

BUILDING Spike Auto Mata

By Lee Magpili



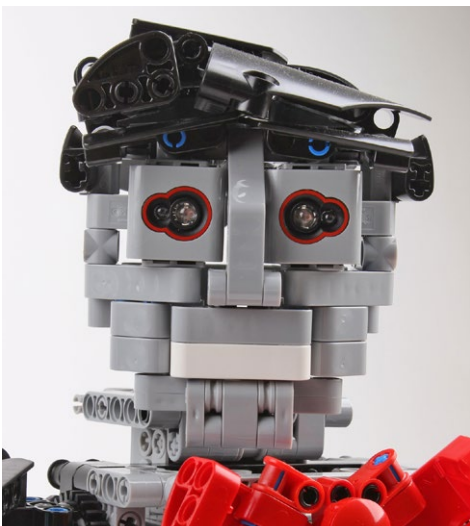
SAM's origin came from building a new robot in the vein of EV-AN¹ using the new Spike Prime platform—taking all those new parts, and seeing what I could do with them. It doesn't take much more than that, and once I had enough parts to play with and a bit of time to dump ideas out onto the building table, I went right in and got started.

Part 1: Head, Hair

I built the head and the chest area in one sitting, but that doesn't mean it wasn't complicated. Using the first EV-AN² as a template, I placed the color sensors as eyes and wanted to give them a subtle expression. The Spike sets have a 7m gear rack that can be used for creating a steering mechanism for left-right movement.

The shape of the new motor made mounting everything incredibly easy. The nose was next, with lots of ideas again coming from EV-AN, although finding the right size was a challenge. One of the biggest challenges ended up being the lips—SAM suddenly became a girl once I started working on them. I wanted to give her a feminine expression without making it overt, so I tried grey lips first, but it looked so dead. Red lips were just too much, and I finally chose yellow, hoping the parts would be available. I think the expression ended up great—playful and expressive without being too girly. To get the shape right, the 3m axles are not pressed all the way into the cross blocks, and the lips float to center. They can move around a bit, but this just adds character and expression.

I pride myself on the hair for my Edison and Einstein robots made a few years ago, so making feminine hair shouldn't have been so hard. I stumbled on using the banana gears in black, which created a perfect shape for a ponytail. Just layering them together and tilting a little made for a perfect head shape. As I finished it up with



Edison's head, left and SAM's head, right.



EV-AN 2013 runs amok in Grand Central Station.

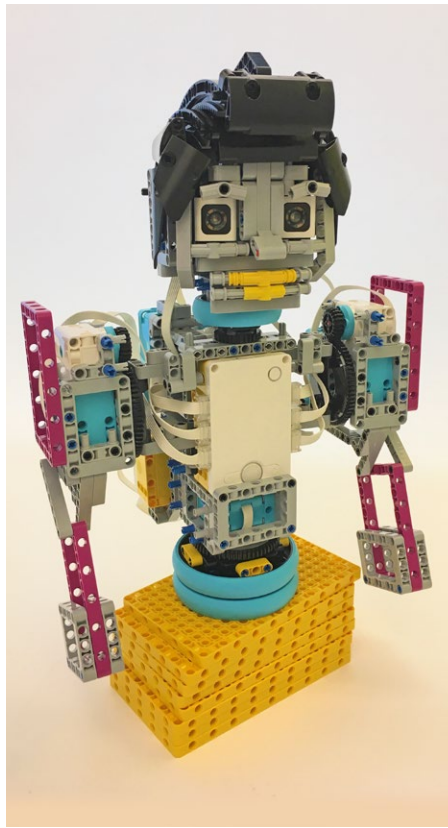
some panels to add the bangs, it almost built itself. Shaping the rest of the head was close to the first EV-AN, building around the color sensor eyes.

Mounting the head on the Spike Prime hub was simple, as this is a natural chest element. I was sure it would just be a 'temporary' mount, stuck on there with a turntable and motor behind the hub, but the mount ended up being permanent, unfortunately leaving me with difficult access to the port of the hub. Adding a couple of frames to stabilize the model brought me to the end of a good first day's building. Turning it on for the first time felt magical, although the eyes were definitely brighter than I would like them to be. Later, I would find a python command to control this.

