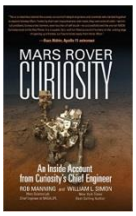

Mars Rover Curiosity: An Inside Account from Curiosity's Chief Engineer by Rob Manning (Author), William L. Simon (Author)
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Mars Rover Curiosity: An Inside Account from Curiosity's Chief Engineer by Rob Manning

At the beginning the author takes you right inside the control room at the Jet Propulsion Laboratory (JPL), a NASA field center at Pasadena California, to experience the final '7 minutes of terror' and sets the tone for the extraordinary achievement of the unprecedented Mars Science Laboratory (MSL) landing in search for organic life on Mars : "to seek answers to questions about the origins of humankind and the origins of life - this is the story of "one giant leap in the search for answers".

"Sunday August 5th 2012 10:17 p.m.: I'm sitting in the crowded chilly cruise mission support area that serves as our control room on the campus of the Jet Propulsion Laboratory in Pasadena a short drive from downtown Los Angeles, the team members are amped up in ready state….if everything works as designed MSL should now be starting to perform a series of contorted maneuvers that in just 7 minutes will slow it from 12600 miles an hour, 5.6 kilometers per second to a gentle landing on the Martian surface, in a relatively smooth area that has been named Gale crater. These seven minutes are what we call the seven minutes of terror. If the landing is successful a coded message, a string of ones and zeros will be beamed back to us through space to confirm that all is well. It will take 13.8 minutes for that signal to reach this room ….

"….The single most challenging part of putting the Rover on Mars, known in our business is EDL, for "entry, descent and landing" is now taking place. Hundreds of people have worked on this one process. Computer simulations flashing on the screen follow the data flowing from the lander, the stream of events that is the hallmark of landing on Mars ticks off item by item, a message arrives that the cruise stage has been successfully jettisoned. Years of work by more than 100 engineers are over in a heartbeat. The spacecraft next does an about-face to aim its entry heat shield to the planet. The most complex lander scheme in the history of spacecraft is getting his first all-up test 154 million miles 248 million kilometers away from home. EDL team member Jody Davis sees that the event record she's looking for has appeared on her computer screen in the separate EDL war room. We all hear her voice over our headsets as she calls out "tango delta nominal". We each experience a surge of thrill. Tango and delta are phonetic identifiers for the letters T and D which the team uses to mean "touchdown". The "nominal" means normal, fine, just as planned. Only insiders understand the phrase, used so that onlookers, reporters and people in the global audience will not jump to a premature conclusion. It may mean that all years of effort will soon be successful - yet there is still plenty that can go wrong. The next call comes quickly "RIMU stable". The Rover Initial Measurement Unit is signaling us that the rover is sitting on relatively level ground. It's not sliding down an embankment or being dragged across the surface. On hearing that call, team member Brian Schratz has started counting to himself. If UHF radio signals are still arriving from Mars after the count of ten it will confirm that the spacecraft itself has rocketed away from the rover as planned to crash on to the Martian surface at a safe distance from the rover, Curiosity. The project's EDL team leader Adam Steltzner is pointing at Brian waiting for that count. On reaching the count of ten, Bryan announces, "UHF is good". Adam pokes Al Chen. Then what we are longing to hear: Al Chan, the systems engineer has been tasked with calling the play-by-play for the viewers on TV and the Internet. He makes the official announcement calling out "TOUCHDOWN IS CONFIRMED! We are safe on Mars!" The local time is 10:30 pm, August 5 2012."
The huge relief can be seen on the YouTube movie produced afterwards for PR promotions: "We're NASA and we know it" [1]. Unforgettable, Bobak Ferdowski's iconic on-console presence as system engineer during the landing phase (the "Mohawk-guy").

The beginning of this Mars "invasion", culminating with the MSL landing dates back to a not so well known declaration of President Clinton at a press conference on Aug. 7th 1996: [2]
"I am determined that the American Space Program will put its full intellectual power and technological prowess behind the search for further evidence of Life on Mars." At that press conference NASA scientists announced that they have discovered small carbonite globules inside a Mars meteorite that have been picked up in 1984 from atop the snow at the foot of the Alan hills in Antarctica. They concluded that these tiny structures were evidence of microscopic Martian bacteria. The rock was formed very early in Mars history, some 4 billion years ago, less than a billion years after our solar system was formed. As an immediate consequence NASA was instructed to prepare a Mars sample return mission.

