Rosetta's comet touchdown: LEGO® in space

By Maarten Roos

An idea

In October 2009 I sent an email to media@lego.com. I had an idea for a series of educational films about Mars exploration, and for one of the films I wanted an engineer and a scientist to build a big Mars Rover out of LEGO®. Well, I never made the Mars films (did not find financial support), but I did film LEGO, a lot of it!

A few days after my first message, I received an enthusiastic reply from Steven Canvin, the LEGO MINDSTORMS Marketing Manager at the time. It was so enthusiastic that I decided to go and visit him.

In the meantime, a science colleague of mine pointed out that people at the European Space Agency (ESA) had been using LEGO for some time to help them plan space mission operations, in particular for the Rosetta mission (http://sci.esa.int/rosetta) and the Venus Express mission (see http://sci.esa.int/venusexpress). So I found Detlef Koschny, a planetary scientist at the European Space Research and Technology Centre (ESTEC / ESA) in the Netherlands, who had been building small models of those missions. A few days before I went to Billund, I managed to visit Detlef, and recorded a short interview with him (LEGO in space mission operations).

The conversation with Steven was short (he seems always in a hurry :-)), but effective. He introduced me to LEGO MINDSTORMS (I had never heard of it) and he said he wanted to develop something using LEGO MINDSTORMS related space exploration, something that can be shown on interactive exhibitions, or used in class rooms, etc.. He gave me a MINDSTORMS box and I left. During the 11 hour drive back from Billund to the Netherlands, I thought about our conversation and a concept grew in my mind: an educational kit with LEGO MINDSTORMS, from which students can build a model of a real existing spacecraft that mimics some of the functionalities of that spacecraft. But which spacecraft should it be?

The next day I went to ESTEC again and gave Detlef the MINDSTORMS box. We discussed the idea and Detlef suggested that probably our best bet would be to take the Rosetta Lander: it is small, it can stand (not just orbit around a planet as most other space missions) and it is now on the way with the Rosetta mission to a comet (named 67P/Churyomov-Gerasimenko). Rosetta will arrive at the comet in 2014. If we developed this idea now, and bring the kit on the market, then we could also bridge the three-year long sleeping period that Rosetta would be put into from mid-2011 until mid-2014, and during which no media attention was expected. This way we could keep the mission alive in the minds of the public.

I asked Detlef if he could make something using the content of the MINDSTORMS box. Ten days later I visited Detlef again, and he had indeed built a first model of the Rosetta Lander, together with his son Julius. The model could rotate and had a drilling function, all controlled by the NXT computer. I took my camera out of the bag and recorded another interview with him (The first LEGO MINDSTORMS model of the Rosetta Lander).

With all these ideas and tests in hand, I drafted a project on paper, in order to help find support to make it come true. I first found support at the German Space Agency (DLR), from the people of the communication department. ESA also showed interest and we submitted the project for support from the European Planetology Network (EuroPlaNet) outreach programme. LEGO also entered as a sponsor. Early April 2010 we got a final OK from all these organisations and we were on the way to make our educational kit.

The Rosetta´s Comet Touchdown Kit

At this point in time, we started to create all the elements of the Rosetta's Comet Touchdown educational kit., a kit around the theme of cometary exploration and using LEGO MINDSTORMS. The idea was to officially present it during the European Planetary Science Congress (EPSC), organised every year by EuroPlaNet, one of the sponsors. After that, it would be tested by a class at a school to see how it works in a real learning environment. The target group are students 15 years and older (no upper limit!).

The kit is composed of three elements:

1.- A demonstration model of the Rosetta Lander;
2.- a series of films with background information about comets and the Rosetta mission;

Building the lander model (by Martijn Boogaarts)

A special mail from Steven Canvin came to ask if we could build a functioning LEGO® MINDSTORMS model of a lander that had to show its actions during both a movie shoot and on events. Such a task is not simple, since most of the things you see in the movies are faked, and have to be repeated over and over again.

As a group of expert builders we said “sure we can” even before we realized what the whole assignment would mean. We started by getting information about the real lander and also the requested movements like turning, drilling, measuring the temperature and deploying the landing feet. As a good start you just take all the key elements (motors, sensors and the NXT (computer brick) and just pile them up to determine a basic size of the model. That will help you in developing other parts like the feet. Since the landing gear should be strong, sturdy, deployable and interlocking when fully extended it was important to start with that.

