Luca: First of all, thank you very much for inviting me.

Stuart: A pleasure!

Luca: I watched quite a few of your videos and I have always asked myself who was behind them! These are very interesting actually and I think they are quite detailed. So, I was even thinking it probably was someone actually inside F1 - are you working in F1 somehow, or you can get information?

Stuart: I'm not...just a lot of research. I'm trying to do more - like with you - talking to people this year, getting some insight from people as best I can. Because I'm not a journalist I don't quite have all those inroads yet, I'm working on that. [Inaudible] Alice reached out?

Luca: Alice, yes.

Stuart: Someone from EM tweeted at me as well to talk about flag things. And it's interesting because you were already on my radar.

Luca: I'm not sure what your main goal is, but what I can tell you it's what year motorsport proposed to, to form a one or two other championship as Assistant General system integration. So basically, EM sport provides what is called the Marshal system. The Marshal system was born in 2006, roughly, in Formula One after collaboration with the FIA to implement in front of one possibility to trace the GPS position or the cars around the track, and then being able to reach these cars and to by radio and to inform the drivers about possible dangers associated with an accident. Of course, this doesn't since the system has evolved. And the radio quality, or let's say the bandwidth, or the information that we are transmitting from rescuepro to the cars had increased, and the same as for cars to the ground. And 2009/2010, we implemented for the first time the flag panels. So that is what's called digit flags, electronic flags, and we call them flag banners. Or TSP as an abbreviation. And since 2009, every two, three years, we have been evolving this product - try to make it brighter, better, all this technology, that as Formula One is always improving that our technology, we do the same. And this year, for the first year, we have also produced the flag panels in Moto GP. So I just came back yesterday from Guatemala for the first race where they have introduced the panels for the first time in the history of Moto GP. I'm quite happy about that.

Stuart: As you were just saying, back to the beginning what - before EM started this project and then working with the FIA and stuff - what were they replacing? What was happening on track, originally, was it just marshals on the radio?

Luca: Yes, correct. So basically, in the cars there were no signals, no information to the driver apart from the marshal waving the normal flags around the circuit. Of course, this was creating some issues because the driver maybe was not looking in the right position, so he couldn't see the marshal flag. But it was also dangerous for the marshals to be exposed on the track to wave this flag and try to reach as possible [to see if the show itself is flags basically] and so it was quite dangerous for the time as well. But now with the panels, we can place the panel very close to the track so the driver can clearly see it. But the marshal can be kept safe in a position beyond the fence and maybe far away from a corner in some situation. Some circuits we have 300 or 400 metres of cable between the marshal and the panels so that the marshal is really able to see the entire sector that he is working on and is in a safe location so he can manage and display flags whenever he needs to. And he can react very quickly, because the information is not only displayed on the panel, but it also displays to those in race control. And to the driver dash so the driver can see the flags appearing on the steering wheel. In Imola, this week we had the accident between Bottas. So there is an onboard camera from [rockery?] that was just behind where the crash was still happening. You can see on the record steering wheel, the flags coming on. So basically, in the moment, the two cars will steer colliding with each other, the marshal presses the yellow flag, the flag was displayed on the panel and information was sent to the cars that were approaching. So in a fraction of a second, all systems they're working for many people in both.

Stuart: I mean, I'm interested in this as an interconnected system, because you have the marshal posts and someone has some controls there, I'm guessing that some of the marshals are in control, and you also have race control. So maybe you could talk me through how an incident unfolds? Does it start with the marshal activating a system which goes to race control? Because both people can override whatever is happening can't they?

Luca: Yes. So basically every panel has a console connected to it, and which is let's say managed by marshal. So the marshal has the ability to display a few flags, like yellow flag, double yellow flag, slippery surface, blue Flag, green flag or white flag. The marshals are still very important, because it's true we have lots of technology, we have the cameras, we have GPS positioning, we have all this technology, but the human reaction and the human perception of what is happening is still the most important thing. So, when the marshal sees something that is happening that may be dangerous, he knows already if he was to show a yellow flag or a double yellow flag depending on the situation and the moment you press the button, the information is sent to race control. So race control can clearly see that there is a part of the circuit where there is a problem. So then after seeing this information, they can direct the CCTV camera or something to better understand the situation. Depending on the situation then race control can decide to deploy a safety car or a pace safety car or even a red flag depending on the problem or the gravity of the situation. But basically, the marshal is the first input and the race controller

can take over depending on how the situation unfolds. Of course, any commands and every information is sent directly to the drivers. So for example, if a car's there is a yellow flag with a panel is yellow because we did the same in different sectors. In a circuit with 19 panels, that means there are 19 sectors. And each Marshal is controlling one of these sectors. So if something happens in one of the sectors, the marshal presses the yellow flag. Every car entering the sector receives the yellow flag on the dash as well. But the moment race control deploy a safety car or pace safety car or flag, this information is sent to all the cars so they know straightaway that there is a red flag or a yellow flag or whatever. So this is basically the chain of reaction of informed information. And also, of course, when the marshal presses the yellow flag, it's also displayed on TV when you see yellow in Sector one or two that is all connected to the system.

