



KEEPING IT REAL

USING STATE-OF-THE-ART TECHNIQUES TO GROUND *DUNE* IN REALITY

BY KAREN MOLTENBREY

Sand. Lots and lots of sand. If there's one thing that people immediately envision when they hear the title *Dune*, it is the infinite landscape of brown/orange sand. Also, the giant sandworms. And, of course, the futuristic vehicles and otherworldly environments and objects.

All these were first described in the 1965 science-fiction novel by Frank Herbert and then later brought to life on both the big and small screens, first in David Lynch's 1984 feature film and then in John Harrison's 2000 three-part television miniseries and in 2003 with the sequel miniseries *Frank Herbert's Children of Dune*, based on the author's second and third books in the series. All were extremely ambitious projects. And while the miniseries was well received, the feature fell short with audiences. Not so with the recent *Dune* (2021).

Late last year, moviegoers were re-introduced to this futuristic world of sand, greed, deceit, and danger both aboveground and below as Director Denis Villeneuve (*Blade Runner 2049*, *Arrival*) presented his vision of this epic story from Warner Bros. and Legendary Entertainment. The film tackles the first half of Herbert's book, with *Dune: Part 2*, which covers the second half of the tome, expected in October 2023.

The screenplay, like the book, is set at some distant point in the future and centers on the noble House of Atreides, particularly son Paul (Timothée Chalamet). When his father, Duke Leto Atreides (Oscar Isaac), is offered stewardship of the desolate planet Arrakis by the emperor, he knows it is a trap but cannot refuse the royal request. So, the duke and his family leave their home on the ocean planet of Caladan to oversee the mining operations of "spice," a rare substance produced exclusively on the inhospitable lands of Arrakis that is highly valued throughout the galaxy for its psychogenic powers.

After arriving there, they face great danger from the giant sandworms that produce the spice, which is mixed in with the sand, and find themselves in the midst of unrest, as the local inhabitants, known as the Fremen, are distrusting of the new custodians after long fighting for their freedom and homeland against the planet's previous guardians, the cruel Harkonnens, who were expelled by the emperor and replaced by House Atreides.



CG artists built the giant spice harvester and ornithopter (at right in image).



DNeg flew its CG ornithopters into a blinding sand simulation.

Meanwhile, House Atreides forms an alliance with the Fremen. Soon, however, the Harkonnens wage war on House Atreides — just as the emperor had hoped would happen, thus weakening the powerful Atreides.

Dune reunites Villeneuve with Paul Lambert, two-time VFX Oscar winner who had worked with the director on *Blade Runner 2049*, serving as overall visual effects supervisor for this latest project. The director signed on in early 2017, after Legendary Entertainment obtained the *Dune* film and TV rights the prior year. Filming took place during the first half of 2019, although COVID delayed the movie's release for more than a year.

There were 1,700 VFX shots created for *Dune*. The main VFX vendor was DNeg, with 1,160 shots coming from the studio. DNeg's work ranged from simple plate-based extensions, digital creatures, digital crowds, and massive FX simulations, to 100 percent CG shots. Rodeo FX provided a handful of beautiful establishing shots of Caladan and Giedi Prime, the historical home world of House Harkonnen. MPC provided previs, while Wylie Co. handled all the postvis along with

blue eyes, in-house shots, and the cemetery and hologram sequences.

"We touched on the full gamut of visual effects, although a lot of the work involved the set extensions and CG vehicles," says Lambert.

Even with so many VFX shots, the intent was to achieve as much in-camera as possible. "Obviously this is a sci-fi movie, so you're only going to be able to [physically] build things to a certain extent. But, we tried really hard to at least have a basis in the camera so the visual effects artists could copy that and extend it out, rather than just leaving everything to post, where you can spend a lot of cycles, i.e. money, trying to get something to look believable. Whereas if you know exactly what you need to do because you have a basis in the plate, it's a lot more straightforward to get something to look more believable," Lambert explains.

While many already had a picture in their mind of *Dune*, whether from the book, the past film or TV series, the filmmakers basically started with a clean slate, bringing this film to life based on Villeneuve's vision. The director and Production Designer Patrice

Vermette had spent at least a year defining most aspects of the movie and devising all the looks. When Lambert came on board, he contemplated whether to re-read the book from his youth, not wanting it to influence any decisions outside of Villeneuve's script and direction.