Subconsciously, I wanted to be able to build the head using only parts from the Spike Prime set and the expansion set. It might have some funky colors, but would be buildable mechanically. The shape came out great for a first draft, though it never really got reworked anyway.

Part 2: Shoulders, Torso

At this point, building really became organic. I like to let the parts speak for themselves and this was no different. The 15M beam above the Hub naturally became a clavicle or collarbone. Attaching a turntable there was easy and provided a natural pivot point for shoulder



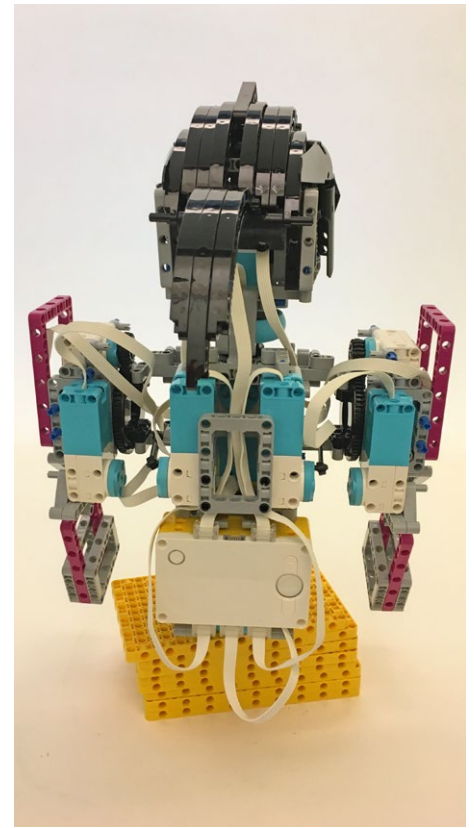
Shoulders and torso.

movement. EV-AN also had a shoulder-raising motion, which gave some strength to him, although it wasn't as expressive as I would have liked.

The new motors really make it fun to connect turntables, and there are so many ways of doing this. Here we can really appreciate the system. The final part of the build really takes advantage of frames and beams with pins. We also have great potential here for adding armor and attachments to the magenta 7 x 11 frame. Feeding the wires through the hole between the hub and arm connection was satisfying. The flexibility was not even hampered! The soft wires are fun and relatively easy to clean up.

Another motor easily fits just below the hub, making a sort of belly-button area. With Gundam-like proportions, the torso ends up being quite small. As with the shoulder joints, the torso needs to move an immense amount of weight and torsional stress. It was tempting to use a worm gear construction, but actually, the motors are less conducive to that build with the 90-degree turn needed. At this point the build already had a lot of character, and movement was quite stable with enough control.

It seemed natural to use the larger wheels at the waist, matching the neck joint. The model would still balance, as it was still quite light. This was also a great way to show off the possible connections of the wheels. The waist also seemed



Back.

a good breaking point for dismantling when traveling. The waist could be locked into the hips using the wheel, though this would take a lot of work. I chose to keep it loose for easy transport, although this would haunt me later. A lot of holes and pins were left exposed on purpose, for the later addition of armor and detail.

Part 3: Back and Biceps

This was easily the most interesting section of the robot, and one could probably spend a college semester on the elbows alone. It again began organically by finding a way to power the chest movement and attach the second Hub. The hubs run independently and they don't really need to be synced. That being said, I still want them to be synced, and I hope in the future we can achieve this and get some really fluid actions. The front hub controls the eye color sensors as well as the shoulders and elbows. Yay for six ports! The rear hub controls the eye movement left to right, and the chest, neck and waist movement. They all run pretty much randomly but look cool when it's all running together. Having a blocky, square hub with lots of holes and so many places to connect makes building such a joy.

The shape of the small motors made them easy to add to the back. Some trial and error was needed to provide enough movement for the chest. The subtle movement really gives it a lot of character. More movement would have

been possible, but three modules gave just the right range. The dot on the motor provides a zero point, which was very useful for both placement and programming.

