NXT Space Shuttle and Hubble Telescope

The Symbols of the Conquest of Space

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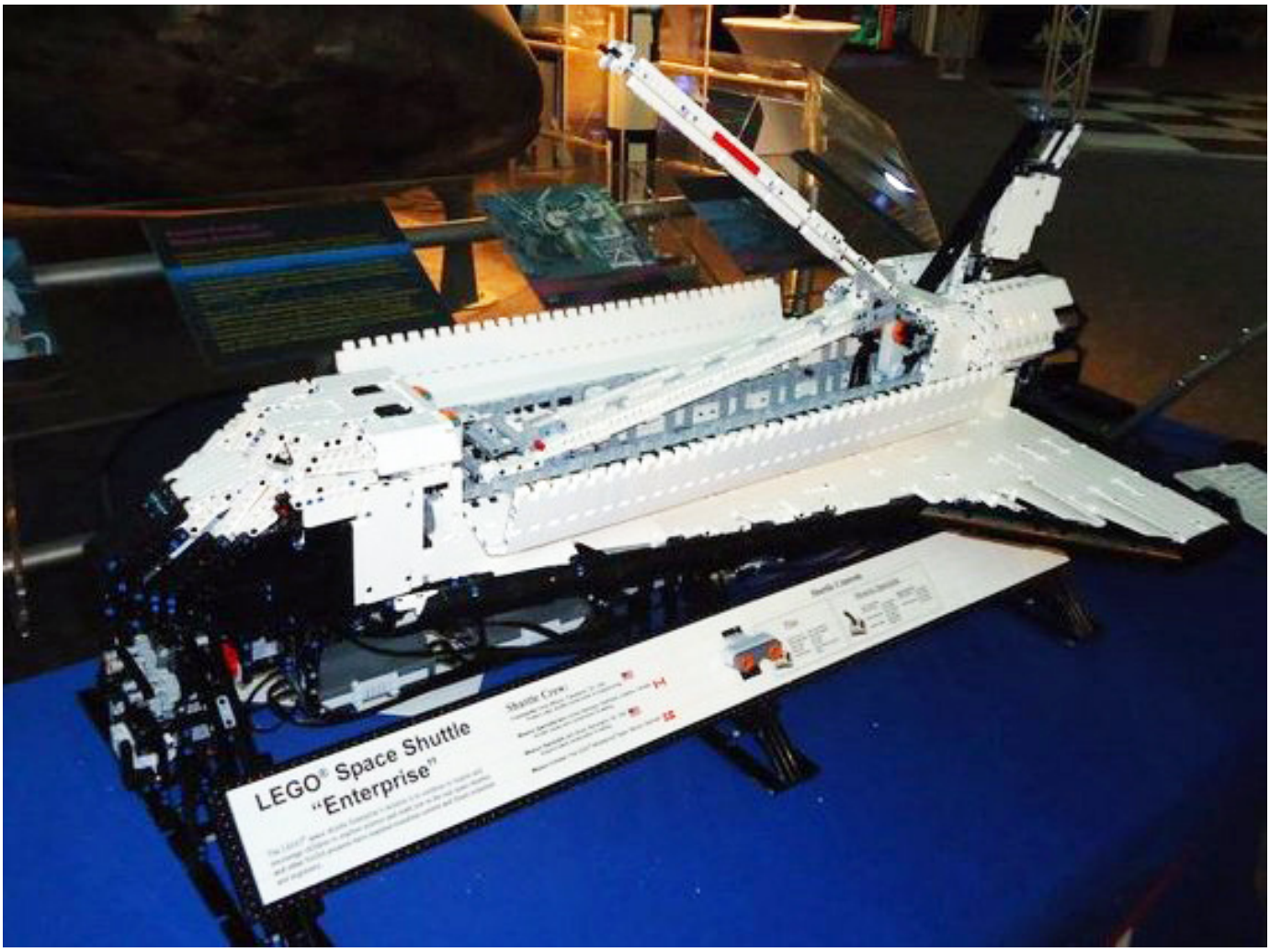
The Space Shuttle is probably the most complex machine ever built, and one that sparks almost everyone's imagination. It was awe inspiring when it was presented, 30 years ago, and has become iconic in our current conception of space travelling.
The NXT Space Shuttle, though not nearly as big or complex as the original, was built as a tribute to this icon and is remarkable in its own way. Wanna take a ride?