Creating Unique Worlds

Dune was filmed in a number of locations, including Budapest, Norway, Jordan, United Arab Emirates, and California. Extremely large sets — “absolutely enormous,” as Lambert describes them — were devised by Vermette in conjunction with Villeneuve, as the pair spent a good part of a year coming up with those designs. Then those sets were built in the real world inside the various studios.

Despite the size of the sets, visual effects had to extend them even farther, which meant virtual extensions. “Denis was adamant that he did not want to deviate from this,” says Lambert of using CGI as a tool, rather than to drive the story.

Of utmost importance was matching the lighting (DNeg uses Isotropix's Clarisse for CG lighting). “We're at the point in visual effects where I can replace any background on any piece of footage you give me, but if the new background lighting doesn't correlate to the on-set foreground lighting, there's not much I can do about it,” explains Lambert. “When you go down a path of ‘we'll fix it in post or redesign something in post,’ it inevitably means you want to do something in the background that doesn't correlate to the foreground, and there will always be a slight mismatch. So, we made sure that Greig [Fraser, DP] was satis-

fied that the lighting was correct for what the background intent was.”

Without question, the inspiration for the VFX was realism, as Villeneuve wanted all the digital imagery to be grounded and as photoreal as possible. “Even though we were making a sci-fi movie, Denis never wanted any of the work to take you out of the film,” says Lambert. “He never wanted the blue eyes of the Fremen to be so electric that each time you turned to character, you'd think, What the heck? and it would take you out of the story. He never wanted any virtual camera work that you couldn't shoot with an actual camera. He never wanted you to get too close to one of the CG ornithopters. Things like that. He wanted to keep things as physical as possible, so everything was weighted with a certain amount of believability.”

The filmmakers also avoided using greenscreen and bluescreen, a film staple (only one sequence utilized bluescreen). Alternatively, Fraser, Vermette, and even Villeneuve pooled their collective experience to work things in-camera so they would have a solid basis for the visual effects. For instance, whenever there was swirling dust and that sort of thing, the actors all were shot in one pass, rather than in different layers — making it, in Lambert's opinion, far more believable.

“Obviously there are times to actually break things down into layers. But if I have all the characters and we are blasting them with sand and dust, and we've got a partially-built ornithopter in the background and everything is swirling around, I'm only adding CG wings to that composite,” he says. “It makes for a much harder compos-

ite, but in the end, it is more believable.”

Despite their efforts, there were times when bluescreen/greenscreen was unavoidable. This is when Lambert came up with an alternative: a brownish-colored screen that blended with the backgrounds. This idea came during prep, when discussion turned to construction of the physical sets and the materials that would be used, and the need for the typical bluescreen and greenscreen that would be used to extend the sets in post. But in Lambert's experience, especially for interiors, you never really get bluescreen lit correctly.