Stuart: And that's what you call the electronic flag system isn't it? And the track map with all the information that's happening across the whole scene.

Luca: Yeah, so we call it marshal e-system, and the partners are part of the machines.

Stuart: Because there's a lot of you have a lot of systems that are now connected to each other. It started essentially with the positioning system during each car, and the flag panels. And now actually you have information panels and that has more data - I think people will be used to seeing those often on the grid. They'll show driver numbers, and they'll show you start procedure information and stuff. I wanted to ask about these data positioning modules, because they're very accurate. On your website, it speaks a lot about being able to quickly know if like a car stopped on track or if a car's cut a chicane or you know, things like that, that may be out of the ordinary that may need flagging up for marshals and race control. How would that play out? How would that work and how accurate is that?

Luca: So, knowing where cars are is probably the core of a system, because everything is based on current position. We have been developing a positioning system through the years and we are still based on the technology that needs GPS and [???] platform and some algorithm to define the position on the cars. Let's say in a situation with clear sky or in a good environment, we can easily reach like 20 to 30 centimetres. The situation is a bit more complicated when we are under a tunnel in MonteCarlo or Singapore or Baku - these are conditions where infrastructure like GPS can have some issues. And in this condition, we need to intervene with sensors like national sensor or gyroscopes and work together with this sensor to create an algorithm that gives us the possibility to position the car in the right position. Maybe in this situation, we don't add the 50 centimetres but we're still able to understand you know one or two metres position even if the car is on track or is off track or which sector the cars are falling. The positioning of the car is very important apart from the safety car also for detection. For example [???], we provide the information regarding the DRS use. So DRS detection and

notification in activation. So knowing that the car is actually eligible for opening the wing that we are weighing is it's quite important to have this procedure.

Stuart: So your system is connected to the DRS zones in this case?

Luca: Yes. Yeah, of course the difference is still based on the timing information that someone else provides us with information, but the notification is from our system.

Stuart: I guess I'm pre-empting what people may question about the positioning things because that you know, 30 centimetres, one metre tolerance is, well much more accurate than I guess private GPS would be your car or your phone because that's got quite a large margin you're using more precise but probably not at the level needed to do the whole track limits detection that's...

Luca: Now fortunately the GPS may still have some drift depending on the force, that lateral force of the vehicle that is the drift. I mean GPS works quite well in an empty field. If I have, I don't know, a farm tractor that is driving a straight line for the 20 kilometres per hour we can have a two centimetre position sure, but on an F1 car with the hard braking and deceleration, acceleration - that is less accurate. So when we are talking about track limits, we are talking about really two or three centimetres. It's possible to give a sort of indication that the car is out of practice on the track limit, but it cannot be used as an official measurement for procurements.

Stuart: Yeah, I understand - that's kind of out of scope, isn't it? But, yeah, I think some people are, or wonder why it's so difficult to keep track of cars when you have all these things. But that's sort of beyond the realm of what you're trying to do with safety. How much of what you know, I mean, you started from the basics, and you've expanded the scope of what you do, how much of that is - you guys thinking about what Formula One needs? And how much is the FIA? We're not just talking to formula one but whole motorsports coming to you and saying, "can you now do this for us?" As you take over, you're now sort of controlling the start procedure? For example, that whole timing. Is that your scope?

Luca: No, not for formula one. Not often, but the starting procedure is a product that we provide to the circuits, but formula one is separate. But it is quite interesting as this question, because basically, it started with a single question, and was from Charlie Whiting. Asking, "I want to see the position of the cars." And that was the first day - "can you do it?" Yes, of course, we. It took us some time, but in 2006 we are the first cars forecast with GPS position. And then it was quite a collaborative relationship with FIA for formula one for the first few years. But we reached a certain point where the system was providing a lot of information. And we thought that this information could be useful for other championships outside from the world. And, in fact, but there is a while now, we are proposing the same concept on a different solution to

other championships, that they don't need the same precision and information as formula one. But still to provide the efficiency of adding yellow flags or car positioning to race control and information for the drivers. So we are expanding to these markets. And we noticed that everybody has different requirements, different questions. And so adjusting the system to everyone is probably the fun part.

Stuart: Yes.