Zwolle, October 2010 – during a brainstorming session at LEGOWORLD, the MCP huddle around Steven Canvin, the LEGO MINDSTORMS Community Manager, to propose and comment ideas. Suddenly someone says: "wouldn't it be great if we could build a cool large scale model or something we could present and give to NASA!" Almost immediately the Space Shuttle was proposed, with solid rocket boosters (SRB), an external tank (AT), the mobile launch platform and the crawler… no lack of imagination there.

After the initial positive feedback, Andy Miluzzi, who proposed the idea, opened a thread on the MCP forum to poll who would be interested in participating in the project and how it could be carried out. In his own words: *"I have always been a fan of the United States space program (NASA). As I am sure you know, NASA has been critical to many technological advancements we now take for granted. For example, the cordless drill is a direct result of NASA work. As a result, some of the technology behind LEGO® MINDSTORMS has come from NASA.*



I thought it would be cool to pay tribute to the shuttle fleet, which retires in 2011 and thank NASA for all they have given us." Other motivating factors included that it would be a way to thank NASA for the inspiration they've given to many people over the years through the space program and use LEGO as a way to help continue to inspire kids through the display of this model.

It took some time to take stock of the possibilities and decide what direction the project should take. Building a massive model of course has the immediate wow-factor, but LMS is all about robotics and being able to interact with the model was a first requisite for the design. It takes the crawler on top of which the complete launch stack (Shuttle + SRBs + AT) about 6 hours to cover the 3 miles from the vehicle assembly building to the launch pad and replicating that in scale with LEGO®, although impressive, would hardly be very attractive to watch, and hard to interact with. In the end, the construction team, made up of Andy Miluzzi, John Brost and Marc-André Bazergui, decided to build an interactive model of the Space Shuttle with lighted engines, working flaps, ailerons and rudder and cargo bay doors that open and close to deploy the fully functional Canada Arm.

The shuttle was built without any blueprints. *"To construct the shuttle, I knew the rough dimensions and looked at pictures from shuttle launches and landings"* says Andy, who is a huge NASA fan. *"Much of the design was how I thought of the Shuttle."*

When Marc-André Bazergui was asked to participate in the project he jumped on it. *"I offered to build the Canada Arm – being Canadian myself – and my proposal was promptly accepted. The arm seemed like such a simple idea but I was soon faced with the obvious: it was meant to work in zero gravity! So the goal was to build the longest arm I could before the LEGO gears cracked. This turned out to be very instructive and a fun challenge. Of course, because we are not in space, this LEGO arm can barely lift a minifig let alone Matthias' Hubble telescope!!!*
The key elements where the use of the new 5x7 frames to brace a worm gear onto a large turntable - this turned out to be very strong! I had to put a big weight on my assembly when testing its lift power, as if it was braced into the heavy shuttle. I shipped the arm in sections as I knew Andy would have to shorten my design to fit it into the shuttle, so i made it easy for him!"

John Brost was in charge of building the support for the shuttle. *"The design changed very little from the initial concept ideas. Basically we wanted a single long beam that the shuttle would attach to. At each end this beam would be attached to a leg that would let the beam rotate, thus allowing the shuttle to "fly". I also wanted the entire structure to be as small & hidden as possible so as not to detract from the shuttle itself. Lastly, I had learned from the last large project I worked on (Monster Chess) how important it was to be able to break things down for transport, so I wanted to design the support stand so it could easily break down & be put together again.*

