A BattleBots Championship Insight

Jason Dante Bardis, World Champion BattleBot Builder
Offers some insight into the evolution of design methodology

Study the pic's, hear the words, and witness the evolution of Jason's design skills.

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I first heard of **BattleBots** when Trey Roski and Greg Munson put their first event together in 1999, after legal problems halted Robot Wars competitions. I first learned of Robot Wars from a 1-page article in Wired magazine in 1993 or 1994 depicting a white lab-coated mad scientist with a remote-control truck with a gas chainsaw on it. I was immediately intrigued, but it would not be until 1996 that I had the means and the opportunity to enter the San Francisco competition.

Rampage

My very first robot, a 17lb featherweight for Robot Wars, was my least successful bot, losing its first and only fight. However, by putting something together and watching it fail, I learned much about robots, mostly what *not* to do…Rampage was built on a very small budget, using the drive train of a radio control buggy kit from my childhood and poorly-machined chassis, armor, and weapons.

The first lesson was that the motor, gearbox, wheels, battery, speed control, and steering system from a 3lb buggy are not well suited for a 17lb robot that has to push 25lb robots around. I experienced motor failure, taxed my speed controller too heavily, broke steering linkages, and drained batteries prematurely.

The second lesson was that, if you create a wedge-shaped robot, make sure that the tip of the wedge rests *flush* against the ground if you want it to work properly. There were several other lessons learned, but they are so obvious and well-documented today that I need not dwell on them further. The sturdy shell survived, but the drive train was not worth reviving or even maintaining. Rampage was designed by gathering existing components and laying them out on a chassis. Once the chassis was complete, I mocked up the body and weapons in cardboard before cutting any metal.

Bot Will Eat Itself

So, for the following year's Robot Wars, I gutted Rampage & added an all-new drive train. Taking a hint from other robots, I purchased a pair of large, powerful motors from a surplus store. More motors meant more power. Unfortunately, I didn't fully understand the importance of gear reductions, so I mounted the wheels directly to the motors. This gave the bot terrible acceleration, little pushing power, fast battery drain, and was hard on the tiny hobby speed controllers. But it had a nice top speed, which wasn't very helpful. Also note that I switched to a 2 motor, 2 wheel tank-style drive train, for the ability to turn on a dime, which Rampage could not do with its car-like drive setup. After noting the success of powerful wedges and lifters, I created an independent suspension to keep the wheels on the ground even if the bot were lifted in the air.

Each motor/wheel/battery/speed controller was mounted to a hinged panel and gravity did the rest of the work. This was the only truly clever feature on Bot Will Eat Itself, with the added bonus that it provided for easy and instant access to the interior of the bot for maintenance and battery changes. Unfortunately, because of packaging constraints, I had to offset the 2 drive wheels, so the robot turned better in one direction than the other.

For both defense and offense, I added lengths of piano hinge all the way around the robot to act as wedging devices and anti-wedging devices. They were too light and too flimsy to work terribly well. I cut a hole in BWEI's roof and installed a computer fan to keep air flowing through the body, helping to cool the improperly used motors, batteries, and speed controllers. Finally, I experimented with diamond grit abrasive blades instead of thin, toothed woodcutting blades. I soon learned that tiny weapon motors with no speed

reductions are not well suited to abrasive grinding attacks, so I switched back to the old toothed blades.
Bot Will Eat Itself was designed by taking an existing bot, Rampage, and shoehorning a new drive train into its body. A few drawings and plans were made, but the bot was designed on-the-fly as it was being machined and assembled.

The Missing Link

This was the first robot of which I could truly be proud. I was still on somewhat of a budget, basing the robot around a hollow titanium wiener I scavenged from a recycling dumpster, but I spared few expenses beyond that. I started with the same motors from BWEI, fastened back-to-back, and then ran them through 10:1 coaxial speed reducers to let the motors work in a more efficient part of their power band. Onto the ends of the speed reducers were spherical steel float wheels, wrapped in sticky rubber tread, rounding out the ends of the hot dog-shaped body. I upgraded to a nice PCM radio, used a large-capacity sealed lead acid gel cell battery, and installed a Vantec speed controller. Even though this robot drive train was running at a lower voltage than BWEI's, it still had far more power, speed, torque, and run-time than the old featherweight, thanks mostly to the speed reducers.