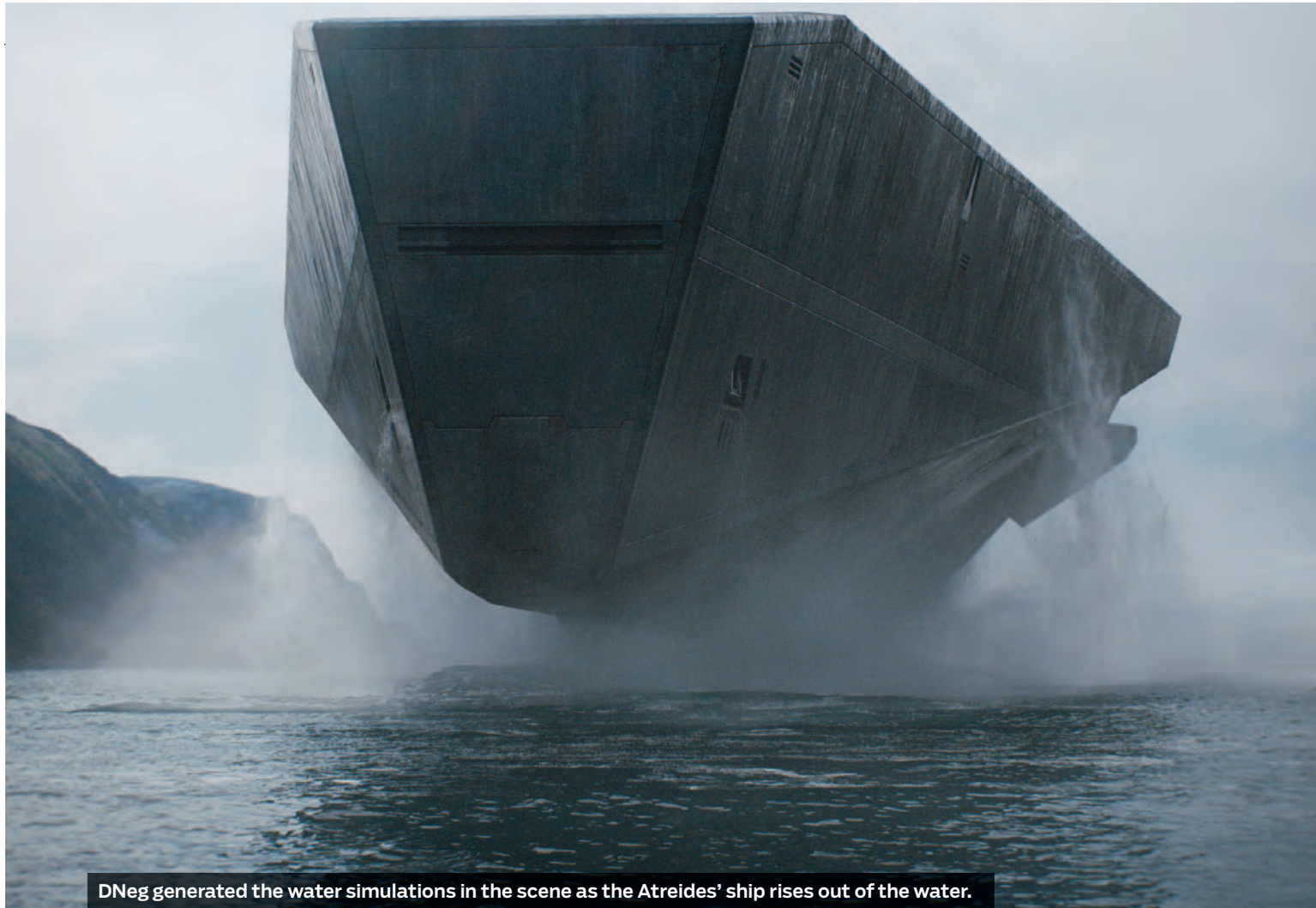
Because the group knew what the extensions were going to be, Lambert suggested using the tone of all the extensions and build that instead. “So if it's an interior on Arrakeen, it's going to be an off-brown color, and we'd put in a brown color, instead of blue, up to the ceiling. Just like the scaffolding, which was wrapped in cloth, the girders would be the proper color, too,” says Lambert. “So the idea, then, was rather than doing a full extraction and extending that, I would just be adding texture.”

This enabled Fraser to light his scenes without worrying about the digital world. In fact, all the interiors were constructed in this way. It worked, Lambert contends, because the filmmakers knew what the extensions were going to be at that point.

In fact, there were instances when the filmmakers retained the raw sand screen in the shots, as it blended in so well. For example, the exterior sand screens also allowed visors and any diffuse reflections on the various troops and ornithopters also to be kept

The artists built the imperial ship shown here as the emperor's entourage arrives on Caladan.





DNeg generated the water simulations in the scene as the Atrides' ship rises out of the water.

in-camera, as they felt that they were either immersed in the desert or Arrakeen.

Home and Away [Caladan and Arrakis]

Prior to the Atrides leaving their home on Caladan for Arrakis, their flagship is shown slowly rising out of the water, as water runs down the sides — a scene generated by DNeg Montreal using water sims produced in SideFX's Houdini. That took quite a bit of work, trying to find reference for such a huge vessel surfacing out of the water and getting the correct scale of the water and the interactions, says Lambert.