Luca: Just for experience of the last week, as we do the first race, Moto GP with the founders. We came back home very happy how everything went. But with the list of homework, a few requirements for requests from the championship they would like to adjust, which is fair enough, because moto bikes have a different way of racing than cars. So now we just need to learn how they use the system. They also need to learn how to use the system, what is the potential? The possibilities behind the system? And so yeah, there are many things to learn every day and adjusting the system.

Stuart: Yeah. I imagine you went through that procedure like up to 2009 and beyond when you started introducing these things to Formula One. How did Formula One respond to starting to replace or at least complement traditional flags and marketing systems with these electronic systems? And they didn't have quite sophisticated dashboards back when they started coming. They had little flashing lights if I think I remember.

Luca: Yes. I would just want to say that flag panels and the normal flags are the exact same. What I mean is that the partners have not completely replaced the man on track now, we still have flags waved by the marshals. And there is no difference between the flagpole and normal flags in terms of mean. So for example, if I have a yellow flag on the corner and 200 metres after I have a green flag weighed by a marshal, that green flag is still acting as the end of the yellow sector. So even if the green panel is three hundred metres after the first green yellow flag is, of course, and the partners help a lot. They are first of all more visible and more clear to the drivers because they are closer to the track. And also in different weather conditions, if you think heavy rain, or on a sunset situation where you have the sun or maybe setting in front of view of the partners is still a bit more clear why the flag may be shading on the background. So this is one of the advantage points of having an electronic flag system. But as I said before, the introduction was quite smooth, in terms of because it looks like probably two or three years to make the system a complete system and the driver had enough time to learn step-by-step how to identify the flags, the meaning of the flags. And now because the system is used by formula two to formula three all the drivers arriving to F1 they already evolved with the system. So now basically this is part of the daily F1 routine, if you will. It's probably new championship that never use the partners that need to adapt to but from the feedback we have, it's quite a positive step forward. For our safety as well.

Stuart: Absolutely. Can I ask you a little bit about...well, I'm going to ask you how connected they all are to that. But you have excellent recording systems and one of which is your ADR is the accident data recorder, which is essentially a black box with gyroscopes and accelerometers, essentially to monitor the car in an accident. And you've now got accelerometers in the earpieces as well haven't you, to monitor driver's heads. When did that come in? And can you tell me about the data that records and how that's helped both in responding to accidents and learning and developing safety systems.

Luca: So the ADR is quite, it's not a brand new project, it's probably I think six or seven years old. The project started with the request for [???] to have something in the car to log asset information. The aim was to have a box that was not really for Formula One, but for other championship formats from our free formula three to formula four, for W series, it is now so the different championships that are now adopting this solution. ADR is as you said, is a black box like the one from aeroplanes, where in theory, you don't really access the data on this box unless there is something that needs to be analysed, like an accident information. It's a box that has internal accelerometers or sensors that can define the, let's say the accident severity. And loads of information coming from the cars are logged all the time. And this information is useful to FIA, when they do some accident analysis to identify problem brakes or deceleration or impact and all this sort of information that are useful then for future development for a stronger car. So, other future safety programmes there have been quite a few accident wealth information from ADR helped [Fi?] to improve the car chassis or other things. Regarding the EPA, we call it EPA is an ear plug accelerometers. They have been introduced five or six years ago as well. Back in the days, it was still...there are some accelerometer sensor integrated in the in the ear canal, the driver, together with the speaker for the radio voice. We have now of course developing a new system, which it's smaller, with a lot more sensor integrated, and easier to replace as well. Because it looks easy, but integrate all the sensor and all the electronics to dry the sensor and the power in the sensor is all in a very small part of the human body, it was quite complicated. So when something was damaged, quite often the driver is pissed off of something happening, the first thing he does is just pull the ear plug straight away. And usually the mechanics are like why? So now with the new model that we are developing, these parts are easier to replace. So it's also easier for the maintainer. And the customization, because when you have one or two drivers changing every season, you need to readjust the holding for the phone. But not adjust, they actually have to make a new moulding. So integrate sensors. It's a process that takes quite some time. But now we are introducing this new model that everything is capsulated. And everything is integrated, so it's easier for the driver to replace. So to maintain this, this EPA works kind of the same way they do have accelerometer inside and everything equals logged inside the idea and when there are high impacts, this information can be used to understand the brain movements and the head of the driver movements and no oscillation and all this information is because the ear canal is the closest

part to the brain of the driver. It's quite important to understand what they say the effects of an accident over the drivers brain.

Stuart: I think a lot of this information is for you know downloading and analysing but how much of it either the EPA or the ADR give some information immediately? For example, if medics are first responders need to know quite how severe impact a driver went through - does it deliver any information?