The elbows are a mechanism that I haven't seen many people use, though I've been using them for years now since my first professionally designed mechs. Most LEGO elbow joints have a 90-degree motion, and my biggest goal was to get as much movement as possible. The mechanism is a four-bar double rocker with crossed follower beams and equal length base and top linkage. This allows the joint to completely invert in either direction thus giving a full range of movement, and you can give it the strength it needs depending on the mechanism used for powering the lead linkage.

Here, I used another four-bar mechanism leading from the 'triceps' of the model to push the arm of the crossed four bar. Without any additional load, it can bend to allow the wrist to meet the shoulder. Ultimately the design of the hands and forearm needed to be as light as possible. With everything on, the elbows get about 100 degrees, maybe 110. A worm gear would allow for the full motion, but I preferred to get better speed.

It's pretty hard to power the joint though—in my previous mech, I had to double up the mechanism and throw in a 40-tooth gear and

click hinges to stabilize the movement. You're also left with a huge gap where the joint is. I spent a lot of time studying Gundam model kits to see how they close that gap and would eventually add greebles and additional parts. The joint was only used in the elbows of SAM, but in my full-size grey mech it really allows for some interesting poses when used in the knees as well.

With so much space for adding armor and parts, SAM was now really beginning to take shape. I was able to run the first test program with upper body motion, and really loved the zero position of the motors because... However, if the motion got too fast she'd fall right over.

There's so much space for adding armor and parts.

Part 4: Leg Day

From the outset, these legs needed to be different. In many of my previous mechs, the joints were completely motorized at the joints and while that was fun, it wasn't any fun at demonstrations. Inspired by the large Gundam Unicorn in Japan, this one would have animated armor instead of motorized articulated joints. I also decided to incorporate a stand.

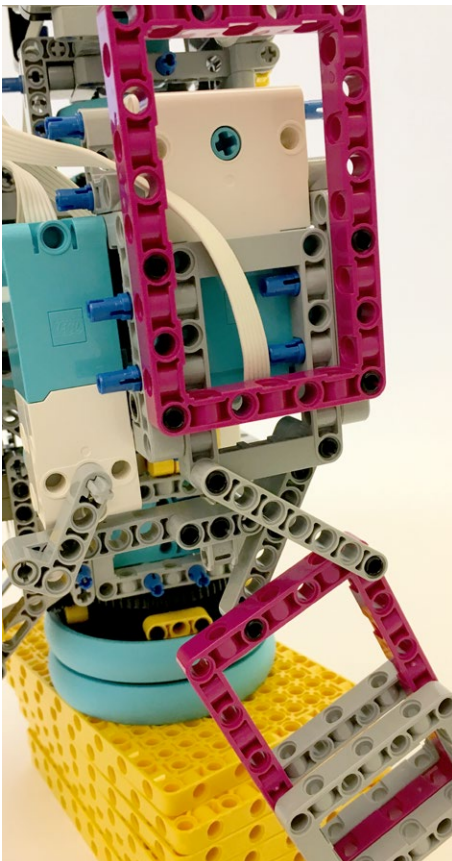
The last big robot I built took forever to pose in shows, but at least he would always hold the position. EV-AN ver. G was a big step up in size, but it wasn't as interesting since everything

moved so slowly. I wanted SAM to be able to react to her viewers nearly instantly.

The angular hip uses some clever placement of 3x5 L-beams to get the right angle, and to allow the wheel to become a belt and stand. The turntables don't have any gearing, and use just a 12t gear on a blue axle-pin to keep the position of the legs in place. She would never walk on her own anyway, and the angle gives the right kind of splay to the model when turned just slightly forward. The lateral splay and thigh rotation were fixed, as this would just end up on a stand at exhibitions.

For the shoes I wanted a shell-top, sneaker look. And again, I wanted to use only the shapes available in the Spike Prime set. The heel uses a 56m 2k molded wheel to keep the friction on lateral movement and it doubles for the style and back of the shoe itself. All the friction joints at the ankle seem a bit weak, but they hold up. I would later add some spring dampers for additional stiffness and motion-limiting—all it needs is enough motion to handle standing positions.

