## Toulouse, Airbus Defence&Space, 2016 september 30th

As you probably know, this Friday will mark the end of the Rosetta mission, in the early afternoon, through a crash landing on the surface of comet Chury :

- ***After so many years of preliminary design !***

Michel Caldichoury (Michel I just realize that your name's end is a tribute to the comet !) and Vincent Guillaud probably remember the CNSR years (30 years ago), when the joint mission concept with NASA consisted in Comet Nucleus Sample Return (at that time ESOC was not afraid of operating a spacecraft at the surface…)

Then came the (so many !) years of R&D studies (Autonomous and Advanced Navigation Techniques) that we managed with Benoit Frapard (and Calixte Champetier as our boss) and with GMV as our partner (remember Jesus Serrano ?), and that finally led to so little autonomous navigation on-board (just a bit for asteroid fly-bys !, but now we hope to improve the score on JUICE…).

In parallel Patrice Villefranche and Frédéric Faye devoted their young engineer careers to re-designing a 100% European Rosetta mission in phase A/B studies for ESA, with no return leg but at that time with two potential landers : the RoLand (for Rosetta Lander) from DLR and Champollion from CNES. At the end they became only one lander under the lead of DLR but with a strong CNES cooperation, and fortunately the RoLand name was changed to the more elegant Philae !

In 1993 the Rosetta mission was approved by ESA as the first Cornerstone of the Horizon 2000 Science Program.

- ***After so many years of tedious but passionate development !***

Our Toulouse story with Rosetta development started with a bad affair as we lost the Prime contract under the lead of Matra Marconi Space from Bristol in the UK…But then in 1997 we won the Avionics contract from Toulouse as we were selected by the Prime Dornier Satelliten System Gmbh, who shortly after merged with us to become Astrium !

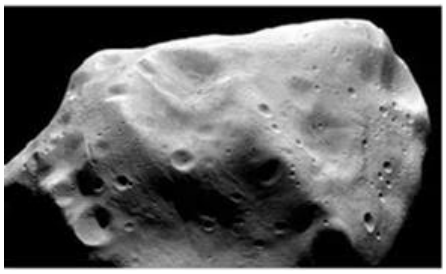
Developing the avionics for such a complex mission was not a piece of cake, with some innovations and European firsts like the first fully autonomous Star Tracker with lost-in-space acquisition and robustness to dust (well, only after Patrick Lelong's efforts to manage the dust CN !, and finally not enough robust in-flight…), first autonomous Earth-pointed safe mode, complex navigation camera (isn't it, Daniel Gheri ?) with on-board image processing for AOCS autonomous attitude guidance during asteroid fly-bys, first interplanetary 3-axis stabilised European spacecraft (well, this is what we thought until 2003…), first spacecraft to hibernate prior to its primary mission, first spacecraft with endless FDIR reconfiguration levels….

But finally we made it, thanks to many of you, with special thanks to Eric Ecale for the strong synergy with Mars Express AOCS that helped a lot, Rob Harris who facilitated a lot our technical interfaces with the Prime, Saturnino Val Serra and his post-its (sorry for the forest trees), Alois Eibner (and his cigars) for transforming our AOCS spin-up and strobing ideas into workable operational procedures …

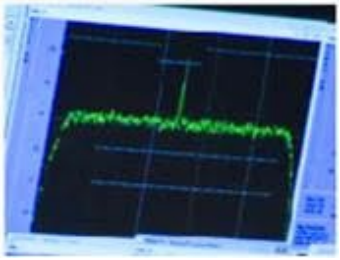
Development planning was very very tight as we had to hold the 2003 launch date because comet Wirtanen was the only reachable one with a fixed launch date (at least this is what we thought as ESA told us, but I think Steve Kemble already knew at that time this was not really the truth…). But when Ariane 5 ECA failed in December 2002, ESA had to postpone, and Eric Ecale had to eat his hat (Mars Express would launch first, to fly-test a few safe modes) …So a few weeks later we had a new comet and a new launch date one year later, quite easily….

- ***After 10 years of not so boring cruise phase !***

Three Earth and one Mars gravity assists, two asteroid fly-bys, one hibernation phase, a few failures, safe modes and SW patches on the way….no time to be bored after all ! One anecdote during cruise phase : shortly before the second Earth Gravity Assist in November 2007, Rosetta was mistaken for a potentially dangerous Near Earth Asteroid by a US astronomer and it took two days for the Minor Planet Center to officially downgrade the collision alert ! At that time Rosetta was not as famous as today….

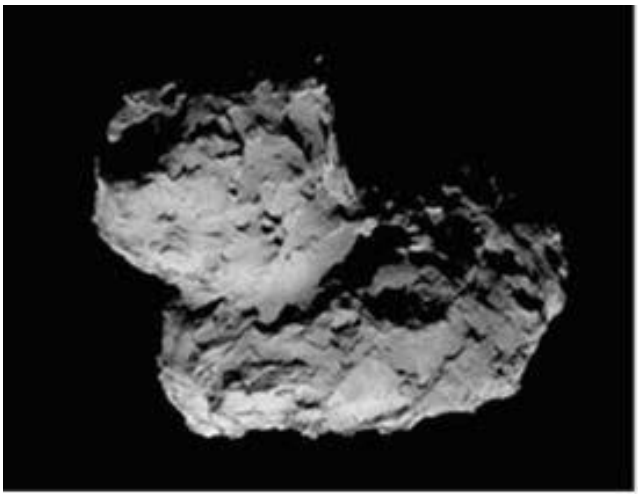


Hibernation entry in June 2011 was a tense moment as nobody could really know for sure what could then happen during 2.5 years in a nearly passive spin mode, so far from the Sun and without any ground contact…(it is around that time that a friend of mine repeatedly said “ça ne marchera jamais !”). Fortunately he was wrong, but the 18min delay of signal acquisition at autonomous hibernation exit on 20 January 2014 was so nail-biting for every one, as getting a signal or not only meant either one comet escort mission or nothing….At the end I am not sure that all hibernation and wake-up events were fully understood and how close we were to a fatal failure…But it was such a relief to see that RF carrier signal raising from the flat background noise level !

