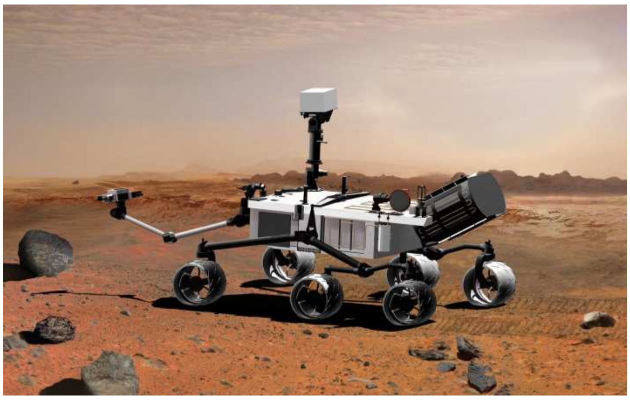
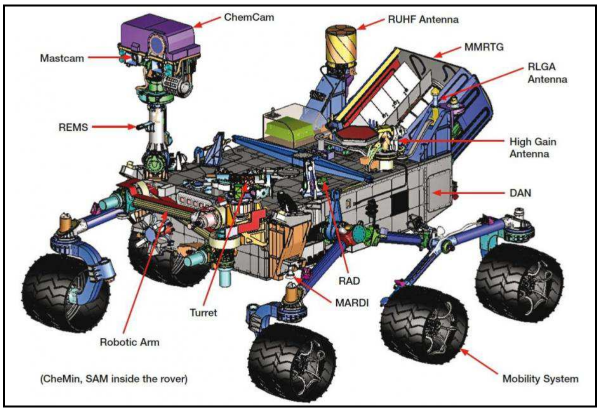
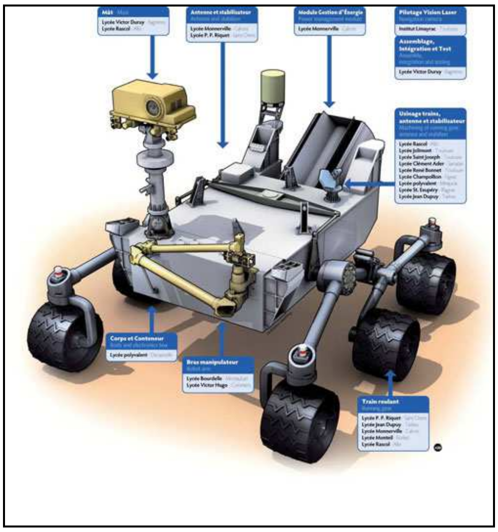
MODELES, DEMONSTRATEURS ET MAQUETTES RELATIVES AUX ROBOTS D'EXPLORATION DE LA PLANETE MARS – UTILISATION DE PIECES MECCANO

INTRODUCTION

Le robot de la NASA "Curiosity" qui explore actuellement la planète Mars fait quelquefois la "une" de l'actualité. Sur le Web, on trouve des milliers de pages, textes, photos relatives à cet engin assez fascinant. Il ne faudrait toutefois pas oublier que, d'une part, ce robot fait partie d'une famille de robots (baptisée MER - "Mars Exploration Robot" avec Sojourner et Spirit) et que d'autre part il existe d'autres prototypes et programmes du même type, notamment les programmes ExoMars (Europe avec un aterrisseur russe) ou le robot Zhonghua de la Chine, destiné à l'exploration de la lune.
Ci-après trois vues de Curiosity et une d'Exomars.







D'un point de vue mécanique, plusieurs sous-systèmes de ce type de robot seraient intéressants à modéliser et, en premier lieu, le système assurant les déplacements (propulsion-suspension) dit "**Rocker-bogie**" qui existe pratiquement sur tous les robots de ce type.