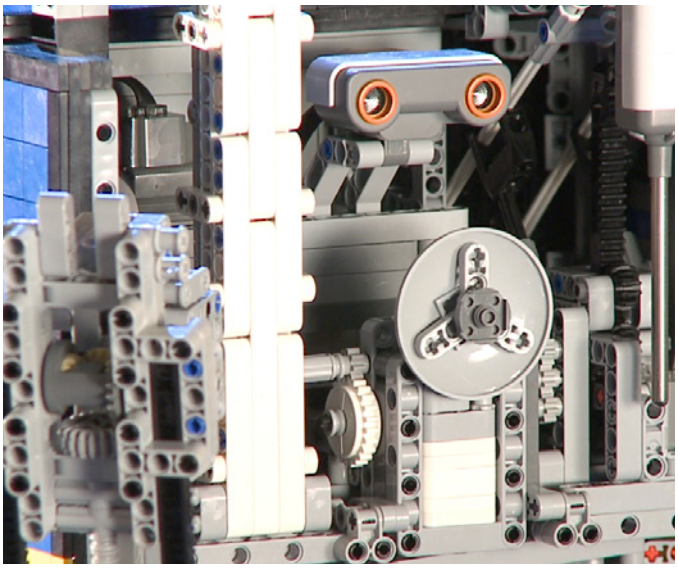
A three legged shape is not easy to build with LEGO since most the structures are square, or 4-side based. As a good thing there is a small pulley wheel with 6 holes, which gave us an option to build three legs around a center column. Eric, Gerrit and I started building with a large pile of technic parts and showing the others what we had invented, trying to impress the others with all the good designs but also understanding that we needed to take the best design in the end. It took us about 20 legs to get to a final version that was
strong, auto interlocking and even had the drills implemented, not with wires, like the real version, but with a differentials.

Since all of us have a good view on what LEGO parts did and still do exist we quickly found that there was a nice part, used about 3 years ago in the mission to mars series, that could act as the drill. A small Bricklink order was placed and a few days later we could implement the good looking drill. After the legs were stable it was time to move on and start with the body, with less than one week to go we still needed to work hard to
get all the functions inside the main hull. As a special feature we wanted to use real LEGO solar panels but unfortunately they did not fit as well as expected and we only had the older green version, since the newer version was not yet available. Some black plates and blue 2x2 tiles looked almost real. For the outreach arm that holds the temperature sensor (a rock drill in the real version) we could not determine how it was done form the drawings and the movie of the moc-up model, so we just implemented a swing with the longest possible axle (16 long) that would still fit inside the lander. Later we learned that it was actually a flat band rolled up like those measurement tapes, and when extended, it would curve like a tube, so it gained all the stability needed to support the weight of the drill. Unfortunately that is not buildable with LEGO parts.

On the first day of the movie shoot we drove to the studio with several boxes full of 2x4 bricks a lander and a large box of assorted spare parts, just in case. This was a really good idea, since we found that we did not implement most of the technical measurement instruments, because we as LEGO builders just did not consider those parts important to build.

While shooting some other parts of the movie we started to build and added 4 more sensor mocs to the lander. While building we discovered that the turning mechanism was not working as expected, resulting in a major inside rebuild. The first shots were already done so we could not change the outside as you would see the difference in the final movie. Just in time we got the model working and we could start making the shots showing its functions. Then it turned out the robot did not perform its functions at the moment they were needed in the film, so we ended up compiling, downloading and starting small sub programs via the Bluetooth link, almost as a remote controlled vehicle.

