Exquisite Danger

PIXAR ARTISTS SEND A 'BOY' AND A 'DOG' ON A COMING-OF-AGE QUEST IN THE AMERICAN WEST

BY BARBARA ROBERTSON



he film begins with rain falling on Aspen leaves, dripping from pine needles, and splashing on rocks. We see a farmhouse planted in a meadow. Clawtooth Mountains hover in the distance. It's a beautiful,

pastoral setting. But, there is an unsettling undercurrent of danger and a struggle for survival. The pioneers are vulnerable. The land surrounding their homestead is so vast it could even dwarf a family of dinosaurs. And, it does.

In the capable hands of artists at Pixar Animation Studios, it becomes easy to believe that dinosaurs didn't become extinct. Instead, herbivores, like this family of homesteading *Apatosaurus*, became farmers. Carnivores, like a family of *T. rexes* we'll meet later in the film, became cattle ranchers. And raptors? They became rustlers.

Peter Sohn directed the Disney/Pixar film *The Good Dinosaur*, the second animated feature created at Pixar and released by Disney this year.

Pixar doesn't shy away from emotional stories, as the two 2015 films – *Inside Out* and *The Good Dinosaur* – attest. But the two films couldn't be more different. *Inside Out* (see "A Frame of Mind," May/June 2015) took viewers inside a child's mind, a brilliantly colored and brightly lit emotional world filled with reflections.

The Good Dinosaur sends a child outside, on a real and metaphorical passage through an expansive, painterly landscape. His journey of emotional growth plays out in nature.

The child is Arlo, an 11-year-old *Apatosaurus* dinosaur voiced by Raymond Ochoa. Arlo is a goofy, fearful, 18-foot-tall child, the baby of the family, who stays close to his father. Until, one day, Arlo loses his dad in a tragic accident and he falls into a rushing river. The river propels the fatherless child into a wilderness: a huge, terrifying world he'd never seen before. In this film, nature is the antagonist.

"This movie is about facing your fears and finding your way through," Sohn says.

Less fearful in these wild open spaces is a second character, Spot, a feral, six-year-old human boy who Arlo meets along his way. Spot is an orphan who has lived on his own in the wilderness. He barks and howls. He moves on all fours. He doesn't speak.

"This is 'a boy and his dog' story," Sohn says. Arlo, the dinosaur, who acts like a human, is the boy. Spot is the dog – a human boy who acts like a wild animal.

"Spot is everything Arlo is not," Sohn says. "And Arlo becomes fond of the little kid. It's a



AT TOP, SET DRESSERS WORKED FROM USGS TERRAIN MAPS TO CREATE THE VAST LANDSCAPE. AT BOTTOM, THE CG RIVER FLOWS THROUGH 200 SHOTS.

fun, sincere, emotional story of friendship and discovery."

DP Sharon Calahan, Production Designer Harley Jessup, and Sets Supervisor David Munier and their teams of artists worked together to create the environment through which Arlo and Spot travel. They coordinated with teams led by Effects Supervisor Jon Reisch and Simulation and Crowds Supervisor Gordon Cameron. who heightened the emotional setting with motion. The river, trees, clouds, grass – everything in the environment moves in sync with story points.

"This film was an extraordinary collaboration between art, lighting, and all the technical teams," Jessup says. "We worked closer together than on any film I've worked on at Pixar. I don't think the film would have worked unless the settings were exquisite and nature was a big antagonist."

A RIVER RUNS THROUGH IT

Arlo's first terrifying moment with the antagonist happens when he falls into the raging river.

"The river propels us into the journey and provides Arlo with a means to get back home," Reisch says. "It's his yellow brick road. But beyond that, Pete [Sohn] insisted that the river itself reflect Arlo and Spot's emotions. When they first meet, the river is churning. When they connect, the river is glassy smooth. This was the biggest effects show we've done, and the river was the biggest challenge."

Thirty-one technical directors created the effects – twice that of any previous film at Pixar. And of the 900 effects shots in the feature, 200 were of the river. To understand how the river should look and behave, Reisch worked with Jessup and Calahan.