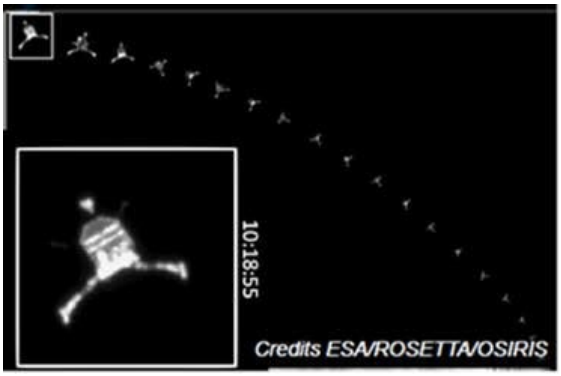


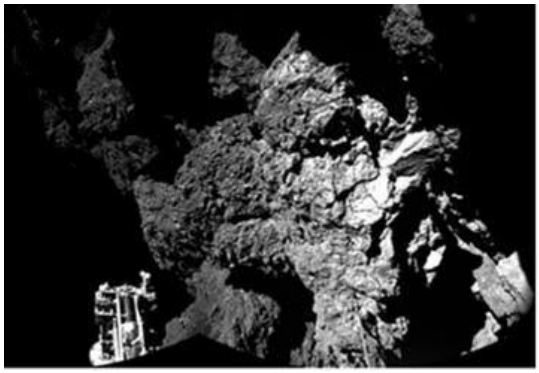
- ***After 2.5 years of an extraordinary comet escort phase !***

First it was so amazing to discover our comet’s shape (Shrek’s boot according to Michel Janvier), so unusual and puzzling (a concatenation of two objects according to scientists).



Then came the time of Philae's landing on November 12th 2014 after a difficult selection of the landing site (not so many flat smooth areas on Chury…). ESOC's FDS and operation teams did really a fantastic job by guiding Philae to within 100m of its targeted landing site ! Unfortunately things went not so smoothly on-board Philae with multiple failures of its landing systems ! But after 3 rebounds if finally settled down in a remote dark area and mainly achieved its primary science mission, providing this historical close-up image of the cometary surface. A small miracle after all, which definitely ranks its mission as a true (partial) success.



Meanwhile Rosetta resumed flying over the comet in closer and closer orbits for high value remote science, but as the comet's outgassing activity increased a lot approaching its perihelion pass (in August 2015), star trackers measurements started being affected by the dust environment, locking on false stars, losing tracking and failing in lost-in-space acquisition mode. This caused a couple of safe modes and new flight rules were put in place by ESOC with more margins in comet relative distance. In parallel we proposed our support to ESOC to investigate the flight behaviour and study potential improvements, but this took a long long time (one year) before ESOC finally approved and implemented (partially) our recommendations (some retunings of the gyro-stellar estimator parameters)….We even had to revive the old STR Engineering Model at ESOC and optically stimulate it with the microSTOS from Philippe Vidal (including thousands of false stars) in order to convince ESOC FDS experts and operators that the proposed changes were valid and safe !

Then Philae woke up briefly in summer 2015 but could not resume science because of issues with its on-board transmitters and because of adverse conditions for the data relay. It took a while before Rosetta could fly-over again at low altitude to finally find Philae in a high resolution picture early September !

- ***And now for a violent end of mission (and a bit frustrating)…***

Rosetta is old and suffers a few failures but is overall quite healthy with a lot of fuel remaining in its tanks, so why ending its mission now ? Well as you probably know the big reason is power shortage as the comet orbit gets further away from the Sun, and now is about the right time because of a long solar conjunction period starting early October and blocking communications with the Earth. ESA and scientists could have chosen to hibernate the S/C a second time but apparently the odds of surviving a longer hibernation period farther from the Sun, and the associated operations maintenance costs discouraged this idea. Some scientists even prefer a fruitful final descent now for sure, rather than a potential but very uncertain second comet escort phase in four years.

So that's it and we have to admit that the end has come,…..except that personally there remains some frustration, due to the fact that Rosetta on-board SW has been patched to switch it off at touchdown, whereas we could have tried to operate it at the surface, after landing. Indeed we have

everything on-board to try to re-point the antenna to the Earth after landing : accelerometers to detect the touchdown, thrusters to prevent the rebound (in open-loop to keep it simple), gyros to propagate the attitude, and a 2-axis articulation mechanism attached to the High Gain Antenna….Of course the probability of success would have been probably low (because of the risks of tumbling and damaging the antenna articulation), but certainly worth the try, assuming a reasonable effort to develop an OBCP SW and test it at ESOC on the S/C EQM (a few weeks…). Well we tried to convince ESOC (for more than 1.5 years !), but without success, probably because they did not believe enough it could work (as the guy repeating “ça ne marchera jamais” ? but certainly not me this time !), they were over-loaded and could not allocate resources on it, and were afraid of the Public and Press reactions in case it would fail…..Not really good reasons for me however, compared to the tiny chance of potentially achieving a great engineering achievement in space exploration, while prolonging Rosetta science return on the comet surface for a few hours or days !

Anyway, for sure Rosetta will remain one of the most successful ESA science mission ever, so farewell Rosetta !

More info on Rosetta through the ESA Rosetta blog http://blogs.esa.int/rosetta

Cheers

Pascal