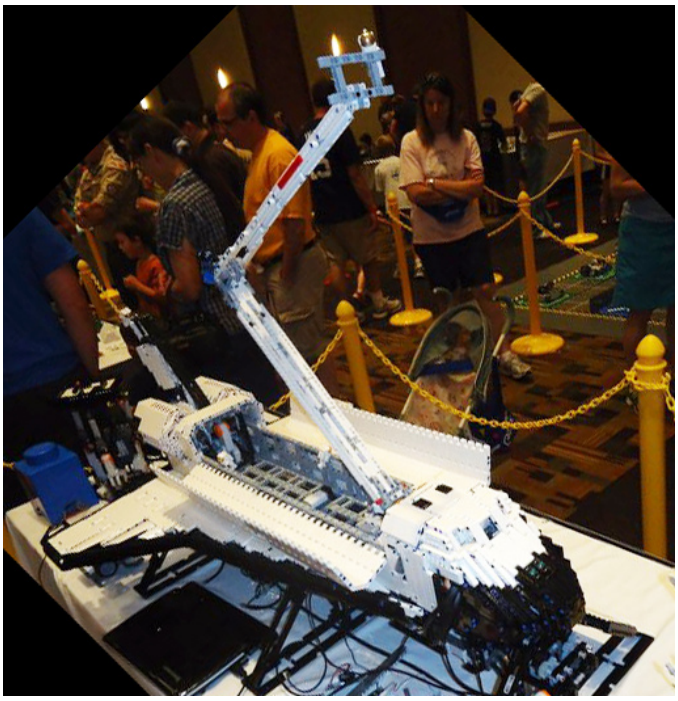
The design of the beam was going to be central to the design of the stands, so I started there. I quickly discarded a triangular truss design as was too large (cross section) and really didn't have the structural rigidity that was required. My next design, based on the LEGO Technic frame and flat panel pieces, was much smaller and much more rigid. It became the final design for the support beam. However, in testing I found that a single beam of this design wasn't rigid enough to span the shuttle entire length. Therefore, I modified the design to include a third support leg in the center of the shuttle so the beam only had to be half the length.

For the leg I went with a triangular design, again keeping with the idea to make it as small as possible. The use of the turntable pieces and the system for driving them to make the beam rotate is my favorite part of the whole build. A turntable is fixed to each end of the beams. Each support stand has a slot that the other side of the turntable is set into. On the underside of the turntable are four z16 gears that drive the outer ring of the turntable, causing the beam to rotate. These z16 gears are driven through a z24 and worm gear reduction by a NXT motor. This arrangement is duplicated on each end support stand. The central stand is not powered.™

Continued discussions with Andy during this part of the design phase revealed a need for a place to put the 4 NXTs that were to power the shuttle & stand. I realized that I could hang them underneath the support beams where they would actually act as a counter-balance to the shuttle attached above the beam. The nameplate/marquee on the front was a last-minute addition. First and foremost, it gives us a place to put information about the model and thank those that helped out with it. Second it helps to keep the three support legs aligned when installing the support beams during re-assembly.

The stand breaks down into 7 components (3 legs, 2 beams, and the nameplate splits into 2 pieces) and it is a snap to re-assemble. It also functions well, it is able to support and reliably move a shuttle that weighs about 12lbs, while only using 2 NXT motors all while being somewhat small & lightweight so as not to detract from the shuttle itself."

The overall dimensions of NXT Space Shuttle are quite impressive: the Shuttle itself was built with around 8000 parts. It is 1 meter long, 40cm tall and has a wing span of 76cm. After extending the Canada Arm the model is about 120cm tall. In all, the model (Space Shuttle, stand and Canada Arm) uses 11 motors, 12 sensors and 6 NXTs. These communicate through RS485 and Bluetooth. The software is written in National



Instrument's LabVIEW. HiTechnic Accelerometer, Gyro, and Color Sensors are used to control the system. It also uses light sensors and touch sensors to limit movements and PF lights illuminate the model.

So exactly how is the model interactive? *"Like any LEGO® Brand kit, we wanted to have a 'play experience"*, Andy describes. *"The model is designed for two people to control the shuttle. They are given a short mission to navigate the shuttle to the International Space Station and replace a broken support. After the pilot has successfully moved the shuttle into position and it is stable, he opens the doors and the arm operator takes over. The arm has to be deployed (an automated process) from the parked position and then it is up to the operator and pilot to ensure the beam is safely placed. Once complete the arm operator has to store the arm and the pilot need to close the doors to prepare for re-entry."*

Not all shows are the same and sometimes how the Shuttle is displayed needs to change. *"Taking the Shuttle to a bigger LEGO show or to a school is a completely different venue. The Shuttle needs to be flexible and allow for both autonomous and unrestricted control. For example, in a school, we can explore how the mechanics of the model work, showing the limits of the sensors and motors. At a larger show, it is much easier to let the Shuttle run itself and look impressive (but it still does some "special functions" when you trip the ultrasonic or color sensors)."*

The model was first presented at Yuri's night (April 16th, 2011), a commemoration of 50 years of space travel, at NASA Langley Research Center. It has since been on display in Local schools, inspiring children to pursue a career in math and science. It has also been to Brickworld and will be shown at a number of other events including the final launch of Space Shuttle Atlantis [1].