"Sharon [Calahan] painted color strips and did pastels –

early studies at different times of day to show the lighting and how much we can see underwater. Once we knew we were all pushing toward the same goal, we worked with technical directors to make sure we had the tools. There was quite a bit of development."

Pixar has built its effects pipeline around Side Effects Software's Houdini, and the team used that software program's Flip solver for the river. To conquer the problem of simulating a river that ran for hundreds of miles, the team divided the work into manageable chunks.

"We did close to seven or eight simulations, each a quarter- to a half-mile in length," Reisch says. "It took half a dozen layers to get the surface, and more than that for the churning rivers. So, we'd parallelize at every stage. We'd surface in small chunks and then reassemble clustered sims into a coherent whole. We wanted Pete [Sohn] to have the ability to tell the story with the best assemblage of shots. We would integrate the modules and then light and dress them differently so the audience never saw the same river."

Pixar's ability to draw on a 30,000-core renderfarm made it possible to handle the 17TB of data churned up by the rivers.

"The water was the thing that scared all of us the most," says Susan Fong, global technology and rendering supervisor. "We had to re-think our approach. My team wrote tools to help the effects team understand the scalability so we could handle the water and the simulation of vegetation. These were highdata scenarios. It took between 50,000 and 100,000 CPU hours to run the sims."

To render the white water, the effects team decided to use volumes.

"Before, we did white water with points," Reisch says. "The white water in this film is almost all volumes. We'd break down the detail in those volumes so we could store them on disk. With multiple levels of resolution in one file, we could pick higher or lower resolution based on the camera."

Placing the river into the set was an art in itself. To give Sohn plenty of elbowroom for location scouting, the sets team adapted approximately 65,000 square miles of US Geological Survey (USGS) terrain data. Ultimately, although USGS data provided the topology and the height data, the artists would change the terrain in Autodesk's Maya as necessary for story points.

"In the past, we'd build foregrounds and use matte paintings and matte-painted clouds to extend the world," Calahan says. "For this film, we used the USGS survey data and procedurally created detail using the "wonder moss" technology from *Brave* (see "The Royal Treatment," June/July 2012). And, we re-did our approach to volumetric clouds. We wanted procedural clouds in every shot."

Arlo's journey takes him from the Snake River Canyon on the border of Wyoming and Idaho north to Montana – a big-sky area centered in the Rocky Mountains that includes Jackson Hole (Wyoming), Grand Teton National Park, Yellowstone National Park, and multiple national forests and wilderness areas.

"Pete [Sohn] wanted Arlo always moving into new territory we hadn't seen before," Jessup says.

With an elevation of 13,770 feet, Grand Teton Mountain, the highest point in the Teton Range, became the model for the film's Clawtooth Mountains. Arlo's family homestead is set at the base of the Teton Range, with the stylized Clawtooth Mountains in the distance.

FIFTY MILES OF ELBOWROOM

"Before this film, I explored kitchens in Paris and the racing world of Europe, and that was fun, but this was fantastic." Jessup says. "It was exciting to wrap our heads around the project of building sets that were 50 or 60 or 100 miles in diameter, and then detailing them in a way that made it possible to stylize, control, and exaggerate the environment to capture the awesomeness of nature, the power of it. We were always stylizing, simplifying in a way that a landscape painter might simplify."

They call the style "painterly realism." It owes much to Calahan's artistic vision.

"This is my third film with Sharon [Calahan]," Jessup says. "The collaboration with Sharon and the lighting department was extraordinary, but because of her experience in the area, she was also a great guide."

Calahan, who had spent holidays painting landscapes in the area Arlo would journey, provided those paintings as well as new ones for the film.

"I'm happiest when I'm outdoors painting," Calahan says. "I'd do paintings showing the color and beauty for inspiration. Some for time of day. Some for a setting, for mood, for moments when the characters interact – rain, sunset. Some for scope, for the big-sky feeling, the see-forever clear area. I wasn't trying to create finished paintings, just observations of light and color, memories of sound, cold, heat. Sometimes I would paint single ideas – flowers floating on a river. We call them haiku shots – brief moments of visual poetry."