"We always use a lot of real-world reference when creating visual effects to ground things in reality. It was hard to find reference of something so massive emerging from the depths underwater. Paul ended up finding a video of a huge iceberg breaking off a glacier. It sort of tumbled on its side revealing the massive part of the iceberg that was underwater. The displacement of the ocean surface and all water cascading down the sides provided some of the reference we

needed to help ground us into something that is real," says Brian Connor, VFX supervisor for DNeg Montreal. "Scope and scale are especially important when trying to nail the look and performance of the various water simulations. What made these shots particularly difficult is the volume of water that was displaced. To help get the scale correct, Paul suggested that we literally add CG humans onto the sides of the rising Atrides flagship. This actually helped all the artists understand the scale in context, which is important when creating massive simulations like these."

DNeg Montreal also handled the scene as the Atrides and their ships arrive at Arrakis, including the pomp and circumstance that occurs as all the foreign dignitaries arrive for the transfer of guardianship, which entailed placing digital crowds that were generated using Massive software. That scene, says Connor, and others the studio did as the Atrides arrive at Arrakis, really set the tone for the movie and for establishing how large, arid, and inhospitable the planet is. It also serves as an introduction for the audience

as to how the rest of the story will unfold.

Whereas Caladan was a water planet, Arrakis was the opposite, a desert planet where most of the film takes place. DNeg Montreal was further charged with work on the spaceport at the Arrakis capital of Arrakeen (which the team at DNeg Vancouver later blew up in spectacular fashion). "We literally created [the spaceport] from a drawing by some of the best concept matte painters in the world working under Denis' direction. We also textured it based on the textures they had used," says Connor. "Our CG version and the concept practically matched one-to-one."

As for the digital work pertaining to the expansive Arrakis desert environment and the city of Arrakeen, that was mostly handled by DNeg's Vancouver office. The city of Arrakeen was constructed based on the premise of strong desert winds coming from the direction behind the city wall (shield wall) and up and over the wall while sand pelts the city. So, Tristan Myles, visual effects supervisor for the DNeg Vancouver team, devised the concept of having the buildings



The iconic giant sandworms were created in ZBrush and Maya.

slant upward, opposite to the direction the wind is coming from, thus enabling the wind to blow over the tops of the buildings — “an architectural functionality in the city that’s designed to withstand the sandstorms that inevitably sweep over the city from time to time,” he explains.

The Vancouver team ran an effects simulation on the city as a whole based on that wind direction to determine the resulting buildups of sand against the buildings and in all the little pockets and crevices where it settles throughout the city. The team did some texture work, as well, to achieve the hard sun-baked sand look on most of the structures, making them look lived-in but also quite old and well weathered, Myles adds.

The shots inside the city structures were filmed on what Myles calls “highly detailed” sets that were quite extensive, extending to the ceilings rather than just half-height. Nevertheless, the artists still had to add some CG extensions. “Paul’s bedroom and the training room, for example, were built with just a little bit of augmentation for the skylight, but very little,” he points out. Meanwhile, all the aerial shots of Arrakeen were CG, while most of the exteriors were either desert plates or shot on the backlots in Budapest using the sand screens and replaced with spaceport or courtyard shots, as is the case in the scene when the loyal soldier Duncan (Jason Momoa) escapes from the palace.

Also affected by the strong winds are the unique-looking sand dunes on Arrakis, which contain some sharp peaks sculpted by the blowing air. The look is based on the

dunes found in the Wadi Rum valley of cut sandstone and rock formations in southern Jordan, as well as aerial and ground plates shot in the UAE, all of which Villeneuve was determined to use.

“The biggest challenge there was getting the sand to look similar to the plate and getting the topology of the dunes to match [digitally] as well — that was key,” Myles says. “We couldn’t generate our own sand dunes; the director wanted them to look like those in the plates, which really do have a very unique look.”

Once Villeneuve selected this location, a team was sent to do Lidar photogrammetry scans for the CG build. “We made this massive CG Arrakeen environment from an actual location,” Lambert points out. “Again, we always tried to ground [the CG] either with plates or something real, so even though this was a massive CG build, it was still based on a plate behind it.”

Worms and Sand

Of course, the prevalent features of Arrakis are the sand and the worms. The CG worms were created from concepts by Villeneuve and Vermette, and then sculpted and modeled using Maxon’s ZBrush (formerly from Pixologic) and Autodesk’s Maya. Then, using Maya, the DNEG animators had the complex task of making them move.

