for Completion of DH-1 Add-On

The preliminary prototype was created by Andy using fairly simple, un-textured meshes of approximately the right shapes and sizes according to the book. Vinka's spacecraft.dll (2003 version used for testing, not spacecraft2.dll at this point) and multistage.dll were used to define and control the spacecraft with properties from the book (converted to metric and massaged a bit to get it all working, see spreadsheet and .ini files). The purpose was to try to get the masses and thrusts more or less correct, and to test the basic vertical-only, then horizontal-only flight profile to achieve orbit. Very little attempt was made to make a controlled vertical landing of the first stage – for one thing, no drogue chute was defined, and all the fuel was used on ascent! Another point is that this vehicle has only main engines, so for landing, it's a tail-sitter, which is tricky to control. Similarly the second stage was very simple and included no animations, visible RCS thrusters, drogue chute, or parasail for landing.

Basic proof of concept was achieved with this fairly simple model, but we believe that to really try out the Rocket Company RLV concept will require a custom DLL as well as an improved and textured mesh model. We are hoping that one or more of the Orbiter community's advanced add-on developers will get interested in this novel space system and take on the completion of this project. Note that these are only suggestions – any improvements on the prototype in terms of graphics and flight modeling will be welcome.

4. Modeling issues (refer to graphics at end of document)

1. **First stage shape and detail –** Andy's model has the right general shape and size, but it lacks fins on the outboard jet engine pods, it lacks a "bubble" to indicate the pilot's canopy on one side of the ship, and it has only the five main rocket engines. In addition to these, there are four smaller sustainer or vernier engines, and four jet engines for hover landing. It also lacks an indication of the "petals" that make up the faring between the first and second stage. In the book, these are described as gripping the second stage to add stiffness to the structure for launch and ground handling loads (they also add drag for descent).

2. **First stage texturing –** The color cover graphics show the general paint scheme as well as metallic parts such as engine cones, and a translucent window on the pilot's canopy. If the interstage "petal" faring is not animated, the petals could be indicated with texturing.

3. **First Stage Animations –** Animations are of course optional, but there are a few that would be nice. One is for the rectangular air-intake doors on the jet engine pods to open and close. Another is for the ground-support feet to extend and retract (these slide straight in and out of the structure, I believe there are four). A third is for the stage-faring petals to open and close as shown in some pictures. A final and more dramatic one would be for the pilot's hatch to open and possibly to support a working ejection seat.

4. **First stage engine exhausts –** There are three types of engines, the main rockets (SpaceX Merlin?), smaller sustainer rockets, and jet engines in pods for hover landing. Ideally, each of these would have a distinctive and properly located exhaust texture.

5. **Second stage shape and detail –** The second stage orbiter is a fairly simple rounded cone with a blunt-end heat shield, but it would also have RCS thruster openings and small windows for the pilot's compartment. If the payload compartment door is to be animated, this would be a separate mesh element, but if not, it could be indicated with texturing.

6. **Second stage texturing –** Again the color cover graphic is the best indication though some of the pencil drawings show other details. Main texture difference is the heat shield which looks like thermal protection tiles in the drawings but is described differently (thermal blankets etc.) in the text.

7. **Second stage Animation**s **–** Main ones would be drogue parachute and parasail deployment animations and configurations. The parasail also causes an orientation change (vehicle is carried horizontally, similar to Francis Drake's biconic CEV2). Also essential would be the deployment of landing gear skids. Less essential would be an operating pilot/payload door as shown in some graphics. There are also issues with the engines, which fire through openings in the heat shield – there are doors or plugs for these openings for re-entry.

8. **Second stage engine exhausts –** These are the usual thing for the two engines, though the cones are recessed in the heat shield. There should also be display/animation of the RCS jets. Patrick Stiennon clarifies this:

   The engine compartment is two 48 inch [122 cm] holes which are tangent at the vehicle center axis. The 48 in/122 cm holes are joined to form a single oblong hole. The engine bells are about 38 inches [97 cm] in diameter and a flexible heat shield extends between the engines and the edge of the oblong hole to allow gimbaling, not much gimbaling is needed because the orbital vehicle is not subjected to significant aero loads during powered flight, so 1-2 degrees is enough. During reentry the engines are cooled by LOX, H2, OR He. Because the total heat loading is only about 2500 Btu per ft squared roughly 32 ft2 of the engines and bay can be actively cooled, about 80 lbs of water, or 35 lb H2, 100 lb He assuming no ablative-like benefit from the shielding gases.