Dans les pages ci-après, on trouvera :

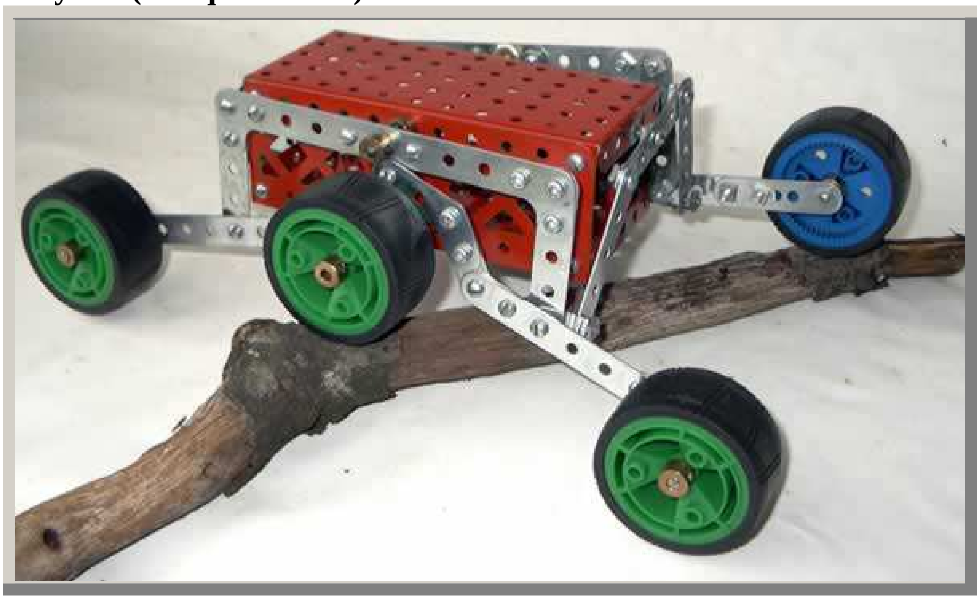
- Trois exemples de modèles, plus ou moins fonctionnels, utilisant des pièces Meccano.
- D'autres exemples de prototypes visant à reproduire tout ou partie des fonctions du robot.

Voilà peut-être un thème à creuser pour les futurs exposants de l'édition 2014 "Exposition CAM –Les Mureaux – 29, 30& 31 mai 2014 ?

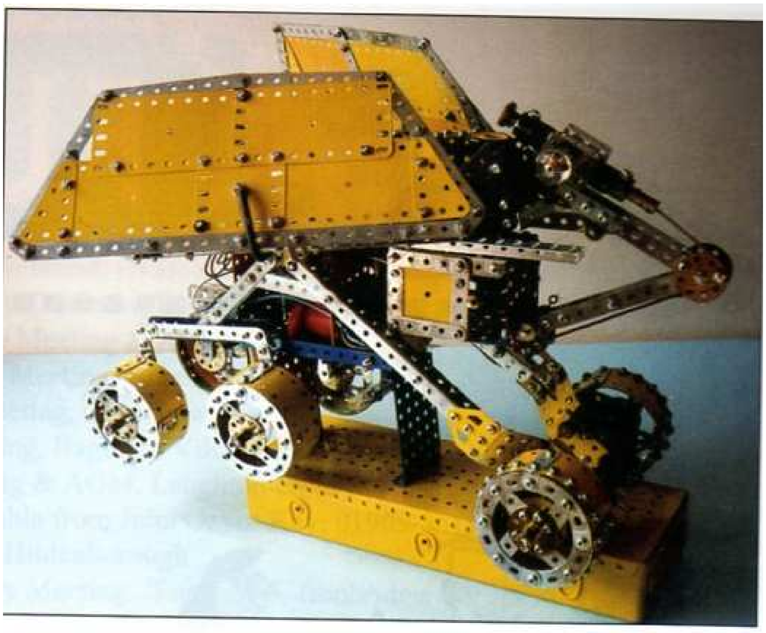
Hervé FORESTIER CAM 673 - Novembre 2013

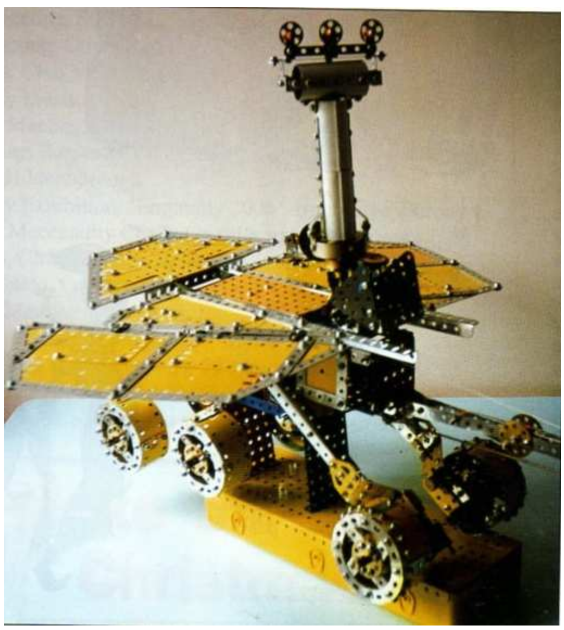
EXEMPLES DE TROIS REALISATIONS DE MODELES "ROVER MARTIEN" UTILISANT DES PIECES MECCANO