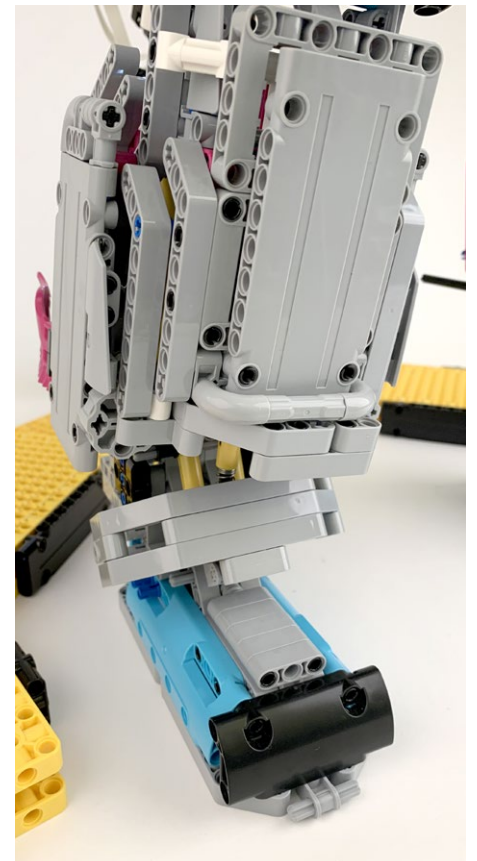
Taking inspiration again from Gundams, the knee needed a double joint with a strong and lockable position. Here I opted for worm-gearing and gear rack. Linear actuators are simpler, but they don't provide enough travel for a complete knee bend. Without any armor, the joint should be able to bend completely, heel to hip. I started



Elbow assembly.



Legs.



Lower leg and foot.

by connecting two gear racks to their respective pivot points. The upper thigh doesn't need the same travel as the calf, so they use different racks.

At the upper thigh, a 13m rack was used and it slides just adjacent to the motor. The worm gear is the 1m gear with a slightly larger diameter than the classic 2m worm. Sandwiching all the layers is a bit tricky, but it mostly all fits within the maroon frame. At the front of the knee is a double-angle beam as the main lever point which holds the leg and is connected all the way to the thigh. I didn't yet know what the armor plates would do, but having a motor there kept my options open. I dreamed of having a Robocop style gun holster, but there just wasn't enough room.

The lower leg was very similar in construction except it used the 14m gear rack with two holes. It was a bit trickier to have it slide over the motor, but I was able to work around it. Again, sandwiching everything to make it fit right was a small puzzle.

I hate stands, but they're necessary. The early version was just a simple layout of technic panels with pegs sticking out to keep the feet from moving. This worked well for me with EV-AN, but definitely wasn't the most elegant solution. The stand would also need to hold the spike prime hubs for the legs. There was potentially room on the legs for these, but it just didn't give the right look. As the stand was integral to the model,

this was the right decision in terms of design and function.

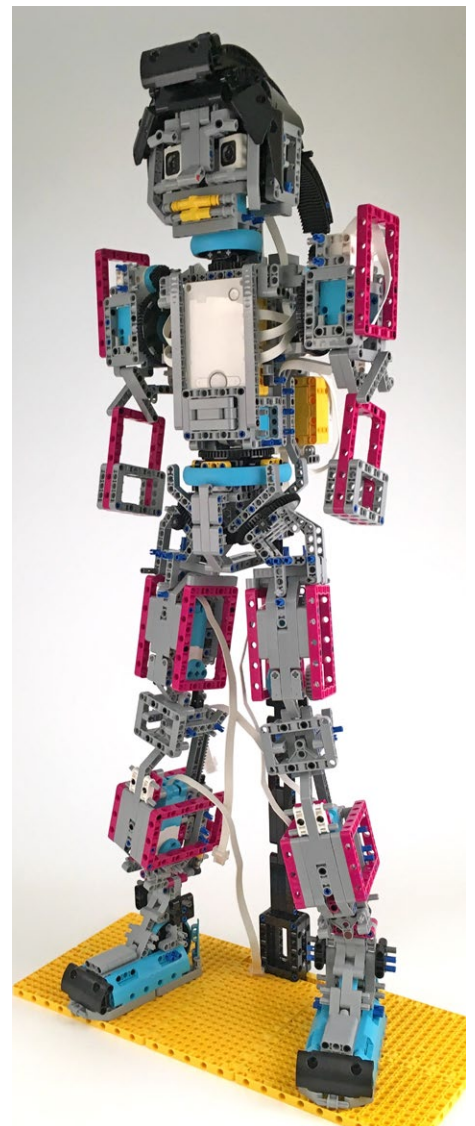
SAM balanced really well on her makeshift stand and had just the right kind of stance for demonstrations. The joints still needed extra support as they were relatively weak at this point. She would shake pretty violently with waist movement, which was a weak point I couldn't do much about, though lowering the power seemed to work. At this stage, the robot was now an open canvas for styling.