5. Operation/DLL Issues

1. **First stage ascent profile –** Launch uses the five main engines, but at 100,000 feet, the vernier engines take over to provide small sustaining thrust using the last 5% of fuel. Staging occurs at 200,000 feet. Jet engines are not used on ascent. The fuel supply for the rocket and jet engines should be separate if possible.

   Either the pilot or the ascent autopilot (if any) should control the direction of thrust to keep the vehicle directly above the launch pad. Orbiter currently has no wind, and Earth rotation for the few minutes of flight is fairly small, so this is mostly a matter of keeping the pitch at 90 degrees. Ideally the VTOL/Landing MFD could also be used with a radio beacon to help keep the vehicle centered above the pad.

2. **First stage descent profile –** This is a special thing in the case of the DH-1. After separation at 200,000 feet, the first stage continues to rise (unpowered) to 350,000 feet. Then it begins to descend in free fall until at around 200,000 feet [61 km] when aerodynamic forces start to overcome the RCS, drogue chutes are deployed to slow and stabilize its descent. These chutes are said to be somewhat steerable (?) but accuracy in reaching the landing pad depends more on accuracy during launch and then steerable (gimbaled? Thrust vectored?) jet engines used to slow the final descent and land vertically.

   Landing legs should be deployed just before landing. The VTOL/Landing MFD should be usable to guide the hover landing, although if it's a tail sitter, this can be tough since there is no auto-hover or auto-level built into Orbiter for this case. With a custom DLL, it should be possible to provide the equivalent of auto-level and maybe auto-hover, OR to use a trick involving the a change of the mesh and/or thrust directions and/or definition of the jet engines as true hover engines to provide some automated (stability) support for the hover landing.

   In addition to the VTOL MFD, it would be ideal if the pilot's main view for landing could be downward looking, configured if possible so that the Surface HUD would provide correct pitch references for the vertical landing. There's really nothing much for the pilot to look at on ascent, so the direction of the view could be straight up, straight out the side, or straight down. In the book, the pilot is said to have an optical periscope for looking down, and maybe even for configuring the view direction (he is lying on his back looking up for G tolerance on launch). He is also said to have a large flat panel video screen with feeds from a number of tiny hi-def video cameras at various points on the vehicle, allowing for a number of different "synthetic" views.

   The first stage pilot has an ejection seat that can be used (I believe) at any point in the flight profile. It would be nice but not essential to model this.

3. **Orbital stage ascent profile –** This is pretty normal stuff, although there is some question about how safe separation is achieved and the vehicle is transitioned to horizontal orientation to start thrusting for orbit (without colliding with the still-ascending but no-power first stage – I guess there is a brief period of vertical thrust to achieve separation before pitching down to build orbital speed).

4. **On-orbit features –** This could be "nothing" but it would be nice to have an opening payload door, and the possibility for EVA and payload deployment. The heat shield has some sort of mechanism to cover the main engine openings for reentry – it would be nice but not essential to animate this, but it should have two modes if possible (open for engine exhaust, closed for reentry).

Note that as specified in the book, the DH-1 orbital stage has no actual docking port, but on page 170 of the book, a docking apparatus (arm or hook or ?) that passes through the wall of the spacecraft somehow is described. I don't quite understand it, but I assume that with no "hard dock" mechanism, that EVA would be required to actually transfer crew to (say) the ISS. Patrick clarifies and provides some links for further information

The opening for docking uses a magnetic fluid to form a seal the magnets which hold the sealing fluid are mounted to a dilating iris so the size of the vacuum seal can get bigger and smaller. Normally the technology is just used to seal a shaft going through the wall of a vacuum chamber.
http://www.liquidsresearch.com/products/ferro_sealing.asp
http://www.rigakumsc.com/vacuum/about_tech.html

Note that the book also describes a personal re-entry system that would allow escape and re-entry by the pilot at any phase of the flight. It is similar to Sputnik's Paracone add-on and that could perhaps be used to simulate it. RC Chapter 12 picture shows this escape system.

