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Selected Credits:

Project Gotham Racing series, Fur Fighters, Forza series, Disney's Treasure Planet





You've worked on a large number of racing games now. What do you think are some of the unique challenges when it comes to racing game audio?

The biggest challenge for racing games is the car audio itself. Cars are very complex sound objects. So you think of many audio objects in games as a single thing, but a car is multiple layers of sound combining together to create a single thing. So the engine, the intake, the transmission, the exhaust system, the four tires are all completely different sounds, all reacting in entirely different ways to physics inputs coming in. So having the character of the car change on you all the time means that we've got to build each of those layers separately from one another so we can capture them. And then when the player is playing the game, obviously we need the sound to react to what he's doing, not necessarily how we wanted to record it in the first place. So building up an interactive model of the engine, the intake, the exhaust, the turbos, the transmissions, the superchargers, all these different pieces, whatever is attached to the car, all need to be doing their own thing, but then they all need to come together in the right way to create the final sound that you hear, so not just thinking about each of those objects separately, but also the positional information of that. So if the engine's at the front, the exhausts are at the back, the tires are on the four corners, as you move around the car, the sound's going to change based on what the piece you're nearest, what you're looking at. So how can we bring all of those layers of sound together to create what is essentially one single object, which is a car? So that's hugely challenging.

If you're in an adventure game, you want to play a footstep, you play a recording of a footstep, but we have to build it from layers and layers and layers of sound, so instead of using one voice or two voices to play back the sound, we can be using thirty, forty voices, easily. Because if you think about the tires in themselves, they're very, very complex objects. You've got the rolling sound of the surface, but then that could be a loose surface, which means there's going to be kick-ups, so you've got debris coming up and hitting the bottom of the car that you need to reproduce. Then it starts to skid and it's, depending on if it's a lateral skid, or if it's a longitudinal skid—so is it wheel-spinning? Has it locked the tires? Are you going left to right? How much are you going left to right? What's the friction between the surface that you're on and the tire itself? All of these are different sounds that all need to interact together. So a tire model can be even more complex than the engine model in many ways.

And then you think about, in a racing game, you're going to have thirty to forty different driving surfaces, all with different sound characteristics. And the four tires could be on separate surfaces. So you could have your front left tire on a rumble strip, your right tire in the dirt, and the two left tires on asphalt, all doing different physics interactions and all making different sounds, so you can chew up easily twenty voices just simulating the four tires of the car. Then you add in all the different sound components of the car itself, and you can be using thirty, forty voices creating these big complex models, but without that, you're not reproducing accurately the sound of what the car's doing. But then that's just a car. And then in the game you've got lots of other cars. And you've got the





world around you, and the sound interacting with the world, so racing games are a very different challenge because you've got so many sounds all interacting with one another constantly.

You mentioned the need to simulate. How much of it is trying to get as accurate as possible a simulation of reality versus either a televised reality or a creative, emotional design reality?

Everybody has an opinion on the authenticity of a car sound. Some people have driven it in real life. Some people have seen it driving around in the streets or on a racetrack. Some people have watched a YouTube video. Some people have seen it in Hollywood, in a movie. None of those things sound the same. So, what is authenticity? Authenticity is your personal perception of how that car should sound. So we have to take all these things into account when we're trying to design. What is an authentic sound? Because you'll have people who will say, "You've got the sound of this car wrong. Look at this YouTube clip," that was recorded on somebody's cell phone that's just a big distorted mess. But they'll say, "This is what that car sounds like." And to them, that's their authenticity bar. Where somebody else will like, "I own this car, I drive it every day and it doesn't sound how it intended, how I remember it, or how I feel it should sound."