As production neared and final decisions about the look of the film needed to be nailed down, Calahan created a style guide to give the artists in the sets department rules for how to create environments that were believable, dangerous, visceral, but not photoreal.

"I wanted to reduce the chaos of realism into something that captures light and color the way the eye sees," Calahan says. "We spent a lot of time creating a set-dressing structure. If the set looks painterly, I'm thrilled."

Rather than individual trees, Calahan wanted only enough detail to give the impression of a forest, for example. She wanted the set dressers to mass together values and colors to create a flow without the chaos of true reality.

"I tried to find ways to use colors and determine what to emphasize," Calahan says. "We had five different species of trees. If we mixed them together, all the scenes would look the same."

There are no matte paintings in the film, but many of Calahan's paintings are translated literally into scenes.

In fact, the sets team used one of Calahan's paintings for an early test that helped sell the idea of using the USGS terrain data.

"Sharon had done a painting of Red Canyon," says David Munier, sets supervisor. "I found where it was located in the USGS terrain, extracted that data into Maya, put the camera in place to match her painting, and from there, a set artist put in textures on the ground and procedural vegetation."

To add the vegetation, the set dressers would paint areas that told Pixar's Renderman where



THE SURPRISING, PET-COLLECTING STEGOSAURUS CAMOUFLAGES ITSELF WITH AN ASPEN TREE PATTERN.



EFFECTS ARTISTS USED A PROPRIETARY CROWD SYSTEM TO ANIMATE THE FIREFLIES.

to place previously designed and modeled trees, rocks, bushes, and so forth. When a set met the river, effects artists would place the river, and then the set dressers would place vegetation, rocks, and beach as appropriate around the riverbank.

"In some cases, we could get away with no interaction between the water and the set," Reisch says. "In other cases, we needed to control where the water interacted. The set that interacted with the water was the same from shot to shot. The set dressers added rocks and so forth to change the look. I don't know how we could have done the 200 river shots without this modular approach."

MOVING IMAGES

As it would in the real world, the vegetation added by the set dressers moves. Grass sways in the wind. Breezes whisper through the cottonwood trees.

"We wanted all these elements in this enormously complex world – hero elements and procedural background elements – to be always moving," Cameron says. "This is true to the idea of nature as an antagonist that is rich and alive. At first we thought we'd do this only for assets close to camera. Then we realized we could use it for almost everything without increasing the cost."

Proprietary simulation tools made this possible.

"It's a hierarchical curve simulation tuned for dealing with lots of geometry," Cameron says. "We built rigging into the trees and used that rigging for simulation. We could also simulate on top of the rigging and then rebind the geometry to the simulated rigging to have high complexity."

The system is semi-implicit and spring-based. That is, it simulates on particles that move guide geometry around. The connection between the simulation data and how a tree moves is determined by weather level.

"We have 20-odd terabytes of simulation for different wind levels for every asset," Cameron says. "For each of type of vegetation, we run simulations with 15 different wind levels to create 30-second-long clips. When we set-dress a sequence, we pull on these clips as a starting point. We can say the weather is four on a scale from one to 15. We can say 'light summer breeze' or 'gusting wind,' and we've set the wind level even if we change trees."

The leaves, however, move procedurally.

"If we were to simulate down to the granular level, it would be very expensive," Cameron says. "So, we can activate procedures that have the same wind levels. The leaves on the trees, the hair on the characters all respect whatever the weather – the wind level – is at the moment. We blend everything together at render time. So, on a quiet day, you can see the grasses and the trees moving in a subtle way, and Spot's hair is moving, as well."

Also adding richness and motion to the environment were flocks of birds, a herd of "cattle," and in one touching sequence, fireflies.