Originally the shuttle was also going to feature a scale model of the Hubble Telescope. However, when it became clear that the Canada Arm was not going to be able to lift it, Matthias Paul Scholtz developed it further as an interactive stand-alone model. This allowed not only for choosing an ever bigger scale of the telescope's model (the final model is at approx. 1:25 scale), but also to separate the release date of both models - a very important point considering the tight deadline for the project as well as the fact that special LEGO parts were prepared for the telescope.

So why the Hubble telescope? Matthias explains: *"LEGO robotics in connection with space always has been a special favourite to me. While I never have been that much interested in manned space flight, the idea of sending robots into space keeps bearing a particular fascination for me. So when I was asked to contribute to the LEGO MINDSTORMS NXT Space Shuttle project, instantly the role of the shuttle in transporting unmanned crafts into space came to my mind and I jumped on the occasion to provide something as a payload that had actually been sent into space in the shuttle's cargo bay."*

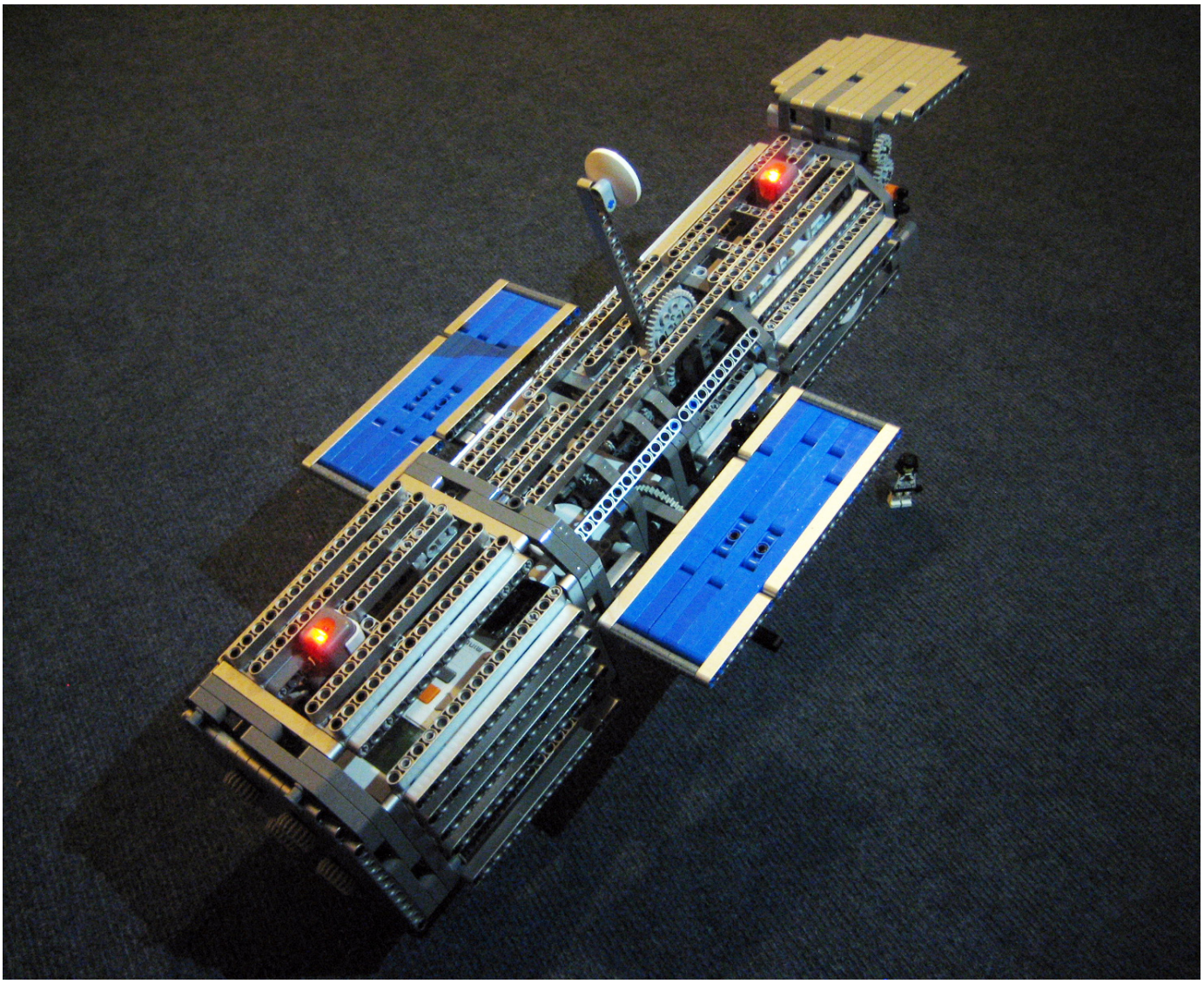
"Most of the probes that had been transported by one of the various shuttle missions were out of question as they were simply too small to integrate any animation. However, there was one device that did not only meet these very requirements but also holds a fascination that is still unbroken after all its years of service: the Hubble Space Telescope (which incidentally celebrated its 20th anniversary in space at that very point in time)."