5. **De-orbit/reentry** – The orbiter should have sufficient fuel (200 kg? more?) after reaching orbit to make small adjustments in orbit and to fire retro for the de-orbit burn. Once this is done, the engine covers for the heat shield are closed, and re-entry occurs blunt-end first similar to Apollo. I'm not sure of what control is possible with orientation prior to drogue chute deployment, but Patrick clarifies some details:

   The reentry controls is by RCS units at the nose of the vehicle, and the vehicle is weakly stable at a slight angles of attack during reentry. The C.G. is offset by enough to create a L/D of 0.1 which can be used to hold max reentry gees to about 5.

   The parasail is deployed and used similarly to Francis Drake's biconic CEV2 to allow landing on a runway (with enough practice!). Landing skids are deployed just before touchdown. Note that Franz's CEV2 also has an inflatable ring around the horizontal perimeter of the craft, presumably in case of water landing.

6. Add-on Expansion/Extension Possibilities

The plans of the fictional founder of AM&M, John Forsyth, extend well beyond lowering the cost and complexity of getting small payloads into LEO. By making manned access to LEO affordable to the space programs of smaller countries, companies, other organizations, and even a few wealthy individuals, he hopes to open up space in a variety of ways. To help with these wider goals, AM&M invents variations on the DH-1 that can (with on-orbit refueling and assembly) provide access to the Moon and later to the asteroids and to Mars.

I won't try to summarize the book here, and these alternate vehicles are not defined in as much detail as the original DH-1. But there is plenty of room for creative expansion of for add-on developers willing to be inspired by the later chapters of the book.

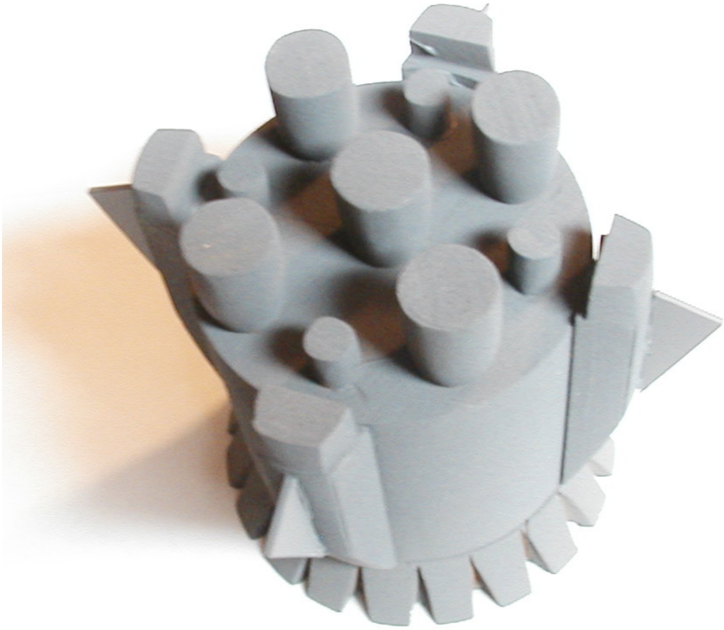
7. **Graphics**

These graphics were supplied by author Patrick Stiennon and are copyright 2005 by the book's illustrator Doug Birkholz. They are provided here only for the purpose of defining the details of an add-on model for Orbiter and should not be distributed, posted on a web site, or used for any other purpose without the copyright holder's permission.