"The fireflies emerge from a field of grasses," Cameron says. "In that shot, we had grass, flesh and skin simulation on Arlo, vegetation moving, and fireflies, too. It was tremendously fun to work on."

The studio uses two types of crowd simulation. A custom, brain-based procedural system created in Houdini handled large crowds such as the flocks of birds, the cattle, and the fireflies. For small-scale crowds, the animation team used a clip-mixing tool.

"We can scale up to a few hundred agents," Cameron says. "We have tools for managing and sequencing the pre-assembled clips. It's non-procedural animation."

SPOT-ON ANIMATION

Turning CG models into believable, emotional characters for the film took the skills of 84 animators.

"The characters are very stylized, and that's on purpose," Jessup says. "We wanted Arlo to feel vulnerable in an authentic, awesome environment, so we have an idealized realism for the settings and a caricatured take on the characters."

Arlo's challenge for the animators was the young dinosaur's weight. To meet the challenge, they referenced elephants: At the height of his back, Arlo is 10 to 12 feet tall, a height similar to that of an adult elephant. Using Presto, Pixar's proprietary animation software, and a Wacom Cintiq tablet, lead animators would draw atop footage of elephants filmed in a zoo, to understand how those heavy animals transferred weight as they moved.

Once the rules for transferring weight were set, animators could adjust the gait for age and species. Arlo moved more quickly than his parents; the carnivores had a more aggressive gait.

Special rigs gave animators controls for Arlo's long neck and his tail. And, a new ability in Presto to see textures helped them place Spot's hand when the "dog" touched the "boy." After the animators completed a performance, the simulation team dialed in a volume simulation to move Arlo's skin and muscles.

As for Spot, quadrupeds always provide animators with complex problems, but turning a biped into a quadruped raised the difficulty a notch.

"When we first built Spot, he was standing upright like a boy," says Animator Mark Harris. "We have a particular setup for rigging humans. But when he was bipedal, he felt human. So, most of the time he is on all fours. We tried to not make him look like a little caveman boy."

Slightly changing the orientation of Spot's legs helped the animators, but they accomplished most of the transition from human boy to dog through acting. Because Spot doesn't talk – he hasn't seen another animal that talks – the animators relied on facial expressions and body movement to perform the character. The imaginative idea in the film is that the child had learned to survive without human parents; he had learned from other animals – dogs, wolves, raccoons, squirrels, even frogs.

"As the animation came together, Pete landed on dogs because they express companionship and emotion while still being animalistic," Harris says.

Even though Spot doesn't speak words, the animators sometimes had to work with a dialog track. In one pivotal scene, for example, Spot's "dialog" is a sniff. The scene takes place on a sandy beach near the river. Arlo has drawn in the sand and created figures with sticks to represent his family. Spot does the same.

"He pushes some sand, looks at his [stick figures], and buries the effigies," Harris says. "Right after that he does this little sniff. That sniff was a half-animal, half-human, self-conscious, sad sniff. It was a tricky balance between having him being too much a boy or too animalistic." At first, Harris tried to play

(TOP TO BOTTOM) THE STORYBOARD, A PAINTING BY DP SHARON CALAHAN, THE PAINTERLY FINAL CG IMAGE.

the scene with Spot sniffing only with his face. Then Sohn suggest using a hand.

"I tried using his fingers, and then settled on a mix of his fingers and the back of his hand," Harris explains. "We had a lot of reference from different animals, and the raccoon fit well in the way they use their hands."

Often, animators want to create the feeling that a character is thinking. The Spot animators tried to do the opposite.

"We simplified emotions, especially in his face, to stay away from expressions that made him look like he was thinking internally," Harris says. "There are no complex brow shapes. We kept his pupils in the center of his eyes and let his head direct his attention. He's the kind of character who doesn't think about himself. All his attention is on the outside. If something grabs his eye, his whole attention goes to it. We took things people understand from dogs. A little tilt of the head. Open mouth with tongue hanging down."

To contrast Arlo and Spot, the team diagrammed the differences between the two.