All I know is I was there, or one of my team were there, to record the car. We have the recording of the car, so if I wasn't there at the session, my perception of the authenticity of that car is the recording we got back, but what if the recording we got doesn't capture something that people think of when they think of that car? So, one of my biggest jobs is to try and take all of these pieces and say, "Well, this *The Fast and the Furious* movie made the car sound this way, but this YouTube clip says it sounds like this, which is completely different. I've got this recording, that doesn't sound like either of those two. There's a guy in the office who used to own this car, and he says, "This is how it should sound." So all of them are right, and none of them are right all at the same time.

So my job is to try and take, well, what is it?, And try and make a caricature of it in many ways. When you think of a certain type of car, a Subaru WRX for example. A lot of people think of the big bassy pulsing exhaust. And the turbo. They're the two characters that people remember from that car. So let's focus in on trying to make those sound, make them sound authentic but also make them sound impactful. We don't want any of the cars in the game to not sound good. And it may well be that some cars in real life don't actually sound that great. But we don't want to deliver that experience. We want to capture the essence of what it is, and the reality of what it is to many people and try and bring all that into a final package. So, yes, we are trying to be authentic, but different perceptions of authentic are in play. So we're trying to distill that down into what we believe people want it to be and deliver the best experience we can.



I assume the same goes as far as where the listener is, to position them in terms of that audio, because how the car sounds from the driver's seat is going to make a different sound from somebody standing beside it and listening to the engine, or somebody in front of the car. Do you create a kind of archetype of a listener position?

All the different sound objects that we do, the engine, the intake, all the pieces. The exhaust, the tires, they're all individual 3D objects in the world reacting correctly. But in the game the camera can only really hear the car from several fixed game cameras or from replay cameras. So in replays we're trying to create a broadcast experience. So people who have been watching this, if this were broadcast on TV, how would that sound? Try and reproduce that. When you're sitting in the car, that's obviously how most people perceive the car. So we need to get that right, too, and obviously in play there you've got the car is filtered because of the body, what's the weight reduction. Because one of the features of *Forza* is you can reduce the weight of your car to turn it more into a race car. So how do we change that character going from a stock Honda Civic through to a fully stripped-out race car Honda Civic? Which you can build your car to be. How do we make the sound react to those changes? And using real-time effects to simulate some of those things and sometimes we're using real recordings to simulate some of those things. So there's a lot of pieces in play there that we can use to try and reproduce that but one of our game cameras is hovering eight feet behind the car, six feet in the air. Nobody has ever driven a car and been able to hear it from eight feet behind and six feet up in the air, driving it 200 miles an hour. That doesn't technically exist, so nobody really knows what that sounds like. So you've heard the car go by you, but we're trying to say, "This is what it does sound like, if you could be in this position, this is what we believe it would be."

***Forza 5*, I think, was a bit of a departure in that you brought Skywalker sound in, as far as getting their perspective on how you might take a more creative angle to create a car sound beyond simulation. Can you talk about that creative aspect and how you balance that with the fans' desire for simulation?**

So one of the goals for me when we were making the sound for a *Forza* title is we want it to be an impactful, compelling experience that people will want to play. And we also want to simulate the car sound as authentically as we can. But when you go watch a movie, people still hold up the bar that movies are the best sounding things you can hear. I get that, I fully get that. But they do a lot of things that you would never hear in the real world. And that's not a skill set I know. I'm a game audio guy. I've come up through the ranks of game audio. Never worked on films, so what are the tricks those guys use to do that stuff? I can listen to a movie and dissect it, but one of the things for me was, well, how would they approach it? The only way to say, "If *Forza* was a movie, what would they do?" Was to take it to a movie studio and give them a video of a lap

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of *Forza* and say, “Here it is, what would you do?” And it was a really, really interesting exercise because they come up with ideas that I’d never thought of, but there are also some ideas that would break it from a video game perspective. Like, they asked me, “Could the car audio go away at certain points?” And I’m like, “Well, no, not really.” And they were like, “Why not?” People need to hear the car so they know when to shift, they know what the engine’s doing. You don’t have that seat-of-the-pants feel you would in a real car, and in a movie experience you’re being taken along for the ride. In this case you are in control. So it was a very big deal for us to try and capture that and really push on them that there are certain confines within the gaming world that we couldn’t break.

