**Interview**

**MISSIONS TO MARS: MSL AND MARS 2020**

Interview with AE Alumnus Gerhard Kruizinga working at JPL

*The Jet Propulsion Laboratory (JPL) located in Pasadena, California is the leading organisation for planetary missions and a point of attraction for many Aerospace Engineers. The Leonardo Times interviewed a former student of our faculty who made the big leap overseas and dedicated his career to planetary exploration from JPL. We talk to him about his job, current and future Mars projects he is involved in.*

**Can you tell us something on your time at our faculty, were you involved in any societies and what was the focus of your program?**

‘I was secretary of the second RVD and I was involved in the Study Tour to Russia that sadly did not work out. For my Masters, I was in the group of Professor Wakker and I graduated on the simulation a validation of Eddy currents in the oceans using altimetry. Since the Eddy currents change rather quickly in time, it was hard to measure it. I did simulations on how to better determine the shape and the movement of these currents using data of multiple satellites.’

**A lot of students in Delft would like to work at JPL. However due to ITAR this is very difficult. Can you elaborate a bit, on how you got to work at JPL?**

‘To work at JPL you need a Green card. Therefore, my idea was to go to the USA as a PhD student and try to find a sponsor for my Green card there. After my graduation, I went to the University of Texas to do a PhD, where I specialized on orbital mechanics of radar altimetry missions. Apart from a sponsor, I also met my wife in that time, so that solved the whole green card issue! Also, I got to know a post-doc at the University of Texas who later went to JPL. He was the one that actually hired me at JPL and is still my boss. So, my advice to students would be to pursue at PhD in the USA, because this maximizes your time there such that people get to know you. But you need patience as well. I spend more than seven years at the University of Texas before I could actually go to JPL. So, it is possible but it takes time, perseverance and a bit of luck.’

**Your specialization within JPL is on navigation for interplanetary missions. Can you describe the biggest challenges for navigation and orbit determination for interplanetary missions and how they differ from earth orbiting missions?**
'The last interplanetary mission I worked on was Mars Science Laboratory (MSL) rover, Curiosity. The biggest challenge would not be to determine the position in the orbit, but to predict the position in time. Especially for MSL, where we wanted to land inside the crater, predicting were you will be in a later time is extremely important. On Mars, there is of course no GPS, so you will have to tell the computer where he is now, what the uncertainty in that position is such that it can adjust its trajectory to land on the position. The uncertainty we had for MSL was around one kilometer in position and two meters per second in velocity.

So, the emphasis for our navigation and orbit determination is in the prediction of the path. In the end, we were only 200 meters off from our target. Partly, this amazing accuracy was due to the fact that the spacecraft was rotating on its journey to Mars. The rotation cancels out a lot of perturbing forces that are hard to quantify. So basically, we only needed to worry about the perturbations in the direction of the rotating axis.

It is important to note that there was actually no onboard navigation on MSL. All the navigation was made on the ground. There is no onboard processing of the sensor data with regard to flying. Everything is downlinked to earth. It is like you are navigation to Mars by looking in the rear view mirror. You look always back. First, we do an uplink to the spacecraft and we can measure very accurately the position and the velocity of the spacecraft. All the information collected on Earth because the onboard processing power for spacecraft is not nearly sufficient to model its trajectory with the required accuracy. However, there are some new developments for onboard navigation like Auto-nav. A first version of this was used on the Deep Impact mission. Since they did not know actually where the comet would be, they included an onboard navigation to correct for the large uncertainties. I think that developments like this will be the future but for now, we are still doing most of the navigation on ground.'

**What would be the biggest challenges in developing the Autonav? Is it mainly computational power, or are there also other fundamental issues involved?**

‘I think it’s making or getting the right measurements, because the thing is, if you want to interpret data on-board, you also need to know, where is the earth, because that’s where all your signals are coming from, so it’s probably computational, but also some things like the Earth’s orientation. Remember the Earth is wobbling a bit as it rotates. We need to take all those things into account, and the spacecraft would not know anything about that. For instance when you are flying to Mars, there are other spacecraft orbiting around Mars, and what we could use is use a link from the spacecraft in orbit around Mars talking to the spacecraft that is coming in, for instance Curiosity. People here are thinking about that, but it
has not been fully worked out yet, I think mainly because we don’t have the right measurement devices on-board.’

And I guess those spacecraft orbiting Mars are also not designed to do that.