<u>Exemple 1</u> : Présenté par Dave Heathcote à la réunion du 24/01/2004 du Johannesburg Meccano Hobbyists (Afrique du Sud)



<u>Exemple 2</u> : Présenté par Hugh Nicolson en février 2009 dans le cadre du TELFORD & IRONBRIDGE MECCANO SOCIETY (informations supplémentaires à rechercher auprès de Chris Shute et Dave Harvey ?)





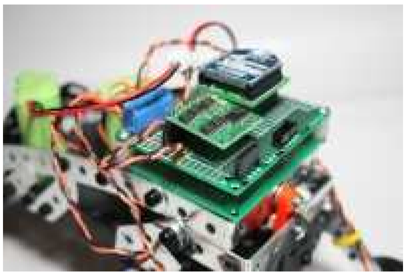
Exemple 3 : Réalisé par le responsable de la boutique de composants "Robotcraft Store" située dans l'Ontarion (Canada) le 20/10/2009

Vidéo de démonstration ici : http://vimeo.com/6679083

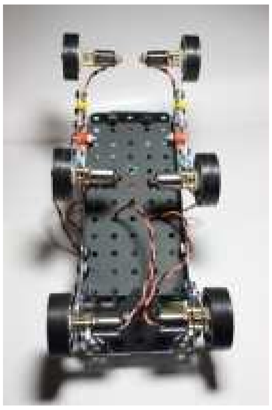
For a while now, I have wanted to experiment with the rocker-bogie type chassis, read NASA Mars Rover, and seeing its mechanical merits. However, the time and effort needed to construct one has been preventing me from doing this. Creating this type of chassis without a significant time commitment is easier said then done, unless you already have the right set of components that play well together.

This is where the right blend of build-plate strips, Meccano parts and micro-motors come in handy to build the table-top version of NASA Mars Rover quickly - the 'R0kker-bot'. The build-plate construction system is a set of aluminum strips that can you can drill, bend and cut to any shape or form you wish.

The basic chassis setup, excluding wiring and electronics took three hours to complete. You can bolt together the main chassis in an hour using Meccano parts, and it takes another two hours to drill and attach the motors using build-plate aluminum strips. Most of those three hours went into trying to fit Meccano and build-plate components together nicely, and into ensuring that the dual-wheel arch frame has enough clearance for rotation and doesn't get stuck against the main robot body. Meccano's large bolts do get in the way; therefore it is essential to make sure that there is enough clearance between the frame and the main body. In the picture below, you can see how the motor/wheel combination is attached to the build-plate aluminum strip and then to the Meccano part with regular Meccano bolts.



Once the mechanical part was finished, I proceeded with getting everything wired up.I decided to set up the initial version of this robot as a remote-controlled platform so that I could evaluate the mechanical merits of the chassis first. I am not a huge fan of wasting my time on a chassis that does not work well from the beginning. However, before moving on to the remote control setup, I needed to address the motor controls portion of the robot first. The rocker-bogie chassis setup uses six motors in total - three motors on each side. Each side, (or channel, from a motor controller perspective) can draw approximately 5A (amps) in a "stall" current. I decided to go withPololu's SMC05a motor controller for this project. This controller can deal the high stall current levels and it can also accommodate the additional current throughput for the motors, when the robot is turning or going up an inclined surface.
One great aspect of the SMC05a is that it can work with either 5V or 3V logic level, which is something that many motor controllers don't have - Kudos to Pololu for a job well done. Considering this feature, plus the fact that it speaks serial when it interacts with command-and-control modules, my exploratory side nudged me to take a different approach, when setting up the remote control portion of things. My original plan was to use a SPE Arduino PRO mini-module with a nRF24L01 and a remote control module from Active Innovation to control the chassis. The Arduino PRO module would shape the captured data into four-byte commands and forward them to the SMC05a to act on. However, this seemed to be an over-kill solution compared to the alternative, with the alternative setup using only a pair of XBee modules and a PC/laptop, masquerading as a remote control. The XBee modules and a PC/laptop are good if you are just trying to test the chassis configuration, as I was, in this case.