But in this particular piece we said, “No, we’ll break them.” We can’t do that, but I want to know what you would do. And they approached things very differently than we would. They normally work from shots and scenes, and in a game you don’t have shots and scenes. You’re stuck six feet behind the car, driving around the track. The camera never changes. So they invented scenes. They were saying, “OK, well, the main straight, that can be a scene. The next corner and the run-down, this part of the track, that can be another scene. Here you’re going through a tunnel. That can be a scene. Here you’re going past a lake with a village on the other side. That can be a scene.” So they actually went through a two-minute lap of our alps track and created scenes and mixed each scene very differently.

They started having a lot of non-literal sound. Just, “Oh, this sound adds some tension, so we’re going to add this sound underneath in the mix to create a feeling of tension because we feel that you should be tense at this moment. Here we wanted a feeling of lightness and openness.” And they were using ambient sounds to really change all of that. There were places on the track where all you really heard was the crowd audio. And then there were places where you heard the car. There were the places where you heard the skids. But the big thing they were doing is they had a very small number of sounds playing at any one time because they really wanted to shift your focus to that area. And that was a big learning for me, and why we can’t go to those extremes in the gaming world, is because there are gameplay cues in the audio that you can’t lose.

But we did look at that and say, “OK, well, can we utilise a lot of dynamic mixing techniques to shift the focus of the mix in a direction?” Not go as far as they did, but say, “Oh, you’re starting to skid, you really need to hear the tires now. Let’s bring the tires up and let’s duck the engines out a little bit.” Not to the point where it’s lost and you don’t know when to shift, but at that moment, the tire audio is the most crucial thing for you to hear to play the game. As you are going down the main straight, you’ve got very little interaction with the car, especially if it’s a long straight and you’re in top gear. All you’re going to do is keep the thing going in a straight line. There’s very little you’re pinned on the throttle, you’re not really braking. On those moments we can push the crowd and the ambient audio up a bit and really sell the world around you because it’s not important to you at that point to really know what the car is doing because



the car is just doing its thing and driving fast. So we've started to design intricate dynamic mixing systems that allow us to look at what's happening in the game and push the most important sound for you to hear at that point to the fore, which also creates diversity and variety as well. You're not just hearing this droning engine going through its cycle. That's important. It's a racing game. The car has to be the star. We want to do that, but there are moments where the car isn't the star from an audio perspective and there are more important things for you to know. And that's really, really crucial for me, is it keeps it interesting. You're not just hearing, "Bwaaa bwaaa bwaaa." We can say, that's cool. That's great. we've got that, but the tires. The environment is another big one. The sound that you hear should change based on the world around you.

So as you're driving through a big grandstand section, you should get big echoes and reverbs off those grandstands as the car goes through. The car is loud. The crowds are erupting. That's a very big sonic experience. Then you might go to the next corner and you're out in a field, there's nothing really much there. We want to bring everything back down. You get close to a barrier, you should hear the car reflect back off the barrier around you. And some racetracks are in the middle of a field with a few buildings and a strip of asphalt running around and there's not really much you can do. But where can we sell it? Where can we overplay it? Where can we bring interest and excitement to the sonic characteristics of the game?

And then we'll do a track like Long Beach in a city, where it's just everywhere all the time, and we're actually looking at, "Well, where is it less important, because we don't want to bombard you with it for the entire lap." So we can bring it up in some big built-up sections, there's a big tunnel section, and we can make that really epic, but then where do we bring it down? And it's more about the constant interplay of the different sounds. The engines, the tires, the reflections, the crowds, the sense of speed. And constantly varying those to keep the audio interested. If you don't, then it just becomes a monotonous huge noise. Plus, you can only have so much sound before it becomes a wall of sound. I know Phil Spector wanted wall of sound, but sometimes that can get really fatiguing. Especially on a loud game like a racing game, so trying to sort of dynamically shift the focus helps you not just be listening to the same thing over and over again and we can really play on that and take this game sound in a new direction.