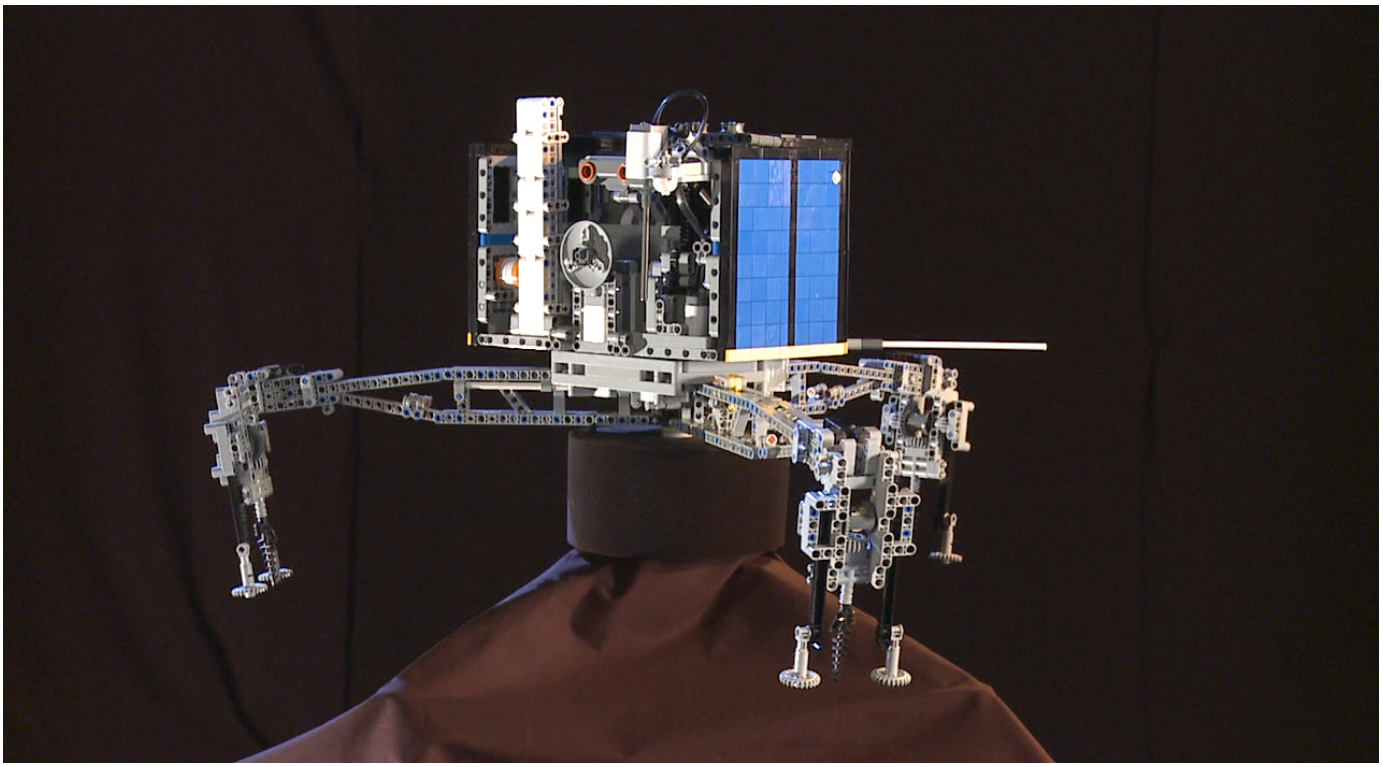
Building a model like this calls for a lot of creativity, and we were inspired by new ideas designed for true space travel. Remember that the real lander has to work after several years of flight, in a situation that has never been tested before.



3.- a set of Interdisciplinary Activity Sheets containing suggestions on how to use the kit.

The main film would be about comet research and the Rosetta mission (science and technology) and would feature the demonstration model. So, the demonstration model had to be made. Steven Canvin brought me in contact with Martijn Boogaarts, Gerrit Bronsveld and Eric Steenstra, three LEGO® MINDSTORMS experts, living in the Netherlands. How lucky I was! I visited them late April 2010 and they were immediately full of enthusiasm and said they could make a model. From that day on until the day of the filming of the main film mid July 2010, I went to visit them regularly to see and film their progress. Detlef also came on one of these occasions and showed them his model. I finally edited a 30 minute film of that process, Making the LEGO MINDSTORMS Rosetta Lander.

For the main film, I first wanted to have a huge comet nucleus from LEGO for the background. Already at the very first



meeting with Martijn, Gerrit and Eric, I realised that that would be rather complicated (and very very heavy!). We found a more interesting solution, namely to make a comet surface landscape out of standard 2x4 LEGO® bricks. We quickly tested this idea by dumping a box of LEGO on the floor in Gerrit's building hut (see the intro of the Making Of film), and we realised that it would work. We just needed the right colours (dark for rocky material and white for the ice). For the film we needed a rather large surface and thus in the end Steven sent us some 40.000+ bricks! The main film opens us with dumping them on the table.

The two film shooting days were very intense, but in the end I got all the necessary material and a film could be edited. In the film planetary scientist Dan Andrews (Open University, UK) and Engineer Ulrike Ragnit (ESA) told the story of the comet and the Rosetta mission. This became the Rosetta's Comet Touchdown film.

The kit was officially presented during the European Planetary Science Congress (EPSC) on September 21, 2010, in Rome. I got a lot of help from local people to organise the event, and I thank everyone involved. Steven Canvin sponsored the event by sending a couple of LEGO boxes.

Twelve student of aerospace engineering (3rd year) and 3 students of design (European School of Design) were interested to participate. By chance Martijn Boogaarts was also in Rome. He brought the demonstration model and participated in the event. Detlef also participated.