Despite the apparent ineffectiveness of chainsaws, I was hell-bent on putting a noisy gas-powered chainsaw on Missing Link. So, I purchased one and modified it to run via remote control, then I figured out which of the screw holes left by removing the handle I could use to mount the engine. Rubber vibration isolation mounts kept weapon impacts and vibration from affecting the drive train.

I added a very expensive carbide-tipped chain to the saw to better cut metal. Since Missing Link had some weight left over, I wanted to be the first contestant to use a tethered projectile. To the dive shop I went, and I returned with a pair of spear guns. After making the triggers servo-operated, I installed a very strong braided steel cable tether system to keep the spears from getting away. Both of these weapons were attached to the drive train only by 2 large bolts and vibration isolation mounts. I realized later that I could easily make any weapon bolt on to these mounts, so I immediately purchased another chainsaw, removed the bar, and made an adapter on the clutch to mount a 14" circular saw. The other 3 modular weapons in the arsenal were a pair of case-hardened steel ramming spikes, a 3 foot long pointy stick with side-mounted spikes (for spinning attacks) and a snow shovel-like scoop.

Missing Link, like my 2 previous bots, was designed around existing items, the titanium wiener and the nice motors. I spent much time sketching, a little time measuring, and even less time making anything that resembled dimensioned technical drawings. Every time I worked on Missing Link, I'd cart the entire bot to the machine shop and make parts on the fly to attach to the parts I'd previously made. Unfortunately, this design method resulted in several complex parts being made to the wrong dimensions, requiring a complete do-over. On the plus side, I spent much time mulling over the design in my head and on rough sketches, resulting in a good, solid bot that fought well in 4 competitions and several other performances. Another reason for its success was that I spared no expense on parts—I bit the bullet and purchased whatever was needed, cutting no corners, which paid off in the long run.

Dr. Inferno

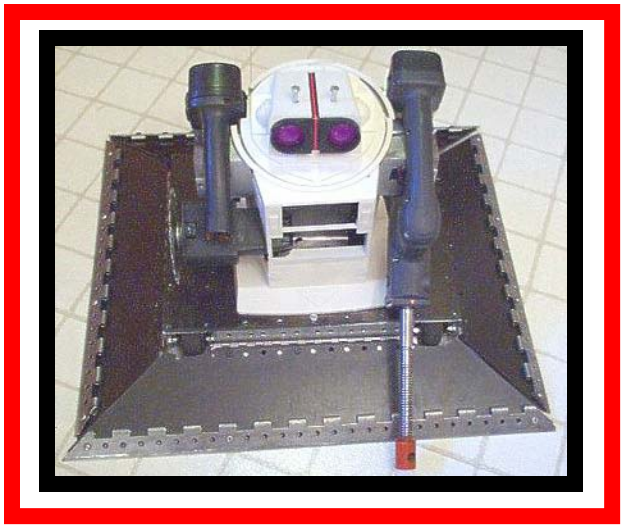
After purchasing a TOMY Omnibot toy at a swap meet, I realized that, even though it would only be a joke of a combat bot, it would make a better fighter than a butler. Once again, I gutted a robot shell and stuffed in components, but this time I went cheap—Dr. Inferno's goal in life was to get destroyed spectacularly, not to win competitions. In went a pair of automobile power window motors to drive BWEI's wheels (modified to be lighter), a small Vantec controller, a small battery, and an FM radio.

Off came his cup holder arms, replaced with power drills that could hold a variety of mean-looking but ineffective weapons. Around the sides and back were an upgrade to the hinge idea from BWEI: hinges with aluminum plates, providing a heavy and sturdy gravity-powered scooping and defense system.Dr. Inferno was designed inside an existing body, with cheap components, in a very short period of time, just for kicks.

Dr. Inferno Jr.