How are racing game players different from other types of game players? Are they more likely to have a surround sound setup, are they more likely to invest in the equipment that would give them that kind of experience than other types of players?

A lot of the hardcore *Forza* players do have racing rigs. So they'll actually have a seat, steering wheel, pedals, shifters, you know, some of them even have triple-screen setups. And part of that will be a surround sound setup. So you have a core, hardcore, very much looking for that simulation experience. But that's a market that we have to aim for, and that we have to hit, and we want to deliver the best experience to them, but there's an



awful lot of people, as well, who are playing the game in a bedroom on a stereo LCD TV with tiny speakers in it. And I don't want to compromise their experience at the expense of the hardcore. Everyone should be able to play our game and have a great audio experience. So we very much do focus on doing two separate mixes. We do one for surround sound for the people who've got the high end gear, but we'll also do a separate stereo mix for a low-fi stereo experience that changes the character of everything. We will mix and master the game entirely differently for that experience as we will on the other side, but without both, then somebody has to compromise, and I'd rather not do that.

So the second part of that question is that, I can imagine that there are those people that understand this is what that particular car sounds like, but if I'm going to play a racing game, I have no idea, and for me it's more about the personality of the car. How do you sort of design the personality into the car? How do you create its own personality and differentiate it from other cars that are in the game?

So if you think of the car audio as in, many ways, in a movie, it's our dialogue. It's our main character. So we have to accentuate the key characteristics of each car. What are the things that you want to highlight? What are the things you want to call out? Some cars have a very loud turbo. Some cars have a very quiet turbo. So on some cars, the turbo will be accentuated. On other cars, it will be pushed back in the mix because it's not really important to the character of that car. Introducing various sounds that come in and out at various places on the rev range or only with certain amounts of throttle input, or only certain physics things happening to the track. The audio system in *Forza* is entirely physics-driven. So whatever the car is doing on the track we're taking all that information and interpreting it to make the audio experience what it is. So 4,000 RPM is completely different with no throttle versus half-throttle versus full throttle. If you could hold the car at a fixed RPM and just sweep the throttle up and down, you would hear the sound change massively between the two. Is the car moving? Is it not moving? Is it neutral or is it in gear? If it's in gear, what gear? All of these things affect the way it sounds. And overselling those caricatures is really the way that we try and do it. But we also mix it differently, depending on whether it's your car or whether it's another car. For example, in a movie, dialogue will always be in the centre channel, unless it's somebody talking to you from behind and they're specifically trying to call out that somebody is in a different place. Normally you would be looking at that person, and dialogue is in the centre channel. That's our car. So the player car, we do mix to go through the centre channel. Not be totally focused on it. We have some width, and if you're in the car obviously it's all around you, but it's centre-focused.

The AI cars, we don't allow them to play through the centre speaker. That is reserved for your car and your car only, and it's the only thing you'll ever hear there. Because it's the thing that is most important to you to hear. So they have a phantom centre, so they'll pan left to right, but they want actually play in that speaker which hopefully gives your car some character and some life, and a presence that isn't available to anybody else in the



games. You should always be able to hear the car you're driving even if you're in a quiet car racing against a really loud one.

I'm curious, because you speak of the cars as characters, and you're mixing them as characters. Do you see the game then as a narrative? Is there a story arc that you can tell through audio as well?