ANIMATORS REFERENCED DOGS AND WILD ANIMALS FOR SPOT'S PERFORMANCE.



RAPTOR BISONAUR RUSTLERS THREATEN ARLO AND SPOT.

When they meet, Arlo doesn't know what Spot is, and he is initially antagonistic. Spot, like a dog, understands Arlo is not harmful and sees that Arlo needs help. Spot shows Arlo how to catch food, how to take care of himself.

"Arlo sits and processes," Harris says. "Spot goes after something. Arlo is in the past or in the future. Spot goes with the flow. At the beginning, Arlo is internal and very human. Spot is external. They learn from each other."

As the characters moved through the environment, the animators faced three interesting problems: the mountainous terrain, interaction between the environment and the characters, and the size differences between Arlo and Spot.

"The land is based on real geology, so there was a lot of uneven ground," Harris says. "But, it was fun to play with the environment, to make things tactile."

Harris describes a scene in which Spot runs through bushes. "We have two ways around that problem," Harris says. "We can move the bush or we can have a simulation artist move it. We tend to do a 50/50 split. We animate Spot to get his performance and timing correct, and then a simulation artist creates the motion for the bushes." As with simulating wind through the trees and other vegetation, the effects crew surpassed their expectations.

"We were nervous about the hero interaction with the environment, especially when the characters leave the trails and touch things," Cameron says. "But, we got better at doing that and did more than we thought we could and that we had planned."

Sometimes, however, animators moved elements in nature without involving the simulation artists – particularly, rocks kicked aside as the characters trek through the mountains, big Arlo with little Spot at his side.

BIG AND LITTLE

The animators started with scenes developed in the layout department, where the artists established the character blocking and camera angle for each shot. For reference, layout artists looked at Western movies, in particular, *Black Stallion*.

"This movie was interesting from a camera standpoint because we wanted to make Arlo feel big and allow the audience to relate to this big animal as a character," says Layout Lead Arjun Rihan. "Arlo is in the wild, so the environment is a character in the film in some ways, too. And getting Arlo and Spot both in a shot and having them read was a challenge. There were no easy shots in this film."

Rihan and his team used one lens kit based on physical cameras that they adjusted per sequence.

"We had lots of wide angles and extremely long telephoto lenses," Rihan says. "We could make the dinosaur look small in these large environments with lens choices, but it wasn't as simple as lens choices. It's also the framing. We'd set the camera far away from him. Framing a dinosaur was something we had to put a lot of thought into. When we framed Arlo in a particular way, he looked like a sock puppet because of his long neck. Over-the-shoulder shots were not easy. And when Spot is in the frame, it's a huge challenge."

When we first meet Spot, we don't understand who he is, and the camera is distant. As we relate more to him, the camera moves closer. But that creates problems with scale.

"There are cheats, but we try to make them seamless," Rihan says. "We might put the camera underground, for example, but very carefully. And sometimes, we have to float a character above the ground." As always, camera movement supports the story's emotion.

"When Arlo is home and safe, we used a stable camera and moves inspired by machinery and farming," Rihan says. "In the wild, we used handheld and Steadicam moves to reflect Arlo's unease, and to allow us to experience the environment."

Sometimes for camera moves when Arlo is in the wild, the crew used motion capture to work with real-world equipment.

"Motion capture helped us relate to where Arlo was," Rihan says, "especially in quiet moments, you really feel the sense that we're out in the wild with him."

HOME ON THE RANGE

During one sequence, Arlo and Spot travel with a family of *T. rex* ranchers. The ranchers stop at an overlook to check their herd of what the Pixar crew call *Bisonaurs* when suddenly a group of raptor rustlers stampede the "cattle." Rihan picks this sequence as the most difficult for the layout artists.

"Everything is moving, so it was a challenge to set up," Rihan says. "We wanted to bring intensity and frenetic energy to the scene, while at the same time retain clarity. And the role of the raptors kept expanding as the scene came to life."