Like many other NASA projects, the Hubble telescope has been well documented and much material is available from official NASA sources [2]. Even so there were many challenges in the build. *"A particular challenge in this project was the shape of the real telescope: it consists more or less of two large tubes that are arranged behind each other. Building round structures with LEGO Technic parts alone is not easy. On the other hand, I did not want to use classic LEGO curved bricks which would have increased the weight of the model too much. I ended up with rings of bent beams that provide the latitudinal structure and result in two octagonal "tubes" – a sufficient approximation to the real appearance of the telescope."*

"To make the longitudinal structure, I started with a design that made the tubes an array of these rings simply arranged directly behind each other. This looked quite good, but the resulting structure turned out to be much too heavy and unstable. What's more, it was very hard to attach any devices to it. Consequently, I changed to a more lightweight approach, with the rings only providing a skeleton of the outer hull and longitudinal beams connecting them using the indispensable Hassenpins. The resulting structure was not only much lighter but also much more stable than the first design."

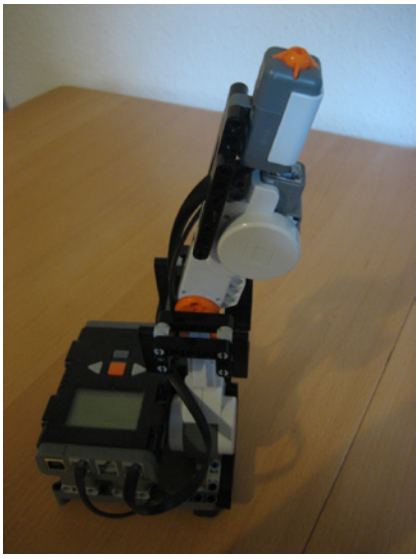
"That way, I was able to attach devices on the inside: the mechanisms that operate the front lid, the antennas and the solar panels. From the pictures one might deduce that the front tube is pretty much crammed with them. This was one of the toughest parts of the building process: designing all these geared devices to work reliably, fit into the octagonal structure and length of the tube and still keep it maintainable from the outside."

"A particular aspect of the model is the colour of the parts used. From the beginning I strived for mimicking the silver-metallic appearance of the original Hubble telescope. There are no silver LEGO beams of the required size and number commercially available; I did not even have enough gray ones at my disposal when I started the project. However, Steven Canvin, community manager at The LEGO Group and sponsor of the project, left no stone unturned to make sure the necessary silver beams were specially produced for this model."



“This was certainly the most challenging NXT project that I did so far, and no doubt one of the most rewarding too. I’d like to take the opportunity to thank in particular Steven “The Captain” Canvin for his ongoing support.”

The model of the telescope is 51 centimetres long and 16 centimetres wide, weighs around 3 kilos, and features three NXT motors and two light sensors that are controlled by an NXT.



The project is not yet completely finished yet, although the telescope is fully operational and can run in independent mode or be controlled with an NXT remote control. When the project is completed a base will allow the telescope to move in three dimensions, so that visitors can point the telescope remotely into any direction desired. There are also plans for integrating a web-cam into the front of the model in order for the telescope to take pictures and send them to an “earth control station”. Due to the state of the project, the telescope model has not been on display yet. However, it will be complete by autumn and will be displayed on several major LEGO® events around the world after that. Interest has been voiced also to permanently exhibit it in technical museums eventually.

As the project advances you will be able to see more pictures and videos of this telescope project on Matthias’ website http://mynxt.matthiaspaulscholz.eu/

[1] For a list of locations you can see the NXT Space Shuttle and the LMS Hubble Telescope, please visit our blog or FB page
[2] see http://hubble.nasa.gov/ and http://www.nasa.gov/mission_pages/hubble/main/index.html
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