‘We are using the current Mars orbiters with the Delta measurement, which is the measurement perpendicular to the line of sight. We are actually making delta door measurements to Mars Reconnaissance Orbiter (MRO) and Mars Odyssey to see where Mars is. When we are flying to Mars, we are looking in the rear-view mirror; we are not looking ahead. So we don’t really look at Mars, in no way or shape or form are we detecting Mars, as we travel. So, we need to know from models, or in this case the measurements from MRO or Odyssey where Mars really is, to make sure that we hit Mars at the right spot. But you can also do a delta door between MRO and MSL, and then you can get some idea of where is MSL relative to Mars. That’s an example where we do use it, but we still go through Earth to do it. I’m sure in the future, it can be done directly. That’s the best way, because then you’re really looking forward, then you’re sensing where Mars really is, because that really matters. Remember people are saying we are flying to Mars, that’s not really the case, what’s happening is, we’re flying in space, and Mars is just catching up with us, and we have to hit it just at the right time. Otherwise, you are coming in too late and you miss the whole thing. Or if you’re coming too early, you probably crash into it. MSL arrived at a velocity of about 5.9km/s relative to Mars; you need to be very accurate. Especially for Curiosity, we had a very narrow corridor. That was quite a challenge. So knowing the position of Mars was actually one of our big challenges too. But because we had MRO and Odyssey and they were making measurements too, we had a really good model for Mars, and where it was. And as I said, we were only about 200m off, so that was pretty good.’

And comparing this to Viking spacecrafts, that were kilometers off…

‘Well the Vikings also first went into orbit around Mars; they spent some time taking pictures of where they wanted to land. Here it is like, you don’t go in orbit around Mars, you just land immediately and so you’re coming at a hyperbolic trajectory into Mars. There is no going back, and that’s it. For Viking at least, like you said, that was kilometers at least, tens of kilometers, but remember if you first go into orbit, if you’re a little bit high or a little bit low, that doesn’t hurt anything. Once you’re in orbit around Mars, you can actually improve your orbit around Mars, then you have better information again, and that’s what they did for Viking.’

Until now, MSL has been quite a success, but are there things, especially in field navigation, things that could be improved for future similar missions, for example, the Mars 2020 mission?

‘It’s funny that you mention that, because I am working on 2020. I’m working on the navigation for 2020. I would say, from a navigation point of view, this was by far the best mission that I worked on in terms of our success of modeling everything that’s happening. Just to give you an idea, Curiosity has a Radioisotope Thermoelectric Generator (RTG), which is basically using the decay of plutonium to generate heat, so we can actually make electricity on-board. We could actually see that heat coming out of the spacecraft putting a little propelling force on the spacecraft. Based on the measurements that we got, we could actually model the force that was acting because of that. There were just a few minor things that we could’ve improved on, but in general, it was really, quite remarkable how well this went. I’ve been on other missions, like for instance Phoenix, which is also a lander, which went to the North Pole of Mars, or near to it. There, we had continuously thrusting, little thrusting, I always compared it to like you’re driving a car and then a little baby seems to be pulling on your steering wheel trying to veer you off course. That was much more difficult to predict, and much more work to actually get to the same result. For MSL, I think it was one of the cleanest spacecraft that I’ve flown at this point, so for 2020 we’re basically going to use exactly the same modeling, and the same assumptions, so not much in that particular changed as far as navigation, as far as improvements.

Curiosity has been operational on Mars for little over a year now, Are you satisfied
‘Well, there was no methane at Gale crater, it could be that at other places on Mars there is methane, but Gale crater so far, they have found very little. But the other interesting thing for me was, where we landed in Gale crater, I always call it a parking lot. We just landed on a nice flat piece, so that we can drive to something that is about 10km away that is very interesting. And then there is, the first thing the scientists do, we’re supposed to take a right, they take a left. And that was kind of puzzling to us, like here we spend as this time trying to get as close as possible to the mountain, from a navigation point of view, and then they go left, going away from it. But it turned out, that was really, I guess, the best move so far, because they went about 500m the other direction and they found clay deposits. And that really suggests that it was neutral water. And that was the main goal that they were trying to go for, find clay deposits, and from that they can conclude that in the environment around that time, life could have existed, because it was in a neutral situation, neutral water amp. Essentially, MSL already has kind of done what it needed to do, to demonstrate that. But no, we’re now on our way, we’ve now driven about a little more than 3km, we still have about 6km to go, but then we’re going to get into a mini ‘Grand canyon,’ driving up this mountain that’s about 5-6km high, and I think just the pictures are going to be just amazing. But there, supposedly, are all these layers, clay layers, and so now they started at the bottom of history and work their way up. I’m looking forward really to see that, but probably still, probably, it’s going to take a year before they get there. They’re trying to get there really fast right now, but still, they’ve found some interesting stuff on the way, so that they’re stopping now and then, to check some other stuff as well.’