The animators performed the *T. rexes* as if they were cowboys on horseback. They're still bipedal, but the modelers created the look by raising the front of the *T. rex* bodies into a position mimicking a rider on horseback, and the animators completed the illusion with acting choices.

"It was a big challenge to do something different," says Animator Kevin O'Hara. "Bipeds are not built to run like a horse."

But, the clever gag worked.

"There were times," Sohn says, "when the scenes looked like a Monty Python sketch – just give them a pair of coconuts. But we found a way to have fun without going into parody."

For reference, Sohn took a team of animators and riggers on a research trip to a cattle ranch in eastern Oregon near the Idaho border. They went to see cattle but returned with stories about the family of ranchers.

"The family had dedicated their lives to working on this ranch," Sohn says. "We were inspired by their love and responsibility to one another. Joe [the rancher] inspired Butch [the *T. rex* father voiced by Sam Elliott]. We wanted to respect their toughness and humanity."

All the research trips were eye-openers for Sohn, who was raised in New York City and attended college in Los Angeles. The creative team spent days rafting, visiting the cattle ranch, exploring Yellowstone Park, and going on trail rides.

"Pete had thousands and thousands of questions," Calahan says. "And, he remembered everything. We took him on a trail ride on the Idaho side of the Tetons to give him an idea about snow and ice and high elevations. There's a scene in the movie where Butch [the *T. rex*] gives Arlo lessons and it sounds like gibberish. That's how Pete felt when the trail boss told him what to do. But, whenever the guide wanted to turn back, Pete wanted to go just a little bit farther. He was like a little kid who never wanted to stop. He saw a moose. He saw the Milky Way for the first time. He was awed by the vast landscapes and how quickly the weather could change."

CHANGE IN THE WEATHER

Wind wasn't the only weather element or effect the crew used to amplify the emotional story.

"We had fire, snow, dust, mist, fog, and rain," Reisch says. "When Arlo slides downhill, there is dust debris. When Spot draws in the sand, we move it with a new grain solver. These are subtle effects – people might not even know they're effects, but from a storytelling point of view, they heighten the mood and drama of a scene."

The effects artists used fog to create a sense of foreboding, and volumetric clouds and rain to punch up the visual tension in a shot.

"When Arlo feels desperate or lonely, we have clouds moving across a full moon behind tall pine trees blowing in the wind," Sohn says. "We tried to make nature breathe and be mysterious."

ARLO AND SPOT WITH THE T. REX FAMILY OF CATTLE RANCHERS.

To help blend the elements into final shots, the effects team worked with lighting and shading artists.

"A lot of what we do is build visual complexity through multiple passes," Reisch says. "We can drive material properties on characters or the terrain so when rain splats as it hits the ground, we can add darkening and specular reflections. The way light interacts with effects elements makes them feel part of a scene."

Rain, which falls in 400 shots (nearly half the effects shots), was particularly important. Sometimes it's soft rain, sometimes threatening.

"We did depth-of-field work in compositing like we did for 'Blue Umbrella' (see "Moody Blue," January/February 2014)," Reisch says. "I wanted to make sure that it didn't look like a rain machine. So we took time to make rain boxes for the background, mid-ground, and extreme foreground. We instanced along the curves and noised up the normals to reflect and refract and give the lighters more control over the rain."

Light rain helped set the scene when Spot and Arlo meet on the river. Blustery, heavy, driving rain, by contrast, created a dangerous mood toward the end of the film, fulfilling Sohn's vision of an exquisite antagonist in action.

"I knew this film would be special because of the emotions and passion Pete [Sohn] would put into it," Calahan says. "It became clear early on that to tell the story properly, we had to think differently. I jumped at the chance to work on it. I feel ruined for anything after this."

The story is improbable – a dinosaur as a human, a wild boy-child as a dog. Two children finding their way in a wilderness, a vast, mountainous, forested environment that only a studio as brave and talented as Pixar would dare to model, dress, move, and render in painterly realism.

"The artists and technical people here can do anything," says Producer Denise Ream. "We had to give them a story worthy of their talent. They really made the movie beautiful."