After the surprising success of the shoddy Dr. Inferno, I got another Omnibot on eBay and planned his successor, but this time it would be a "real" robot with a cosmetic, expendable toy robot shell instead of using the shell as the bot's main structure. As with my previous bots, I designed on the fly again, but I had had much exposure to other bots, both successful and unsuccessful, and I had enough experience to execute a "make it up as you go" strategy with some plan bouncing around in the back of my head. After

seeing much success with power drills for drive trains, I picked up the cheapest 18V power drills in existence, not fully comprehending that expensive power tools are usually expensive for a valid reason. This proved to be the Dr.'s Achilles heel, as I treated these motors as disposable, replacing them with a brand new set after almost every one of its 5 competitions. I'd forgotten my lesson about investing wisely in the beginning for long-term benefits. Mostly as an exercise, I machined overly complex, overly durable, overly strong hubs to attach the wheels to the axles, thinking that I could later re-use these parts on a heavier bot. Indeed, after retiring the doc, these are the only salvageable, useful parts left. The rest of the drive train was laid out carefully (again, on the fly), using expensive, sturdy components like large bearings and axles. The structure was a set of aluminum channels and several panels of carbon fiber composite material, which made for a very light, very stiff structure. The same hinged flap idea from the first Dr. was used, but with beefier hinges and carbon fiber panels edged with steel to act as a sharp leading edge and as a barb to snag scooped opponents.



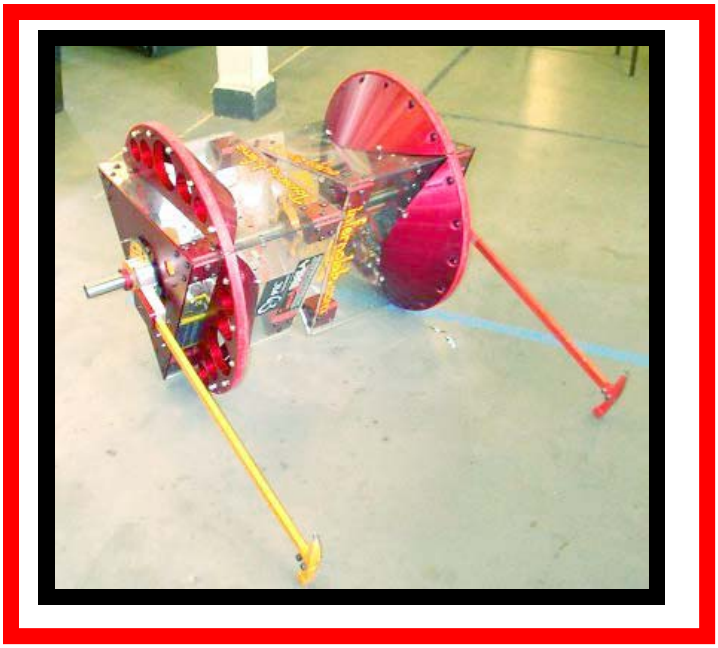
The top of Dr. Inferno Jr. was a sturdy aluminum skeleton with a pair of power tools for arms: a circular saw on the right, and a reciprocating saw on the left. In addition to mounting these up at the shoulder, I created wrist rests to support these long cantilevered weapons. Unfortunately, I mistakenly used Plexiglas instead of Lexan for both mounts, leading to some minor failures. The plastic robot shell bolted on over the skeleton, in a mostly cosmetic role (It protected the weapons' wires and the radio antenna.).

Dr. Inferno Jr. was designed after some successful drive train concepts seen in other robots (power drills, hinged flaps, upward-turning large-toothed saw blade, 4-wheel drive). While these ideas were in the back of my mind, I again did most of the actual designing on the fly, bringing the bot into the machine shop and measuring and referencing the assembly as I made new parts for it. A permanent was probably my most-used tool.

Towering Inferno

With several robots under my belt, some good media exposure, and a few small trophies, I was able to get enough sponsorship (I tracked down some sponsors, and some came to me.) to finally build a heavyweight. I had been toying with the idea of an all-new combination drive train/weapons system for a year, brainstorming with many students and engineers. The bot would consist of 2 enormous hammers and 2 large prismatic pods with circular wheels wrapped around them, all spinning freely on a common shaft

running through the whole bot. The hammers would not only be pounding weapons but drive the bot by pushing off against the ground, making the pods rotate away from the hammer's tip. This bot's goal was to be more of a unique, impressive showpiece than an effective, efficient fighter. It would be just an added bonus if this showpiece performed as nicely as it looked. The uniqueness of the design, the required investment, and the continuous pitching of the concept to sponsors kept me from commencing construction for a full year but forced me to think and rethink and rethink some more the crazy design.