Every race is a story. If you think of the flow of our game, musically we do actually tell a story. We go from your car in what we call our Home Space, our core area, so it's you and the car in a beautiful space. It's beautifully lit. It looks amazing. It's almost an intimate moment between you and the car. So we're looking for, sonically, it to be a very intimate feel. Musically, sound design, it's very much set to be a zen space for that to exist in. But then, you choose your car, you choose your track and off you go. So we're then introducing a sense of wonderment and discovery you're going to new exciting places. You're going to go race your car, but then you get to the track, and it's all about the preparation for the race ahead, the battle. So we do shift the, sonically, things up, musically and sound design-wise, we go for very much, much more that big epic preparation for war. This is your battle tent behind your lines where you're preparing your car for the race ahead. Then you get your car ready. You've got your set-up on your car. You go to three-two-one. All about focus. You're getting set for the race, so we shift things sonically, we bring the music down, we bring the sound effects down. You've got your focus moment and then boom! Go. Off you go. And the race is all about striving to beat the guy in front of you.

If you think of a race, you're not thinking about getting to first place to start with, you're thinking about overtaking the guy in front. That when you've got past him, you're overtaking the guy in front. You're working your way up through the field one car at a time. Sometimes they're in bunches and you can do more of that, but we think of it as you're slowly climbing the ladder to get to the final place where you want to be. So we try and build the tension throughout the race with that, and then you get to the finish line, you've got that sort of exhale. It's, "Ahhh. Race is over." So we have that breath, that moment. And then you're in the reward scene. You're actually getting rewarded for what you've done in the race so we create a celebration. I don't want a *Mario* fanfare, but I want a celebratory moment where you can look back and say, "That was cool. We had a really good time." And so there's a narrative. And then at the end of that you're either off to another track or you're back to the Home Space. So every race is a story, and we're trying to tell an audio story throughout each race musically, sound design mix, a role shifting in each of those phases and even within them doing different things. So the story is really important and you need to tell that over and over and over again, so we've got to make sure you've got variety in there in the cars that are in the game, the tracks that are in the game, the mix that's available. All those things will allow us to tell that story different ways each time.



If we can go back in time a little bit, was *Project Gotham Racing* your first racing game?

Yes. When I was at Bizarre Creations, when I joined we were making two games, *Metropolis Street Racer* for the Dreamcast, and what became *Fur Fighters* for the Dreamcast. They were my first two titles. So I was actually working on *Fur Fighters*. That was sort of a racing game. I didn't work on, day-to-day, was *MSR*, but that was the first racing game that I was involved with, but my first racing game from an audio perspective was *Project Gotham Racing*.

What would you say are the highlights or main changes in terms of how audio has changed over that time period?

So when I started out doing audio for *Project Gotham Racing*, I knew nothing. It's my first game. I had friends who'd done audio for games. I was trying to learn from them how they would approach doing car sounds. I was looking at it from my perspective of what I thought was important. We were partnering with Microsoft, who'd done *Midtown Madness* and some other racing titles, so they had some perspectives to offer. But it was very much a clean-slate approach. It's like, "OK, well, we need to record a car being driven, but driving it around, it's difficult to record without wind noise and what-have-you at the time." And it was like, well, why don't we put it on a rolling road. We can keep the car stationary but we can drive it. Yes, we have to worry about dyno noise, but that's easier to deal with than wind noise a lot of the time, so let's try that approach. And other racing game studios were doing similar things at the time, so it was something that we did and we recorded it and we chose the wrong microphones, we put them in the wrong places. It was very much a trial-and-error system, but over the years we've developed, "Oh, this works. This is the sound I need." And then you'd start meeting car guys. And car guys would say, "This sound is important." And I was like, "Well, I didn't know that. I didn't know that sound was important."