Once the motor controller was picked and the remote control portion was decided, I had to get things wired up and talking to each other. First and foremost was the VCC power for the XBee modules and the SMC05a motor controller. I installed a 3.3V voltage regulator with a couple of capacitors for that. The VReg out pin was connected to the XBee's VIN and the SMC05a VCC pin. I used a XBee 1 module so the 100mA 3.3v voltage regulator is adequate, but if you have the XBee 2/2.5/PRO module, you will need a more powerful voltage regulator as those modules draw higher current levels. Be sure to consult your XBee datasheet for the current draw requirements. You also need to setup both XBee modules for the point-to-point communication with a 19200 baud rate. The 19200 baud rate is the MAX bit-rate a SMC05a can handle. I have used two 6V (600mA) batteries wired in parallel to provide ample current to power the XBee, SMC05a and six motors.

Now that the robot's transceiver/motor controller portion was complete, it was time to move into the testing. First, I downloaded and installed the Pololu's Serial Transmitter (PST) utility. This is a great utility if you need to test Pololu-made modules quickly. I then connected an Xbee Xplorer board module to my desktop PC. Then, I pointed the PST utility to use XBee as my serial line and sent a group of four byte commands (motor A & B: forward/reverse, stop) to the SMC05a module. Motors turned and stopped as expected. Now, it was time to move on to a trial run of negotiating obstacles. Here is a video of the robot driving over a couple of books that double as obstacles. Each book is at least as thick as a wheel diameter but that doesn't stop r0kker from getting to the other end of the obstacle course.
As a next stage, I need to make controlling the robot easier than banging out 4 byte commands in the console or the PST. I am currently working on a Java Swing-based application to capture the keyboard's input, translate it into four-byte commands and then send it to the r0kker-bot over a serial link. This should complete the test system.

In the end, I'm happy with the results. I was able to whip out a r0kker-bot pretty quickly, able to control the bot without any wires attached, and able to get from the concept to obstacle course within 48 hours. Last but not least, the chassis turned out to be pretty solid with a lot of potential to be used as part of other, larger robot projects. It turns out that mixing build-plate strips and Meccano components allows for a great robot prototyping system, and combining the Pololu SMC05a motor controller with the XBee wireless module delivers a perfect wireless motor control platform for wheeled and/or tracked robots.

Vidéo de démonstration ici : http://vimeo.com/6679083

AUTRES EXEMPLES DE REALISATIONS DE MODELES "ROVER MARTIEN" N'UTILISANT PAS DE PIECES MECCANO

EXEMPLE 1. A la page http://www.robo-works.net/robots/rockerbogiedemo.html on trouve la réalisation d'un démonstrateur d'une suspension type "rocker bogie" utilisant le kit "**Vex Robotics**"

Exemple 2 : A la page http://tpeplanetemars.free.fr/spip.php?article19 **trois lycéens du lycée ST François d'Assise de Montigny Le Bretonneux présentent un TPE très intéressant**, réalisé en 2011, sur les robots martiens et une étude approfondie du "Rocker Bogie"

On peut télécharger ici leur doc en PdF : http://tpeplanetemars.free.fr/IMG/pdf/oraltpe.pdf

<u>Exemple 3</u> : Sur le blog **d'Alice Enevoldsen** (ici : http://www.alicesastroinfo.com/2012/07/mars-rover-rocker-bogie-differential/) , on trouve un article de son père Keith sur un **Mars Rover utilisant des pièces Lego.** Voici une partie de l'article :