Luca: Yes, in case of an impact, there are certain thresholds that define the gravity of the accident and assume these thresholds are reached the system will send radio information to race control. So straightaway they know what is the severity of the accident and they are able to send a medical car in support. A clear example was last year with Grosjean on impact. As soon as the car hit the barrier, we received information of the impact. And of course in that situation the American car was already behind because it was the first lap of the race but information was sent for race control. It was sent to the medical car as well. And so they knew already some of the information of the accident. It's extremely direct information. Last week in Imola again, the accident between Bottas and Russell, we receive the notification as soon as the two cars collide together. So yeah, in less than a couple of 100 milliseconds, we receive information, all the impact.

Stuart: Okay, and that sends, like deceleration information from the car, it hits a certain threshold. And that triggers a warning or a display in the medical car and race control. That's, like straight up.

Luca: There are some information that are important for the medical crew, and for race control, but delivered real time for them to understand what is the situation.

Stuart: Around the I think the ear accelerometer, the EPA, Jonathan Noble was quoted as saying it was key and understanding exactly what happened in that quite infamous Alonso crash in Melbourne. And is that part of taking the data, analysing and sort of recreating a kind of 3D understanding of the movements of the head?

Luca: Yes of course, when you have then access to all this information, you are able to recreate the environment and put all the pieces of the puzzle together, recreating what was the condition out to understand the different holes that you have in the safety environments, and then fill this gap with new technologies or modifying things. And the project of the halo was not created just to provide the safe life to make the drivers safe, but came out after a long process of development of research of data from accidents and impacts under this condition. So from all this information you can create from the small difference to the halo to other things, so everything is useful to help making things safer.

Stuart: This is really fascinating. I think a lot of people would realise just how connected all these different areas of marshalling and information and data and track safety are into sort of one homologated system, we definitely come a long way since well, marshals on the radio. And while marshals still pay that crucial role - being able to spread information quickly and make decisions is important. Is there (maybe you can't say)...what do you have your eyes on? What maybe the next developments are going to be? Or is it just refining what you have? Have you already been asked whether it be in F1 or moto GP or things like for something new or something to get your teeth stuck into?

Luca: You know, it's like when an F1 team decides that they need to, to gain that 10 milliseconds to get faster and they start thinking about different paint on the car to reduce the dragging or the weight. The same is for us, wherever we can improve the system to increase the functionalities, maintaining efficiency or even increase efficiency because there is always margin for improvement. And EM motorsport as a company is always a research development company. We have products and projects but the main core for the company is research and development. So we are always looking for new things and modifying information to improve our services and products. For the future, yes, we do have projects. We do have technology that we want to introduce step by step. Maybe later in the year, you will see.

Stuart: I look forward to seeing what that is! Yeah, I thank you so much for talking to me. Is there anything I haven't really touched on that you think is important.

Luca: I think that this is quite an overview of what the marshal system is, and what kind of information apart from the standard flags and information, but there are many things that the system can handle. So, but I think we kind of covered everything.

Stuart: Yeah. And I mean, you definitely other things you do outside of Formula One for other series that are added for individual teams and cars for logging engine speeds and helping them improve performance and stuff like that, which is...

Luca: Yeah, we are not really into performance. This is something - it's for the team. So we are more on the boring parts, like safety. Yeah, it's, let's say, race management and safety conditioning. Motorsport. Performance is not our main goal.

Stuart: Now, I guess what I mean is, teams, we get any data they can.

Luca: Yes, yeah.

Stuart: Find a way to pay for it.

Luca: Yeah. Yeah. But we see for example, the GPS has been produced for a safety reason. But the teams they made strategies over at pitstop qualifying. Even other things that you can get from the GPS position. So it's, in that case is performance as well.

Stuart: Yeah. And it also provides information to us because your system is linked to the TV graphics that show sector times or when safety cars deployed, that seems pretty, it's the D link to everything that's going on. So we as a viewer are getting information to understand and enjoy the race as well.

Luca: That is a funny thing that I usually tell to some of the marshals. When they do some briefing. I tried to explain to them how important is the difference between yellow flag and double yellow flag, for example, and how important is their role as a marshal. Because when I tell them that the moment they press the button, the drivers will see the flag through the panel. So for the dash race control, see the flag, the teams see the flag, but also millions of viewers will see the flag. So that is what one button can do to the whole world. Just not give them too much pressure, but…

Stuart: You give them a lot of power!

Luca: Yeah, exactly. So this is how the system is actually linked together.

Stuart: Yeah, I think that's all very interesting. Can I ask you something? I should have asked right at the very beginning, but I forgot to do. Can you just tell me your name and your role and your role within EM and relating to Formula One just as an intro?

Luca: Yeah, so I am Luca DeAngelis, and EM motorsport deputy manager and senior race control racetrack engineer for Formula One, and yeah, my work is trying to make motorsport as better it is now.

Stuart: Thank you, Luca.