So I would start learning new terminologies. I remember one car tester at Microsoft telling me that the car wasn't rawty enough. And I'm like, "You made that word up. What does that mean?" And it turns out it's an intake heavy, it's a very specific sound that car guys know. I had no clue. So, I learned a lot over the first two *Project Gotham* games about what makes a car sound like a car. And starting to understand the difference that there is a difference between a flat six and a V6 and a straight six. And I was like, "Well, it's all sixes, isn't it? It's just six cylinders." But they're not. They're different, and they're different for very different reasons. So we started to learn. We started to adapt our recordings. We started to find microphones that were better at doing the job of capturing the sound we needed. Recording techniques got better. In the early days we were lugging around DAT machines or laptops. And at one point we were even lugging around a big old Mac trying to record stuff, because that was all we had to record with, but portable technology got better and we started to get portable multitrack recorders that could do eight, ten channels at once. Microphone technology was improving, especially on high SPL levels, and there were microphones that suddenly we could put two inches from



the exhaust on a race car without it just distorting all the time, so things evolved as we evolved.

And then—I believe it was on the trip to Detroit to record cars for *PGR 3*—I met a guy who was a specialist in fluid dynamics. And it was just like, this is way over my head, but he explained to me that a car is like a wind instrument. In the middle you've got this engine making a "Brrrrrr" sound. And then you have a pipe that's sucking air in and a pipe that's blowing air out. And as you change the length and the diameter of the pipe, it changes the sound that you hear. And suddenly it all made sense, that one of the reasons cars sound different when you upgrade them is because you've added a fatter exhaust with less muffling. And that's exactly the same as it would be on a wind instrument. You know, you change the character of the sound by changing the pipe work. You're using the buttons to change the length of the pipe and the notes that you hear, and as you go from a trumpet to a tuba, the pipe works different, the sound is different. And from that point onwards it all made perfect sense of why everything sounded the way it did, and using those principles it's been really easy then, from that point forward, to say, "OK, I need this car to sound this way. I can do these things to make that happen." Or, "I'm looking for a car that has these specific types of mods on it, because that will have the character that I'm looking for, and get a lot closer to what it is that you need to do.

How will you deal with electric cars?

Well, hopefully, we can license our audio tech to manufacturers, so they can start making them sound good [laughs]. Electric cars. They're very interesting because they allow you to hear things that you don't normally hear. The first time I went out in a Tesla, I was amazed how much tire information you could hear. I knew what tires sounded like because we'd close-miked them and recorded them over the years for various games doing various manoeuvres, but actually sitting in a car and driving around and hearing all those little subtleties without any engine noise drowning it out was really cool. And there are companies now that are trying to tune electric engines, trying to make them sound a certain way. There are lots of people out there investigating whether or not they can actually pipe engine audio from a car into an electric car and use the RPM and the throttle response to play back an interactive system, similar to what you would get in a game, and how a button that, maybe, you say, a Ferrari, Porsche, Mercedes, Audi, you can choose what you want it to sound like. So those things could be pretty cool, but I quite like driving the electrics in the game, because you get to hear a lot of stuff, there's a lot of detail in what we do that a lot of the time you get, it's implied, or it's sort of there, but you don't really get to hear how much work went into it. And now suddenly you can hear all the work that's gone into all of those sounds.

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What about haptics and the feel of the subwoofer? Do you use these to recreate the feel of the car?

So in a racing game, if you're racing a car in real life, an awful lot of the driver's feel, and I've spoken to a lot of the race drivers about this, is not from the audio or it's not from the steering wheel, in some cases. It's the g-forces. You actually, you can feel the vibration of the wheels through the steering wheel. And you can feel how the car is reacting to the g-forces basically from the seat of your pants. You sort of get that natural vibration and sense of movement, all of which is completely lost in a racing game. We can use force-feedback steering wheels to simulate the tires, but a lot of the cues a driver would use to let them know that things are going to happen they don't get. Audio is a big part of simulating that. When do you need to shift? Well, you can use audio. If you listen to the car's engine, you can pick out when I hear this tone, which it reaches this pitch, that's my time to shift. If you're listening to the tire audio, we've got lots of cues in there that are like, "You hear this sound? You're about to lock your brakes. You hear this sound? You're about to start losing traction on the front tires." This is if you're in a rear-wheel drive car, it's this sound and it's in the rear tires. There's a lot of really interesting audio cues that we've put in there that are haptics-type feedback, but it's an audio feedback cue that's telling the player you're about to do this thing, stop doing that. Or, it's time to do something, so there's a lot of information in there that gives you that sense, and we do have a lot of low-end content in our recordings that if you've got a good subwoofer can simulate some of that feel. But people say, "Ah, a race car went by me in a race, and it really hit me in the chest." It's like, "Yes, it's 135 decibels. Of course it hit you in the chest." I don't get that when I'm playing it at home on my twenty-seven inch TV with little half-inch speakers. It's like, no, the laws of physics say that could never happen.