You mentioned, you are also working on the Mars 2020 mission, could you maybe tell a little bit about its objectives?

‘I can kind of give you the philosophy of the mission, the first thing is, it’s called ‘build to print’. What we mean basically is, we’re not going to change the design of the Sky Crane, or the rover, to save money, makes the mission cheaper. So it will look very much like Curiosity, the only difference is of course all the instruments on-board, and right now, there’s just an opportunity, NASA has announced, that they ask for proposals, for people to actually propose instruments that they would fly to Mars. They’ve given some guidance from a team called the SDT, the ‘Science Definitions Team’. One of the objectives is for instance, we may want to get some samples that we store for a later mission and take little samples and store them. Another later mission may actually go pick it up, that may be one of the goals of this mission. Also, Curiosity really went there to see, is the environment suitable for life. I think for 2020 they’re trying more to see, if there are really signs of life. But go online, search for where they actually describe what the goals are for that mission. Currently, it states that people are actually proposing instruments, so that’s all I know at this point.’

So, it will be more focused on astrobiology, especially now that this water has been found.

‘Right, basically the next step, and maybe work on sample return. You know, as I said, it’s all maybe, because maybe it may be too expensive, and then they might not do it, so it’s really up in the air right now. But from a navigation point of view, it will be virtually the same. As I said, we’re going to basically do the same thing.’

Since the focus of your career has been on unmanned spaceflight and exploration using unmanned spacecraft. What would your opinion on manned spaceflight. Are the manned attempts of the possible future worth the effort, from a science point of view?

‘Oh, that’s a good one. I’m a big fan on manned spaceflight. You can build robots and they can do all kinds of things, but in general, a robot is only going to do what you tell it to do. When you put a human into a certain situation, put him on Mars, they will see things that a computer will never thought of, or do things that a com-
computer doesn't have the ability to. So I actually hope to see in my lifetime that we will for instance, will land on Mars. Of course, it's extremely expensive, so that's the drawback. It's a lot cheaper to go with robots in general than with people. But I think for certain things you really need humans to go somewhere and really find things out.'

*On a kind of follow-up question on this, you and your colleagues at JPL, they are kind of the experts on getting to Mars. How do you see the chances of success of these manned exploration missions? In the US, you have Inspiration Mars; on the other side of the ocean, you have Mars One. How do you see their chances of success, is this taken seriously by the space community?*

'It's funny that you mention it, I did some work for Inspiration Mars actually. We look at the navigation, how much propellant you need to bring in order to do the flight. So, from that point of view, it's definitely possible. The thing though is Inspiration Mars, I don't know about the European effort, a lot of hardware still needs to be made or hasn't been flown and they are running out of time fast. I think their challenge will be getting all the hardware in time ready to make the flight. For instance, I think Inspiration Mars wants to launch in January 2018 and you know we are a little bit more than four years away and that's very short. So things are not there yet. So technically, I think it's feasible.'

*You mentioned that you are also working on the Indian Mars orbiter mission that launches at the end of this month can you elaborate a bit on your involvement?*

'JPL has been asked by the Indian Space organization, ISRO, to share navigation. So we are going to help them, as they fly we are going to process the same measurements as they do and just help them with the navigation to Mars. I have also worked on the Indian moon mission called the Chandrayaan, when they went to the moon. It is the same thing we did for them; we did the “shadow navigation” because they had never gone to moon at that time and it's the same now. They have never gone to Mars and there are some unique aspects flying to Mars. They just want us to kind of do shadow navigation so that there will be a mission success and they will make it to Mars. That's why we are doing it. You know there is more and more co-operation between the International space agencies and I think JPL wants to fly an American instrument on one of the Indian spacecraft later. Its called Mars Orbiter Mission (MOM).'

*Can you also tell us something about future NASA missions you are working on now? You already mentioned 2020.*

'I am also finishing up GRAIL, that was a mission around the moon very much like GRACE where we produced a very high-resolution gravity field and we are almost done finishing crossing of all the measurements. These measurements will be the inputs for the scientists. GRACE and GRAIL are two spacecraft flying behind each other about 200km apart and we measure the relative velocity between them to less than μ/sec. With that, you can very accurately measure the gravitational model of the Moon or the Earth. Of course, for GRACE it's designed to produce a gravitational field for the Earth every month. We can see the ice-caps melting in Greenland or Antarctica. We also monitor any glaciers in Alaska, Patagonia. That is basically an Earth science mission. I am also working on something that's going to be called GRAIL follow-on. So I am working on five things right now: GRACE, GRACE follow-on, GRAIL, MOM and 2020!'

*That's quite a lot!*

'Too much actually!' ✅