Three preparatory missions followed: the "Mars Pathfinder with Sojourner rover (Dec. 1996), the "Mars Climate Orbiter" (1998) and the "Mars Polar Lander" (1999). The Pathfinder mission was successful, the other two missions failed. Rob Manning was chief engineer for Pathfinder, but was involved in all three missions. He describes the frustration of how it is, if you are waiting for a return signal to indicate the landing of your spacecraft (i.e., the Polar Lander), but nothing happens – even after four days of waiting. That was one experience he never wanted to have again.
The loss of the two spacecraft back-to-back even prompted Jay Leno to quip: "It proves that you don't have to be a rocket scientist to be a rocket scientist."
Two more missions followed:
NASA's Mars Exploration Rover (MER, launched in 2003). This mission is a still ongoing robotic mission, involving two Mars rovers, Spirit and Opportunity, exploring Mars. Both rovers outlived their planned missions of 90 Martian solar days by far. Spirit was active until 2010. Opportunity is still active. This overwhelming success of those two rovers supported another mission, to send an even bigger rover, named Curiosity to Mars. [3]
The second mission, Phoenix (launched in 2007) was a robotic spacecraft exploration mission on Mars under the Mars Scout Program. The Phoenix lander descended on Mars on May 25, 2008. Mission scientists used instruments aboard the lander to search for environments suitable microbial life on Mars, and to research the history of water there. [4]

Those two flawless missions, also conducted by JPL, had a big boost of moral for the "struggling" MSL team in the years to come.

JPL had to re-establish its reputation after the loss of Mars Climate Orbiter and the Mars Polar Lander and proposed a "flagship" mission, the Mars Science Laboratory (MSL) the landing of a rover with a record-breaking weight of 900 kg on Mars, a weight never attempted before to be "soft-landed" on Mars. The rover was christened "Curiosity" by Clara Ma, the winner of the NASA naming contest for MSL.

Before the author delves into the technical implementation details of the MSL and its many technical and political challenges and its technical "metamorphoses" he describes his excursion to leading a "capability roadmap team", the "Human Planetary Landing System Team", called for in 2004 by George W. Bush's "Vision for Space Exploration".

Motivated by his earlier Mars "EDL"- experience and his recognition as an expert in this field by his appointment as "capability roadmap team leader", Rob Manning felt compelled to see the MSL project through to a successful completion and describes in detail the struggles of the MSL team with the multitude of new technical design problems, implementation and testing challenges with the main focus on the new 'Entry, Decent and Landing' (EDL) approach.

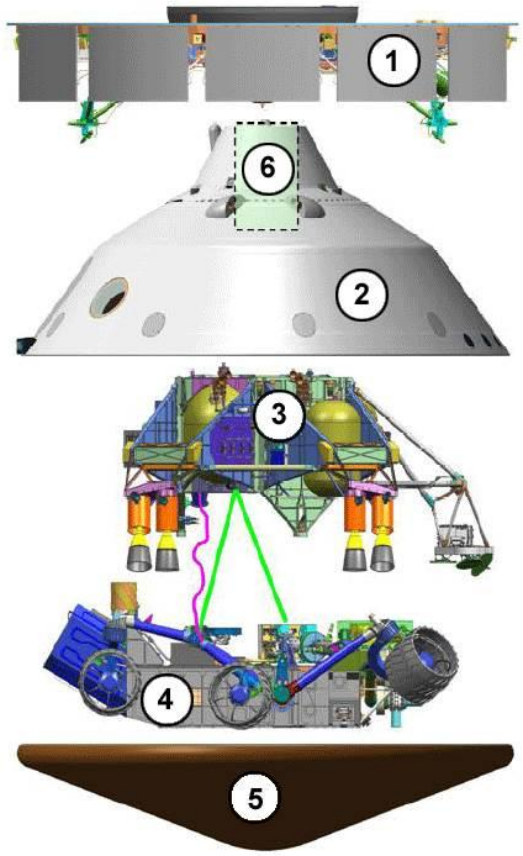
Starting with the unprecedented weight of the rover, the known landing techniques like airbag landing techniques (the airbags for a rover of this size would not survive the touchdown impact), a highly sophisticated combination of entry guidance, heat shield technique, supersonic parachuting and finally the introduction of the so called "sky crane maneuver", lowering the rover on cables allowing an "ultra soft" landing on wheels had to be designed. This all had to take the Martian atmosphere, Mars gravity, Mars shear wind conditions, dust as well the final landing terrain into account. Not to talk about the accommodation of all the mechanical devices, deployment pyrotechnics, retro-thrusters and computer