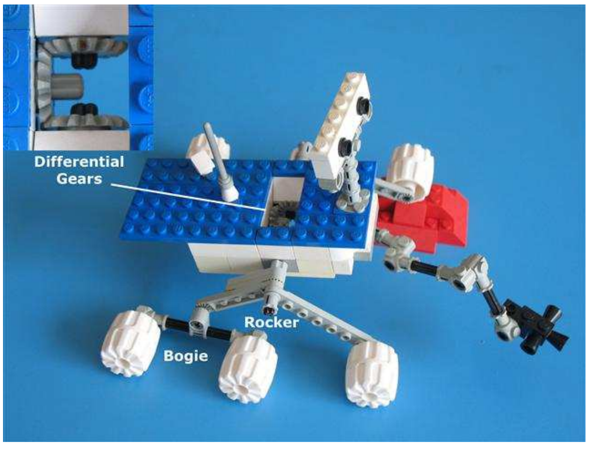
"All the Mars rovers have six wheels and use a rocker-bogie suspension system to drive smoothly over bumpy ground. The rocker-bogies are easy to see in pictures of the rovers (see pictures below). There is one rocker-bogie assembly on each side of the rover. The rocker is the larger link that connects to the rover body (the chassis) in the middle (at the rocker pivot), has a wheel on the front, and connects to the bogie in the back. The bogie is the smaller link that connects to the rocker in the middle (at the bogie pivot), and has wheels at both ends. Each of the six wheels has its own motor.

The Differential

It is not so easy to see and understand how the rocker-bogie mechanism keeps the body level. What prevents the rover body from tipping all the way forward or backward around the rocker pivots? If you build a model rover and you attach the rockers to the body with an axle or two pivot pins, the body will tip forward or backward until it hits the ground! In the real rovers the two rockers connect to each other and to the body through a mechanism called a differential. The differential is what keeps the body level. Relative to the body, when one rocker goes up, the other rocker goes down. Relative to the ground, the body angle is halfway between the angles of the two rockers. That's cool, but how does it work? The different rovers use different mechanisms: a differential gearbox or a differential bar.

Differential Gearbox

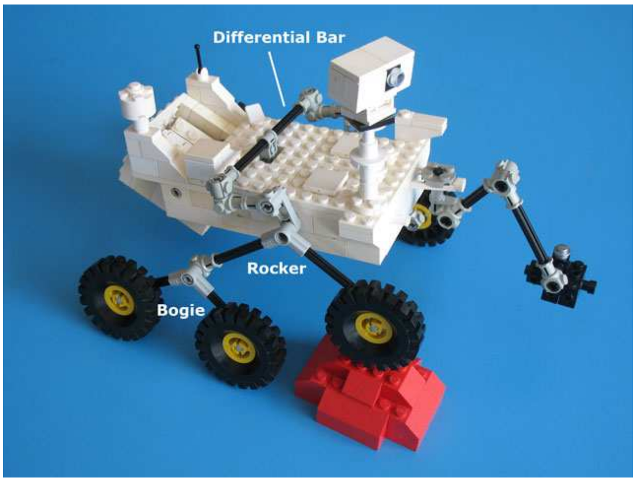
The Mars Pathfinder (Sojourner) and Mars Exploration Rovers (Spirit and Opportunity) use differential gearboxes.



Pathfinder's Differential
The gearbox is inside the rover body, so you never see it. No wonder it is hard to figure out how it works! In my Lego model rover shown here, I use a simple three-gear differential. Two gears connect to the two rockers and the third (middle) gear connects to the body. If you hold the model rover body steady in midair and tilt one rocker up, the gears will turn and the other rocker will tilt down (see the animations below).

Differential Bar

The Mars Science Laboratory (Curiosity) uses a differential bar. This is the big black bar that you see across the deck of the rover.

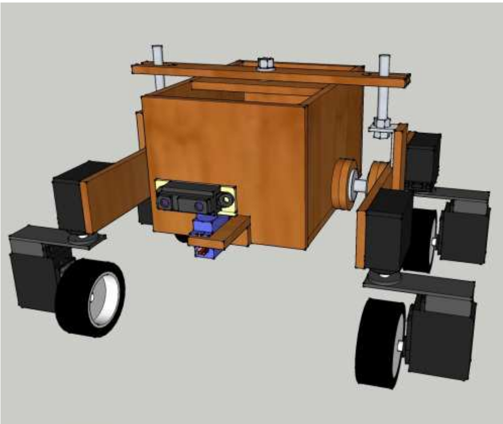
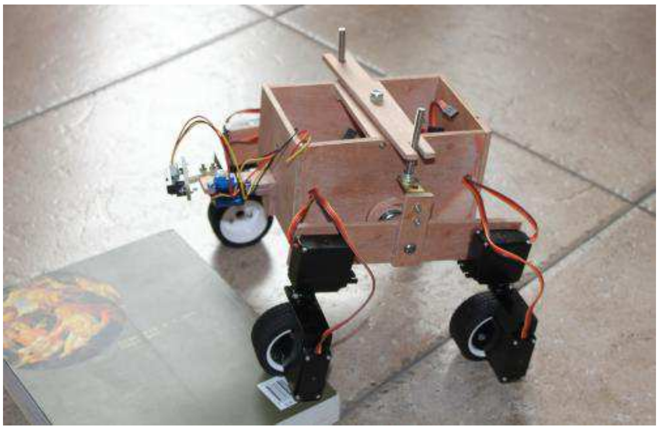