Part 5: Dress Up

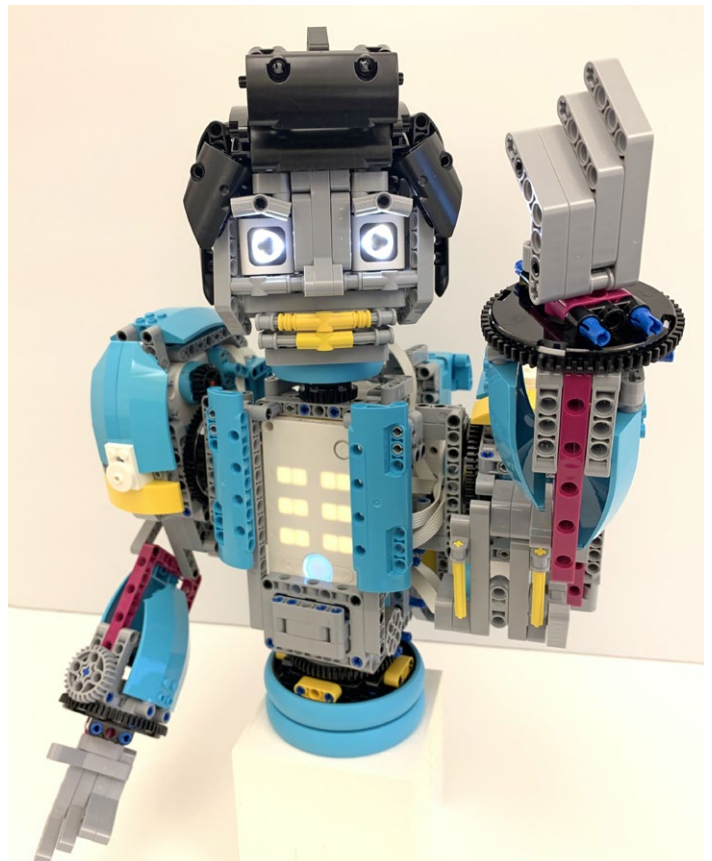
Going back to organic rather than mechanical building can be quite fun. I was definitely looking at the shapes and bricks available in the Spike Prime set once again to dictate what shapes would lend themselves to SAM.

The decision to make fixed hands came from Gundam models that had swappable hands. I thought it would be easier to change a whole hand than to make them completely poseable. An additional advantage was that the hands would be much lighter for the elbow motors to lift. Bowed bricks created the perfect shape for the shoulders and forearms. A variety of techniques were used to support the build and make sure parts wouldn't fall off when being transported or handled.

After doing the initial strength and support



Left arm.