So how can we make it sound that impactful, or that big, without it actually being that loud. I would like to think that if you did actually crank out a game to be that loud, it would hit you in the chest, but it's a physical response, and the subwoofer can play a part in that, and we can simulate a sort of pushing of the air. But unless it's at those volume levels it's never going to hit you in the chest like it does in real life. But there's a lot of work we can do there on simulating loudness. Using various—over the years we've used various distortion and saturation effects to try and make the car feel as loud as it is, even when you're not playing it at loud volumes. YouTube videos are mostly distorted, of cars, and people think that's how they sound, so you've almost got to slightly push things in that direction to make people think that, "Oh, it's so loud it's breaking up." We don't want to distort it and clip it and make it sound bad, but there are things we can imply to really sell that sense of volume and loudness.



Can you talk a bit more about your environment model? Because that's so important to the sense of driving.

So one of the big things for me, when simulating the sound of a race, is simulating the environment that the car is driving through. If you think about in the real world, you've got a car, you've got your barriers, you've got your things behind the barriers, you've got the general ambience of the world. Sometimes you've got tunnels. And if you've got a nice-sounding car, the first thing you do when you put it in a tunnel is you wind the windows down, you slow down as much as you can, and you floor it, just so you can hear what it sounds like. We want to simulate that. But you also get those little sensations if you're driving along and then suddenly a concrete barrier is alongside you, a foot from the side of the car, you'll notice the sound completely changes as you hear the tires and the engine slap back off that wall. One thing I think racing games can focus too much on is the engine sound. You play a racing game and you hear it and it's just engine. That's all it is engine. And it's like, well, surely the interaction of the way the car travels through the world should be just as important. Make it feel like a space. On the graphic side they start talking about HDR lighting and image-based lighting and the lighting reacting to the world around where you are.

I want to reproduce that from an audio perspective, so we're building a system in the game that allows us to model various early reflections and more distant reflections actually real-time. It's not baked into a reverb effect. You'll actually hear, as the car approaches a barrier, you'll hear the sound start to reflect from the barrier. Behind the barrier, you could have buildings and then no buildings and you should hear that sound change in contrast as it does so. You'll enter a big grandstand area and you should hear the sound sort of echoing around in there. Drive through a tunnel and you're completely enclosed, so you want a completely different sound again, so we've started designing systems using multiple delays and multiple reverbs to start really modelling not just the sound of the car but the sound of the car in the world around it and how it changes. So the car itself isn't changing, but everything around it that the sound is reflecting off is changing, and that creates a whole different experience and that's somewhere where we're going to keep pushing further and further because we believe that's where we can make the biggest strides, in making it feel like you are in this space. You're in this space not just because the sounds are right, but how the sounds are reacting to the environment and how far away it is. Distance models on a lot of things in games aren't realistic. It's sort of, the sound is gone, pretty quickly as it goes off into the distance, but we're working on a system now where you can hear the car two kilometers away. You don't really hear the car anymore, but you're hearing the sound reflecting off the environment and bouncing around and that's what you're hearing. You're not really hearing the direct sound of the car. You're hearing all the interactions of the car with its world and that all bounce around, and I think that's a big push. If we can start simulating that a lot better, it will start feeling like you are in the space and the sound is reacting to the space you're in.