The Rosetta's Comet Touchdown film was screened, followed by an explanation by Martijn Boogaarts. The aerospace students were invited to build their own model, while the art students were making a work of art around the theme. They did what they could in a short time (three hours). See the report The kit first tested!

The kit tested

At the moment the kit is being tested by students at two secondary schools: the Bocage Secondary School in Setúbal, Portugal and the Szechenyi Secondary School in Sopron, Hungary. Both have received the Interdisciplinary Activity Sheets, background materials (technical and science papers, three basic design drawings of the Rosetta Lander, transcription of the text of the main film), LEGO® MINDSTORMS® and LEGO® TECNICS® truck boxes.

In Setúbal, three physics teachers are guiding the students: Filomena Rodrigues, Fayaz Bahadurali and Sérgio Lopes. At this school, a group of about 30 students is working on different aspects of the kit. The students are ages 16-18. The results will be presented to the entire school before the end of the academic year.

The activities are:

- Model building, (15 students);
- Large painting / graffiti on the theme of comets and Rosetta (10 students);
- Comets in History, (1 student);
- Working the English text of the films and writing an essay about it (entire class of 30 students).

In Sopron a group of 16 students (age 15) finished their activities and presented the results to their school in the beginning of April. Several teachers were leading the project: Ágota Lang (physics), Csaba Robotka (history), Gabriella Nagy, Bazsóné (arts), Mónika Stenger, Kovátsné (English). The students divided up in teams:

- The History team (4) did a research on how comets appear in Hungarian culture;
- The Arts team (4) designed a T-shirt for the whole group. The T-shirt shows several elements of related to Rosetta (the Rosetta stone, the spacecraft, and a comet nucleus with the shape of Hungary!);
- The Science team split up into different sub groups:
    a- One group (2) did research on comets, on the history of comet observation and on the instruments of Rosetta orbiter and Rosetta lander.
    b- The other group (3) created an animation with a

software programme called “Imagine Logo” about the trajectory of Rosetta spacecraft to it the target comet 67P/Churyomov-Gerashimenko;
- The LEGO® building team (7) followed their own creative ideas about how a lander should look like. They developed a four leg lander with a square body, containing several instruments: a temperature sensor, a gravitational acceleration measurement device and a gas-sensor.
- One student recorded all our advances on camera (film and photo) and edited a film of the all the activities. This film Have Fun can also be seen on the VIMEO channel.

In addition, since on the Rosetta space probe there are Hungarian instruments and contributions to instruments, they visited the Space Research Group at Budapest University of Technology, who worked on the energy supply of the landing unit, and two other teams at KFKI Campus (Research Institute for Particle and Nuclear Physics and Atomic Energy Research Institute) in Budapest. The scientists gave us short presentations about their work and their instruments and afterwards the students were shown the spare copies of and visited the labs. The results of this test are very positive... [1]

Other events

The LEGO® MINDSTORMS® Rosetta Demonstration Lander was shown on two further occasions

LEGO World Zwolle (October 20/27, 2010)

The LEGO® MINDSTORMS® experts had the Lander demonstration model during the whole week on display at the LEGO World Zwolle (the Netherlands). Maarten Roos had prepared a loop-DVD with Dutch subtitles and the films were showing non-stop on a screen next to the set-up.

Expert Eric Steenstra comments:

We played the DVD every day on the two screens. We have an amplifier for the sound in surround! The barcode visible is a direct link to the VIMEO channel and you can read it using an iPhone or Android phone app. Many people did! The bar-code is of course also made out of LEGO bricks.

We received many nice reactions. A team from National Geographic came and took some images of our creations (and other things at the LEGO World event). They are making a film to be transmitted somewhere in April or May next year.

European Parliament Dinner Debate

On February 3, 2011, Martijn Boogaarts (LEGO® MINDSTORMS® expert) brought the demonstration lander to Brussels into the European Parliament at a dinner meeting about Europe’s future role in Solar System Exploration. Maarten Roos prepared 15 copies of the DVD which were distributed at the same occasion. A detailed report of the event is found on the EuroPlaNet website at http://www.europlanet-eu.org/outreach/index.php?option=com_content&task=view&id=321&Itemid=41

Further Developments

The next step it to see how this kit can be implemented on a larger scale. The current status of the testing at schools is positive. A meeting between LEGO, ESA and DLR is scheduled for the near future to discuss it.

[1] The full report on the Hungarian project can be downloaded from: http://www.europlanet-eu.org/outreach/index.php?option=com_content&task=view&id=330&Itemid=84

All the films mentioned in this document are on http://www.vimeo.com/channels/rosettascomettouchdown
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