To merely convey the concept, I had to draw so many sketches and explain it so many times and produce so many visual aids, that I quickly had the robot planned out in detail in my head. The design was so far-removed from any previous robot (I like to refer to most bots, including Dr. Inferno Jr. as a traditional box-on-wheels design), that I wasn't even sure if it would really move the way that I hoped it would. I broke out my LEGO Technic sets, a wonderful prototyping and robotics tool.

I couldn't even find standard pieces that would do the strange things I required of Towering Inferno, so I had to find a work-around by using some bricks in new and different ways. Fortunately, the LEGO prototype worked exactly as planned.
After obtaining some nice motors, some cheap large-capacity batteries, and browsing a catalog and ordering sprockets to make the largest possible speed reduction from the motors to the arms, I was ready to place items and mock it up. I started with a cardboard mockup of 1 prism, using the sprockets and motor and batteries as references for the dimensions. I then wanted to build a hasty, working plywood prototype, so I cut out triangular and rectangular panels and set them up. I soon realized that, given the complex geometries and machining that would be required, it would be entirely impossible to whip up a prototype. With a box-on-wheels approach, drive train components can be strapped/hose-clamped/taped to a plank of wood and the drive systems can easily be relocated, re-geared, and upgraded or downgraded. With Towering Inferno's design, there was no easy way to do this. So, the plywood was promptly donated to our machine shop.

Bell-Everman, a new local sponsor with an excellent CNC machine shop, agreed to fabricate all the parts, but they were accustomed to working with CAD systems, not the iffy sketches and make-it-up-as-you-go mentality to which I'd become accustomed. So, I

initially made a paper model of the first part (12 prism-shaped brackets to assemble the large prismatic pods). By using graph paper, I could easily cut, fold, and tape it together, while drawing directly on it, and it all came out to perfect scale. It was then simple to covert this model to a Pro/Engineer drawing and send it to the shop. Next were the wheel arcs and the triangular and rectangular panels that made up the rest of the pods. All parts were drawn and assembled on the computer to ensure that everything lined up properly. Indeed, the finished parts assembled quite easily and needed no or minor modifications. Additional on-the-fly machining was performed to mount small components (radio, batteries, speed controllers, power switches, etc.). These features were not included in the drawings because their arrangements had not yet been finalized and because I needed the parts to be done in a hurry and this extra planning would slow them down. One interesting feature added to each of the 6 wheel sections was 12 large drilled holes at odd angles (requiring awkward clamping to the drill press table) to make 6 "V" shaped "mouse holes." When the polyurethane rubber tread was poured into a mold to bond onto the wheels, the liquid rubber filled up these "V" shapes, creating mechanically-interlocking loops to keep the tread on the wheel even if the chemical bond failed. Because these were highly customized wheels, changing the tread or swapping out tires was out of the question—the initial tread needed to be durable to last the life of the bot, several competitions.

The finished Towering Inferno needed very little in the way of adjustments and modifications, thanks to the extensive planning, designing, and CAD work. The entire robot was put together in about 4 months—very fast for an oddball heavyweight bot—with plenty of time for testing and refining before the competition. The most serious modification was replacing the (unhardened) chromoly steel rectangular tube arms with solid titanium ones. After only brief testing, the arms were bent from Towering Inferno pounding the pavement.

In summary, Towering Inferno was the best-planned bot and also the biggest, most complex Infernolab bot by far. A year of thinking, discussing, modeling, and sketching led to a relatively brief period of CAD drawing, machining, assembling, and testing of a successful, robust bot.

Even so, unexpectedly weighing in at BattleBots 10lb underweight gave me the opportunity to break out a jigsaw and a power drill to whip up some low-tech, imprecise, on-the-fly chain guards out of some scavenged polycarbonate sheets.

Old habits die hard.