Curiosity's Differential
The middle of the bar is connected to the body with a pivot and the two ends are connected to the two rockers through some short links. If you hold the model rover body steady in midair and tilt one rocker up, one end of the bar will go back, the other end will go forward, and the other rocker will tilt down (see the animations below).

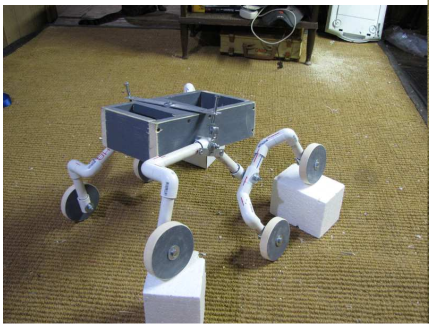
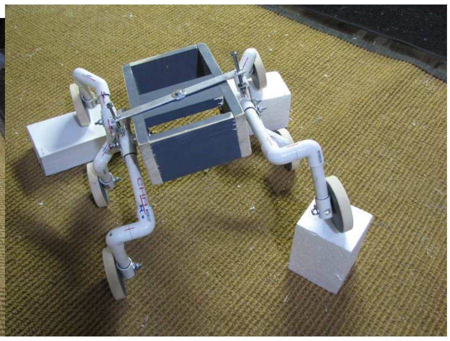
The Mars Exploration Rovers did not use a differential bar because it would interfere with the solar panels. But the Mars Science Laboratory does not have that problem because it is nuclear powered and has no solar panels.

Exemple 4 : **Sur le site "Let's Make Robots",** à la page : http://letsmakerobots.com/node/25587

On trouve une maquette de "rocker bogie" à 4 roues et des vidéos montrant le fonctionnement du modèle

Exemple 5 : **Sur le site "Robotix" (Technology Robotix Society),** à la page http://www.robotix.in/tutorials/category/mechanical/rockerbogie

On trouve un Rocker Bogie Mechanism can be seen in action in the following videos:

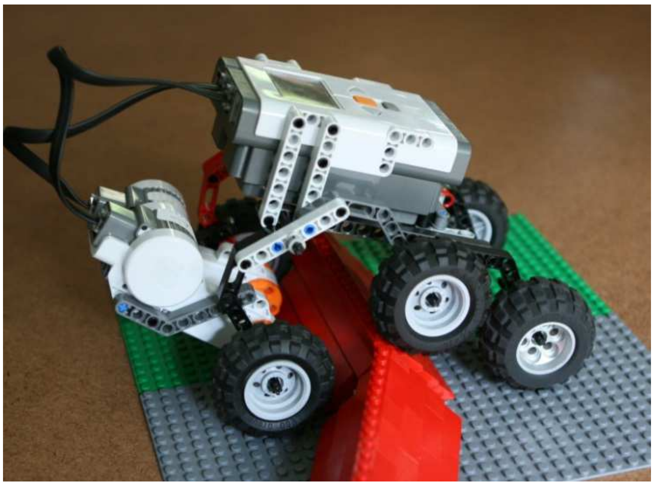
1. **http://www.youtube.com/watch?v=H0KQF50vV5E**
2. **http://www.youtube.com/watch?v=FxE4sayLlV8&feature=related**

Octopus Rover Presentation. Octopus is a fully active 8 motorized wheel robot.

http://www.youtube.com/watch?v=lKV7Rc2TJNg&feature=related

Exemple 6 : **Sur le site "LEGOACES",** à la page http://legoaces.org/MoonBots/Phase_I-Robot_Design.html voir les développements en Lego d'une équipe de jeunes. Extraits :

"**GENERATION 1** Initial rocker-bogie with 2 wheel drive and linked rear rocker.



This design did well as an initial prototype of the suspension and nicely climbed the crater wall with relatively small wheels. We decided to evolve the design to 4 wheel drive.