“Denis had his own ideas of what he thought Frank Herbert was aiming for with *Dune* and the worms,” says Myles. “Obviously, David Lynch’s movie from the ‘80s was on everyone’s mind because it’s what everyone remembers, but it wasn’t looked at [on our

end] or copied; we stayed away from it. Rather, we went back to the original idea of determining what these creatures were and how they could move through sand. The look [for *Dune* 2021] was then devised from that.”

Despite the visual association of the giant worms with the *Dune* tome, in Villeneuve’s *Dune* thus far, their appearance is understated and limited (the movie covers only about half of the book, and most of the worm action takes place in the second half of the book). Therefore, audiences are given a slow introduction to these iconic monsters. “The way Denis played it was a bit like *Jaws*, wherein you only see hints of it throughout the movie until one interacts with Paul at the end,” says Lambert.

According to the book, the Fremen use large hooks and ropes to pry apart a worm’s plating and expose the inner flesh. This causes the worm to stay on the surface to avoid harming its flesh with the sand, enabling the Fremen to then ride atop the worm and steer it with those hooks. “We knew we had to have that as part of their design. We also knew they had baleen-like teeth from the mythology of them sifting food through their teeth, similar to how whales sift through water to catch krill,” explains Myles.

Based on that, the animators began to explore the director’s thoughts on how the sandworms — which are in the range of 200 meters in length — would move through the sand, carrying over the whale concept even further when it came to the giant worms breaching the sand and then crashing down after surfacing.



Complex simulations drove the sifting and as the worms moved below.

They also had to determine how the monsters would actually displace the sand as they moved through it — which resulted in approximately a year of R&D at DNeg. Lambert knew from the start that this would be one of the biggest visual effects challenges. One of the hurdles here pertained to real-world reference, or rather the lack thereof.

Initially the team at DNeg looked at a range of behaviors, including a truck plowing through a huge section of sand. Additionally, while in Jordan, Myles had obtained reference footage of objects being pulled through the deep sand there; that was an early indicator that the sand behaved somewhat like water. Following further animation studies of snakes and worms navigating through dirt and sand, the group found that the action was not really a struggle for them, but again, more akin to a whale moving through water. And that soon became the inspiration behind the sandworms' motion.

"Because the sand was so fine the simulations felt more like rippling water as it was moving, and every now and then it would become more violent and burst through the surface, just like a great big splash," Lambert describes.

The DNeg sand simulations were extremely large — terabytes in size. The simulations themselves were Houdini-based, crafted using a number of tools scripted in-house. "I was getting emails throughout the process saying the storage space was running low. I think we ended up using three servers. I don't know the exact number, but we definitely ended up using petabytes

across the show, between the explosions and the sand simulations," Myles notes. "That was the most I ever used on a show, and I think the most ever used at DNeg."

To save valuable processing time, the group needed a way to show how the sand was likely to move, without doing a full-on simulation, which can take days for some of the larger sims to process. So, they created a system called "ultra res," which enabled them to show different versions of the simulation, using "sand" particles gradually decreasing in size, to get a feel for the motion, starting with particles roughly the size of bowling balls, then the size of tennis balls and golf balls, and eventually the ultra-res version, which was the smooth, sand grain size.

Scale played an important role in the displacement. "The sand grain size really defines the size of this creature, too, because if the grains are too large, then the worm suddenly starts to look a bit small," says Myles. "Scale was always something we had to consider when the effects team started to work on this."

What's more, the simulation had to drive the ensuing dust clouds and other sims for the sand dunes that are farther out from the path of the worm, as it was not just the immediate area around the worm that was affected by the sandworm's vibrations. There are little shifting sands that fall down from a mound or rock formation, no matter how large or small it is, that had to be worked into the overall simulation.

Even though the sand displacement was generated digitally, in some small instances,

practical means were used, such as in the scene when Paul and Gurney Halleck (Josh Brolin), war master for House of Atreides, run for safety across the sand when a harvester is attacked by a sandworm. Here, special effects buried a large metal plate under the sand that vibrated and created the cavitating motion, giving the sand an almost quicksand consistency due to all the shifting

"It became almost like water," says Myles. "It was created by special effects and something that was filmed, but visual effects had to match the look of what the sand was doing and apply it to a broader area [in the shot], since the metal plate didn't cover the huge area affected by the sandworm." Not only did this give the VFX team some much-needed tangible reference, but it also gave the actors something to respond to on set.