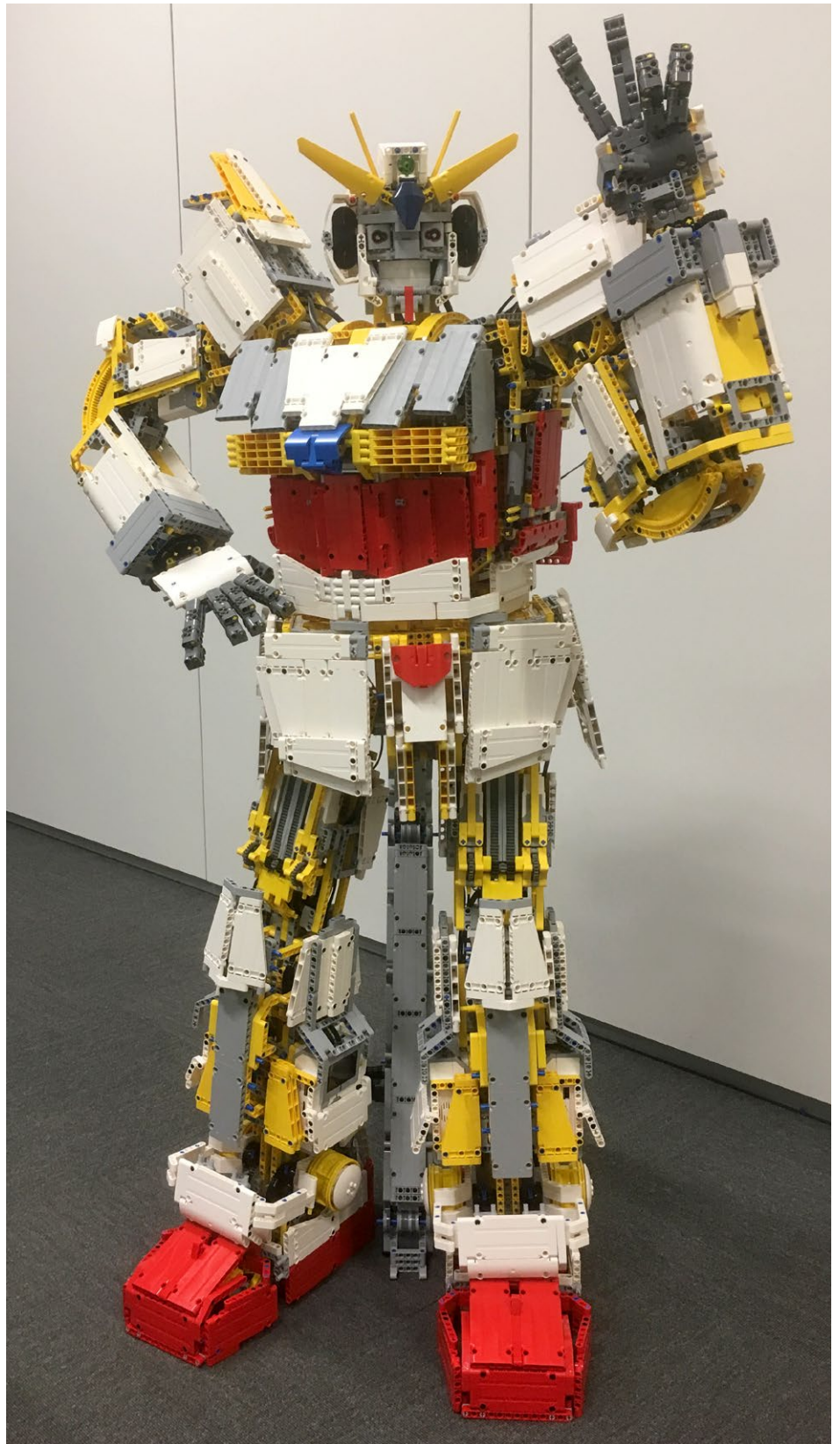




build for the legs, armoring came down to appearance. I used a sketch program on my iPad to check colors and shapes over some layers. Eventually I chose grey and the character really came through as sporty. The shoulders are a bit high, but still feminine.

The model still needed to be able to stand on its own and be structurally sound, so the opening armor panels really needed to be simple mechanisms, meaning there was no way to add a ROBOCOP-style gun in there. Even then, adding functional armor was going to add some volume to the look—she would have thicker legs. At the thigh, the armor opens out to the side and at the front. At the calf, it would expose some of the internals, dropping armor towards the ankle, and the rear leg would expose a vernier thruster or rocket of some sort, which would end up being a color sensor. Lots of shock absorbers were added for detail and metallic bling. I built one leg completely to see what needed to be fixed before duplication, and to show a before and after of the exposed functions.