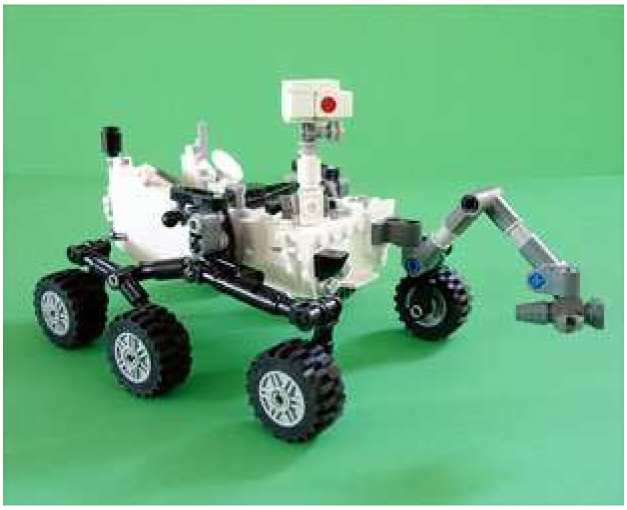
GENERATION 2 Rocker-bogie: The next evolution of the design was a larger wheel configuration with 4 wheel drive. This Gen 2 suspension uses some really cool Lego wheels that have great traction and we have used similar wheels on many great robots. This video shows the Gen 2 design climbing of the obstruction wall. We have experimented with using 4 wheel drive and 2 rear slider wheels to allow for easier turning. We found that the location of the pivot points in the rocker-bogie suspension have a big influence on the performance. This lead us to do some more research on the design and come up with Generation 3 that is based on a NASA JPL design.
GENERATION 3 Rocker-bogie: Our Gen 3 design uses Lego liftarms to mimic the suspension linkage found in this NASA Patent document. One key feature of this design is that the pivot points of the rockers between the independent wheel bogies are located at the same height as the wheel centers. This limits the torquing of the rockers as wheels encounter obstacles. There is also some limitation to ground clearance, but larger wheels will help it climb the crater walls easily while maintaining solid traction and not loosing contact with the ground so that accurate positioning can be maintained while roving over rough terrain.

2.4 Programming and Sensors
Our plan is to combine a compass sensor and ultrasonic distance sensors to locate ourselves on the board. We have used the ultrasonic sensor to do accurate wall-following on other Lego rovers, so we have allready developed algorithms and have experience with positioning using ultrasonics.

2.5 Video and Imaging capability
Our robot is equipped with a 2.4 GHz wireless video camera to take live video and stream it back to a computer or broadcast the video on the internet. This wireless video capability insures that we don't get hung up on wires as we move and turn. We also have a static web camera that can be mounted on the lander or anywhere in the Lunar base to give a static view of the moonscape. The wireless camera we use is very small (3 cm x 3 cm x 3 cm, plus a 9 volt battery) and is easy to mount on the robot. We use a USB video frame grabber to capture the video on a computer. We can take the video and broadcast it on the internet so that anyone can watch our rover from anywhere in the world.

Exemple 7 : Le modèle en Lego créé par Stephen Pakbas en Novembre 2011

à la page : http://www.collectspace.com/news/news-112511a.html



Mechanical engineer Stephen Pakbaz's LEGO model of NASA's Mars Science Laboratory rover

Pakbaz's brick-built Curiosity features an articulated arm, deployable mast, and a working rocker-bogie suspension system that allows the rover to keep all six wheels on the ground and climb over rocks twice their height.

In addition to publishing online photos and even a video of his mini MSL traversing a test ramp (which he also made from LEGO), Pakbaz submitted his model to CUUSOO, a website where the public can vote for fan-created LEGO sets. If 10,000 or more people cast their support behind a particular model, LEGO says it will consider producing it as a commercial model.

Out(reach) of Curiosity

Pakbaz said that he built his LEGO Curiosity because he is a "big fan of space exploration" and of the related outreach efforts that NASA and LEGO have done."I thought this would be an effective way to contribute," he said.
The toy enables him to show one of his favorite features of the rover — the way it can move. "As a mechanical engineer, I also loved demonstrating the rocker-bogie mobility system on the model, which allows the rover to negotiate the rough Martian terrain," he said.

On peut télécharger la notice de montage complète du modèle LEGO