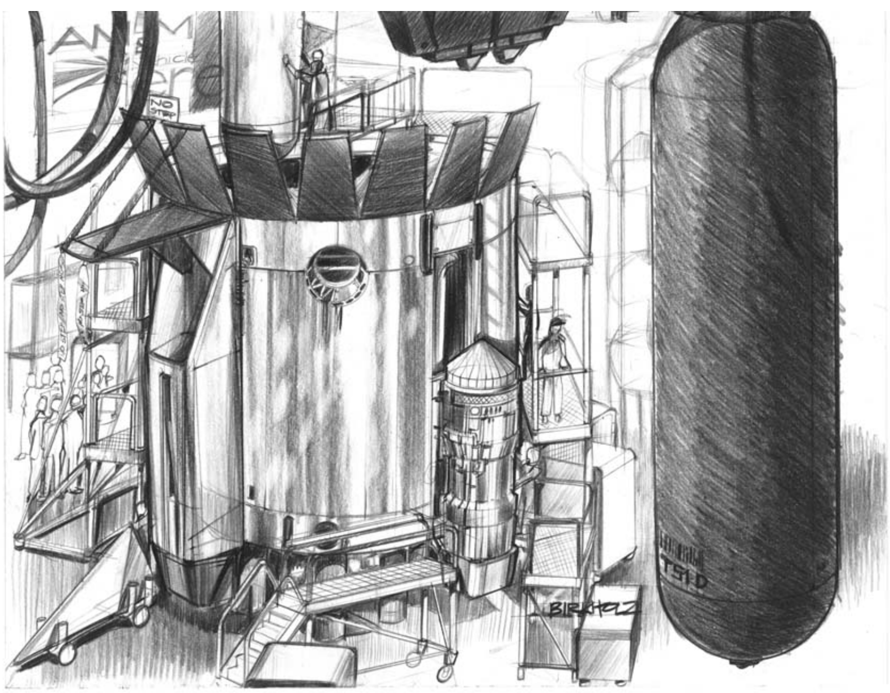
Launch - Cover graphic showing hover jet engine doors closed, main engines (and vernier?) firing. The hatch for the first stage pilot is visible (circular canopy) as are the windows of the orbital stage pilot compartment. Piston-like retractable legs are also visible (they are not exactly legs but really tubes riding along posts in the launch base - see RC page 123). There is no gantry or crane (ground vehicles are used for loading and handling), and I'm not sure what the ladder-like structure on the right is.

Stage Separation – At 200,000 feet, all first stage engines killed, fairing petals open, orbital stage separating (no engine openings or exhausts are visible?). The air intakes for the jet engines used for landing are also open. These and the petals intentionally add drag to the first stage for its initially unpowered descent. The heat shield texturing is visible, looking like thermal protective tiles.

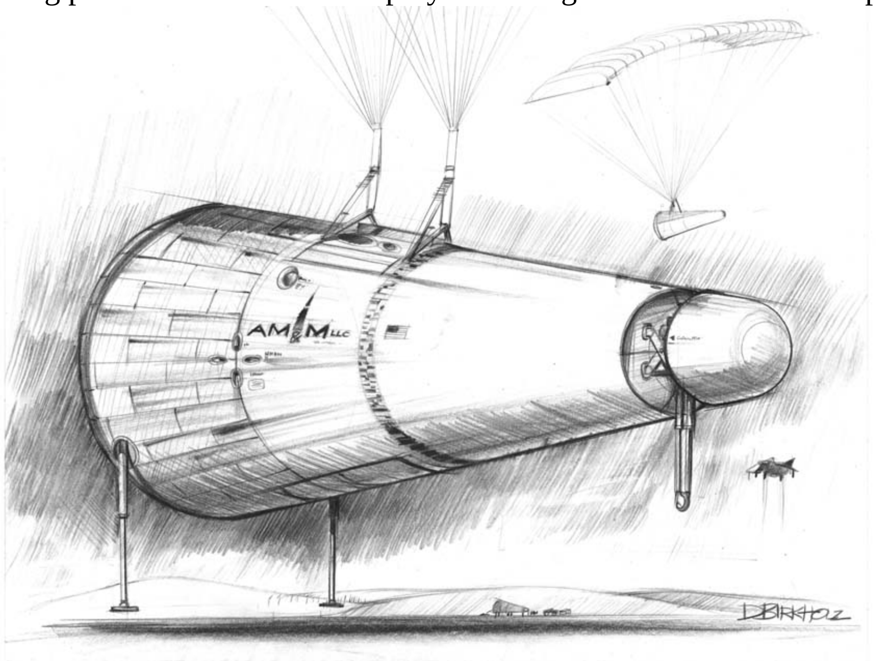
Engine Cluster – This model of the DH-1 first stage shows the arrangement of the main and vernier engines. Legs and jet engines (in pods) are not shown.



Details of Jet Engine Pods – This chapter 26 drawing shows details of the first stage, including the pilot compartment, jet engine pods intake doors open, one with one engine exposed, another pod with its fin removed, interstage fairing petals, and also the relative size of the vehicle and some ground handling ideas.



Orbiter Landing Configuration with Parasail – This drawing shows the attachment of the landing parasail as well as the deployed landing skids. RCS thruster openings are also visible.



Orbital Stage on Orbit – With payload door open, EVA in progress, and remote soccer-ball-size remote inspection satellite ("Wilson?") in foreground.