It was also fun to explore some of the detailing and layering of panels. Magenta wings fit nicely in

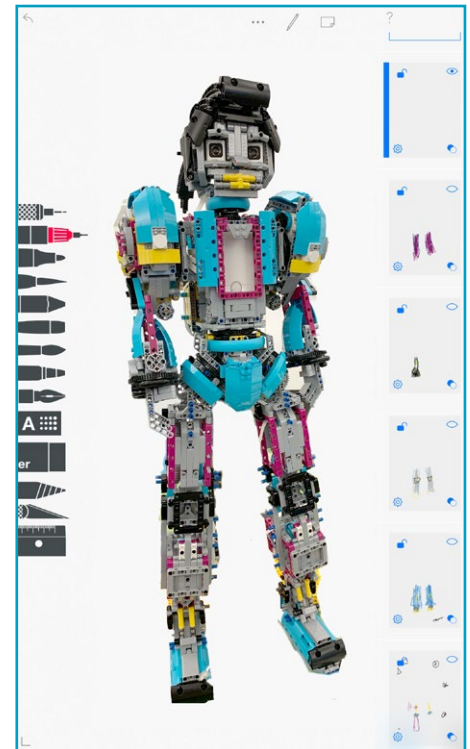
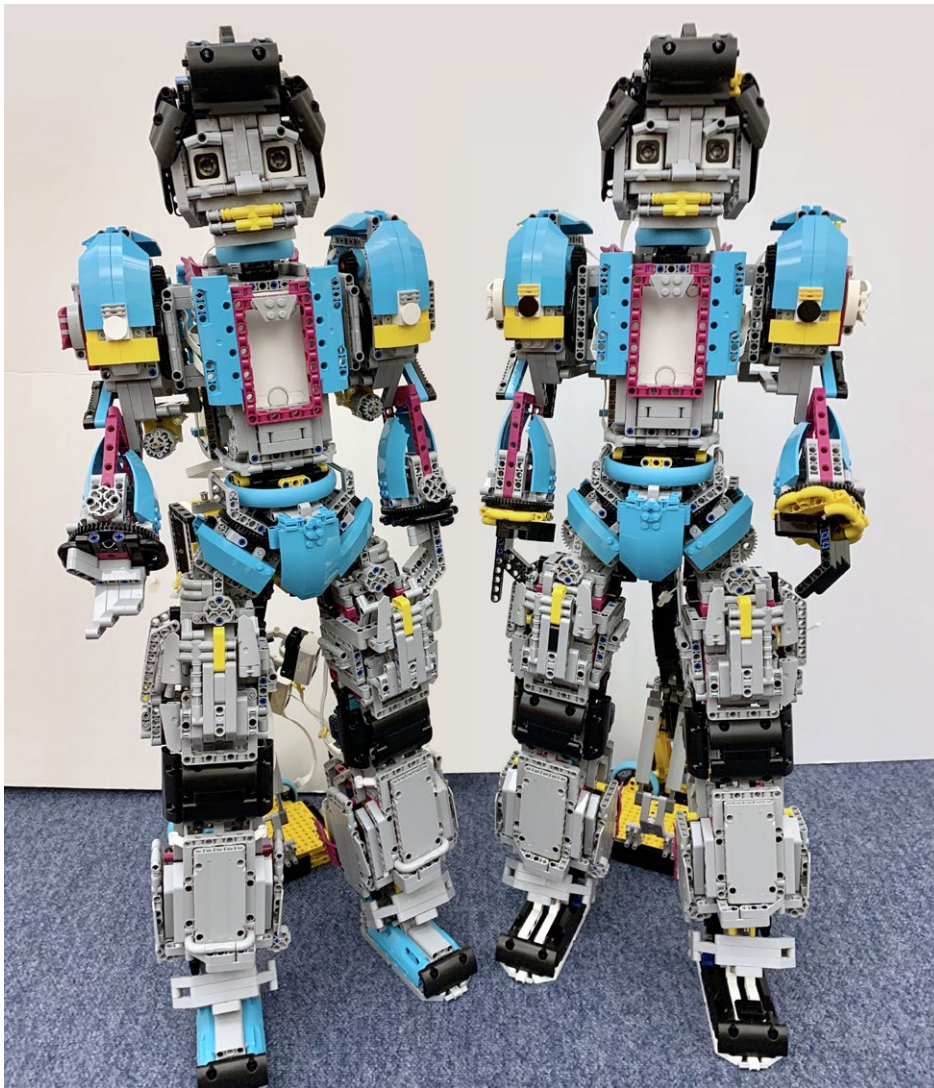