In the Storm

Sand was an omni-present character of sorts in *Dune*. It surrounds and affects the way of life for creatures great and small. "When the Atreides are 'given' control of Arrakis from the emperor, they arrive with all the pomp and circumstance befitting a ruling family in *Dune*," says Connor. "We made sure we matched the practical effects created by Gerd [Nefzer, special effects supervisor] and the SFX team exactly so we could convey the arid, vast expanses of the spaceport."

To this end, the production team built a massive box that encased the ornithopter that Paul and Jessica used to escape the Sardarcaur, the emperor's elite military force. The ornithopter was mounted and animat-



Massive software was used to create the *Dune* crowds.



Digital artists constructed the desert city of Arrakis and covered it in sand.

ed on a motion base that was blasted by the SFX team with different types of sand, which the VFX team emulated and added scope to all the interior shots of the huge sandstorm itself, Connor notes.

The DNeg team separated the sandstorm into three different sections: front facade, interior, and top.

“We came up with methodologies that were the most efficient for each and blended between them when needed,” says Connor. “For the big, wide exteriors, we referenced the massive sandstorm photography we found in a *National Geographic* documentary. The sandstorm can be almost a kilometer high and several kilometers wide and deep. This required extensive R&D to design and render all the shots we see above the sandstorm itself. Each shot seen from above had to be simulated and designed to work with the sequence, as the amount of sand required huge amounts of processing time and disk space.”

CG Craft/Vehicles... and More

Dune is filled with various craft, from the spaceport in the Arrakis capital of Arra-

keen, to the Atrideides spaceships, to the dragonfly-like helicopters (ornithopters), to the huge spice harvesters, and more. Once again, scale was a major hurdle for the DNeg teams. The ships were huge, and the spaceport had to be massive to house those ships. And, the CG models had to be destructible in such a way that enabled pieces to fall off when they exploded during the attack.

“Building to that scale was quite tricky, and then there are the heavy simulations on top of that, too,” Myles points out.

The ornithopter is a most unusual aircraft, with Vermette’s design promoting the notion of maneuverability, making audiences believe the vehicle indeed can fly. An estimated 11-ton partial model of the so-called ornithopter was carried out to the desert in Jordan and suspended from a large crane. CG wings and other augmentation were later added in post. This practical model was used for a shot looking downward at the sand as the ornithopter meets up with a harvester. Back in Budapest, another partially-built physical model was mounted to a hydraulic rig (giving it full 360-degree rotation) and surrounded by the sand screen.

For the most part, DNeg Vancouver built the giant CG spice harvesters, strictly adhering to designs from Villeneuve. Meanwhile, the DNeg Montreal studio built the flashes seen in the early part of the film—the Bene Gesserit shuttle, the Atrideides spaceships, and more, in addition to harvesters and ornithopters. The group further orchestrated the attack on Arrakeen as enemy spaceships are descending and explosions are occurring all around.

DNeg Vancouver assembled two so-called super teams in effects. One handled the sand, which is detailed earlier in this piece, and one handled all the explosions and destruction—small craft, large craft, and those in between.

In Suspense

When Villeneuve signed on to direct a new version of *Dune*, he decided to go big. The set pieces and stages were huge, as were the interiors, which “oftentimes were so massive that VFX didn’t really have to extend them much, just the tops and maybe some sides. But for the exteriors, we always had to do a lot of heavy lifting” says Connor. “Although, there was always something built that we could grab onto and analyze.”

Big, yes. Even the visual effects. However, as Connor points out, there were no visual effects for visual effects’ sake. “Villeneuve was not interested in having something flashy, he wanted it to feel integrated and part of the story. It all had to make logical sense,” he notes. “It was a very deliberate, grounded-in-reality kind of show.”

So, the big question on everyone’s mind is, Is there a *Dune* part two? The film—which was held for more than a year before it was released amid the pandemic—certainly left the door wide open to that, covering just half the book. It has even been called *Dune: Part One* in the opening. And indeed, Warner Bros. has greenlit Part Two, expected in the fall of 2023.

At a production cost of an estimated \$165 million, *Dune: Part One* was an ambitious project, although it brought in a reported \$387 million (and counting) at the box office, even with a simultaneous limited streaming release on HBO Max. And you can bet that Part Two will be just as ambitious. ■

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