safety and redundancy in the cramped descent shell (see figure below). A lot of constraints and unknowns to worry about!
But to make life more interesting, in addition to the technical problems, MSL had to struggle with cost (overruns) and schedule, not as any other project, but under severe conditions, since the launch date (by trajectory constraints) and the cost (strictly limited by NASA) were fixed. So each new technical problem – and there were hundreds of them as described in the book, could mean the termination of the project and the waste of a lot of taxpayer's money.
Being led through the design and development phases with the eyes of the author as a responsible engineer this part of the book reads almost like a suspense story which makes you suffer with the author. And of course the 60 hr weeks, working through weekends and many 24hr testing cycles took its toll: Rob Manning got so involved in his project that family life was taking second place and his own health rebelling – high blood pressure and gaining weight was the sult.

As a reader you get a deep insight into the working culture and the responsibilities of the NASA and JPL engineers and you get high regard for the tenacity and dedication of all the involved engineers and technicians. A little video of Curiosity in the ATLO (Assembly, Test, Launch and Operations) clean room at JPL can be viewed and gives you an impression of the real dimensions of the MSL [5]. A time-lapse video of the whole assembly process is accessible from
https://www.youtube.com/watch?v=cwqwd6aBAz0 or
https://www.youtube.com/watch?v=e34KVi_WIBk)

In addition the MSL mission is painted against the background of what Mars exploration is all about, puts it in perspective with what has been done so far and it leaves you with a deep understanding of how difficult it will be to land astronauts on Mars or to "settle" Mars permanently.
As an engineer having been involved with the International Space Station (ISS) I could follow the Mars exploration only from the sidelines, because we had our own load of problems – therefore I personally appreciate the book very much because it not only describes the technical and managerial approach but also gives a concise summary of insights into the science results and the breathtaking findings available so far.
The book is a delight to read for engineers and managers involved in space exploration, but also very interesting for technically interested readers because it is an eye-opener for how difficult space exploration is, and that it definitely takes the proverbial "rocket science engineer" to be able to drive space exploration to new dimensions.
The search for organic life on Mars, the spending of $2 B on Mars Science Laboratory and its experiments, but also the dedication and endurance of the design-, implementation- and operations teams of the project is best summed up by Clara Ma: "Curiosity is the passion that drives us through our everyday lives".
MSL scientific findings – as they are available yet, are summarized in the final chapters: the most important one being the first drilling on Mars (6 cm deep) at the "Yellow Knife Bay" confirming that the observed ground structure could only be formed in fresh water (hard, clay-like sediment), the in situ sample analysis so far confirmed that Mars had all the ingredients to be able to support organic life.
Impressed by the MSL scientific results, the Planetary Decadal Survey 2013-2022 recommended a scaled down Mars Astrobiology Explorer-Cacher sample return mission, as new flagship mission. Currently the Mars 2020 Rover design, based on Curiosity, is underway at JPL and Rob Manning is contributing his know-how to the next step by preparing a Mars sample return by bearing a final landing of human explorers in mind.
Good luck for the future!

References
[1] https://www.youtube.com/watch?v=vRUUlgXAUUI
[2] http://www2.jpl.nasa.gov/snc/clinton.html
[3] https://en.wikipedia.org/wiki/Mars_Exploration_Rover
[4] https://en.wikipedia.org/wiki/Phoenix_(spacecraft)
[5] Curiosity in the ATLO building https://www.jpl.nasa.gov/video/details.php?id=949
[6] More Curiosity images: http://www.curiosityrover.info/curiosityroverbook/Figures.htm



Just to demonstrate the complexity and uniqueness of the MSL spacecraft:
(explosion drawing)

1- Cruise stage;
2- Backshell;
3- Descent stage;
4- Curiosity rover [899 kg];
5- Heat shield;
6- Parachute
Total weight 900 kg [SHOULD BE 3839 kg total launch mass]

"This is crazy, kind of the right kind of crazy, so crazy it might work" (Mike Griffin)

MSL in flight configuration
(completely assembled and packaged)

[6]