EV-AN ver. G.

the color scheme and made it onto the calves and the shoulders. A pair of white wings came to her back for an angel vibe.

The stand ended up having a shape with some inspiration of a hall of armor. Getting there would take a slightly off-measurement placement which ended up creating a nice shape. Without the locking beams, it would probably explode on the stress alone. The shaft of the stand is supported

and poseable using linear actuators. They give an industrial feel and great complimentary shape if ever exposed. There are two actuators in the base and one at the top where the stand meets the robot's hips. It wasn't completely necessary to have two, as there are only four motors, but it seemed cool and gave the right symmetry as well. Touch sensors for manual control of the armor plates fill out



The final product is incredibly expressive and the build was great practice in learning building techniques for this scale. To me she personifies the character of SPIKE Prime in terms of color and feeling. She's an 80's era workout girl. I'm incredibly happy with the lines and proportions and could definitely use this frame for more robots. But of course, the build is never finished. There is so much more that can be done!

the sensor ports as well as an additional four ultrasonic sensors for lights. I added one more hub to the bottom of the stand for more lights and effects.

She really had a lot of wires that needed managing and I had to make sure everything worked out in terms of spacing. I also had to think about how to dismantle the stand for transport. As I put this all together, she was really taking shape and a few test videos showing the armor working were much better than photos.

Part 6: Details Details

I had the incredible privilege of getting SAM to a photographer to capture all of the details and features of the robot. I rarely get to do this for any of my robots, as they are usually pretty big and don't fit in the smaller photo booths I normally have access to. The model is quite imposing in a darkly lit setting with all of its lights on.

The finishing touches included getting the robot fully symmetrical and fixing a few other things. Probably one of the biggest fixes was to get better access to the charging and programming port on the chest Hub. This meant dismantling

the whole neck assembly just to make space for a wire. The hub itself needed to be moved forward, and this affected almost the entire upper body! Additional final details were the wings, wrist cuffs, knee pads, and touches of color here and there.

Adding six additional ultrasonic sensors to the stand for lights provided for some potentially cool effects at the base, should I decide to continue programming them. With the basic SCRATCH-based coding, you can program flashing, waving, and even some fade effects. The stand ended up more complicated to dismantle for transport than I'd like. It can also be simplified by removing the lights which makes for an incredible clean picture. The stand does compliment the colors of the model though, so I think it helps to complete the model.

The programming seemed pretty simple: random movements to target positions. In EV3-G I had to create a pretty special set of commands to make this happen. The zero position of the Spike Prime motors really made this much easier, as did connecting the motors for movements nearly directly without gearing.

BONUS: The Twin

A time came when SAM needed to be in two places at once and I had to decide how that was going to happen. The result: a twin sister. She wasn't exactly the same though. The younger sister had a bit more of an edge. I gave her a bit more black in her shoes and gloves, and a yellow stripe in her hair, as well as changing a few other details.

Funny enough, I happen to know a set of 'Sam' twin girls who I met in the context of robotics. But this was just a funny coincidence, and I never intended to build two copies of the same robot. You always want to change something. Building SAM again gave me a deeper appreciation, but I wouldn't ever want to make instructions for her.

[1] you can learn more about EV-AN on his dedicated FB page facebook.com/EV3Android

[2] EV-AN 2013 built to go for some events and photo shoots (photo). EV-AN 2014 did a lot of traveling around the world and had a few aesthetic upgrades to the original, and EV-AN ver. G 2017 was a 4 foot tall 1/20 scale Gundam with EV-AN's head as a starting point.