



NAVIGATING POLYNESIA



TO DEPICT *MOANA*'S STUNNING SOUTH PACIFIC ISLANDS, OCEANS, AND CULTURE, DISNEY ARTISTS DOUBLE THE VISUAL EFFECTS WORK IN PREVIOUS ANIMATED FEATURES

BY BARBARA ROBERTSON



With a nod to Disney's legacy and a high dive into the future, the legendary animation studio releases its latest CGI feature to mounting critical acclaim. Set in the lush South Pacific islands and immersed in Polynesian culture, the musical adventure sends Disney's most unusual, daring, and vibrant princess on a heroic journey. As Moana sets sail in the warm Pacific waters on her village-saving voyage, she leaves behind her family, a mysteriously landlocked population, and an island under threat.

On her journey, Moana meets the demigod Maui, whose actions have led to the island's condition, the ridiculous yet dangerous coconut-coated Kakamora pirates, the lobster-like Tamatoa, and a demonic volcano named Te Kā. Her companion is a dumb chicken, HeiHei. Moana's puppy-like small pig named Pua waits at home.

Most of the second act takes place on the water, with the characters in and out of the water, which is one reason why Technical Supervisor Hank Driskill states that this film has the most effects of any Disney animation.

"The average movie we do has effects in 40 to 50 percent of the shots," Driskill says, noting that action-packed *Big Hero 6* had effects in just shy of half the shots. "*Moana* had effects in over 80 percent of the movie."

Driskill and Visual Effects Supervisor Kyle Odermatt had held identical roles as technical supervisor and visual effects supervisor on *Big Hero 6*, and had barely caught their breath when they started supervising effects for *Moana*. Driskill's favorite anecdote from those early days centers on a reaction by Chief Creative Officer John Lasseter after a screening.

"We had our third internal screening while the movie was still evolving," Driskill says. "We were still a year and three months from being done, still early in preproduction and planning. After the screening John said, '*Moana* makes *Big Hero 6* look like a one-man show.'"

"It was the biggest, most ambitious thing we've ever done on every front," Driskill continues. "But, we felt like we owed it to this movie. People were so excited that we were tackling this mythology and this culture, so we pushed hard. A lot of the challenges were ones we put on ourselves."

Directors Ron Clements and John Musker, who had co-directed *Aladdin*, *The Princess and the Frog*, and *Treasure Planet*, and Producer Osnat Shurer (*Arthur Christmas*, "*Lifted*," "*One Man Band*") emphasize the impact of the location and the people on the development of *Moana*.

"Our visits to Polynesia changed the vision of what this movie could be," Shurer says. "We came back with beautiful images – we all know how beautiful it is. But, we couldn't imagine the beauty of the people. When we listened to the people, that's when we touched the beauty of the Pacific Islands. It changed the story, and it changed us. We met archaeologists, weavers...many people. We learned that the ocean unites the islands; it doesn't divide them. We created an Oceanic story tribe that we checked in with on story and design choices."

During those research trips, the team learned the importance of navigation to the Pacific Islanders, and uncovered a mystery, a mystery that led to *Moana*'s story.

"About 3,000 years ago, everything stopped," Musker says. "All voyaging stopped, and everyone stayed put. About

2,000 years ago, it started up again. No one knows why. So, we came up with a theory, which is the basis for our movie. What if one young girl was responsible for bringing navigation back?"

Moana is 16 years old, the daughter of a chief who had one rule: No one goes beyond the reef. But her grandmother, a storyteller, connects her to the legacy of voyaging. Hawaiian singer/actor Auli'i Cravalho, also a teenager, voices Moana; Rachel House voices Gramma Tala.

"Moana has inner conflict," Clements says. "She doesn't know who she is. Her grandmother leads her to a secret cave where she will understand why she has been drawn to the ocean all her life. So, Moana and what may be the dumbest character ever, this stupid chicken HeiHei, take off on a voyage."

HeiHei provides comic relief for what becomes a quirky and dangerous journey. Moana's goal is to return the "Heart of Te Fiti," a powerful ancient jade-like stone, stolen and then lost by the demigod Maui, to its origin.

"So Moana convinces this reluctant demigod Maui [Dwayne Johnson] to join her on the quest," Clements says. "Others are after this Heart of Te Fiti, so they encounter many obstacles. We let our imagination run free without realizing how difficult that could be."

Adds Musker, "We had to make a ship move convincingly at sea and make an ocean have character. We didn't know how to do that in a production-friendly way. But the team didn't ask us to inhibit."

Odermatt gives an example of the kinds of effects demanded by a shot that in any other film would be considered undemanding for the effects team.



COMPLEX VEGETATION, WATER, LONG HAIR, AND MULTI-LAYERED COSTUMES REQUIRED MASSIVE AMOUNTS OF PROCESSING TIME.

"It's a two-character shot of Moana and Maui on the boat, seemingly an acting shot," he says. "But we talked about how we could execute the effects in that shot for a half an hour. Because of where they are, it was complex. We start with them dry, and then they get wet. They're on a boat. They're next to water. They interact with the water."

In addition to various forms of water, Driskill lists hair, cloth, feathers, vegetation, environmental effects like footsteps in sand, smoke effects, fire, and lava as the main challenges. Head of Effects Marlon West adds magical elements to the list.

"Everything we would have asked them to avoid was added to the story, and we had to tackle it," Odermatt says.

HAIR

Both hero characters have long, curly hair that's often wet, underwater, or blown about by the wind. And, the teenager Moana plays with her hair. Artists used an evolution of the proprietary software Tonic, developed for *Tangled*, to specify an initial groom, and the simulation team developed a new system for controlling the hair.

"We needed more control," Driskill says. "So we started on a big project and took it further than we thought we would."

To develop the characters' hairstyles, look development artists (rather than modelers) using Tonic would place tubes on a character's head and specify parameters. Based on those parameters, XGen, a geometry instancer developed at Disney and now available as a plug-in to Autodesk's Maya, would populate the border of each tube, a shell of curves, with thousands of primitives.

"The tubes give us a quick visualization and were good for authoring," says Simulation Supervisor Marc Thyng. "But they have drawbacks. We had so much volume, we started using a new object type in Maya to handle lots of curves."

As for the simulation engine that drives the movement of the hair, the team developed a new system based on what they call "Disney elastic rods."

Thyng explains: "It was important for the curls to hold their twist and have springiness. For Rapunzel, we had used a mass spring model. For this film, we started with a discrete elastic rod model to do twists. Our smart guys here found ways to speed up the simulations so we could do fast iterations."

With simulations taking as little as 10 seconds per frame, the artists could show the supervisors and directors results quickly and use notes in the form of "draw-overs" to make changes.

"We're using real physics, but we cheat

with forces to get 'Disney hair,'" Thyng says. "Generally, the hair wants to pull back to its rest shape. Before, we had constraints that held the hair in place. That was good for art direction, but the hair pulled back in an unnatural way. Now, the hair can move freely. If there is a lot of action, it doesn't always come back to the initial groom. It can be held in a messy kind of look in a pretty good way. That was a big deal."

For example, when Moana bends down, her hair falls forward. Then when she stands, it comes back to a pleasing new shape and stays in that shape.

Also providing challenges for the simulation artists was that Auli'i Cravalho, the teenage actor who voiced Moana, fiddles with her hair, and the animators wanted Moana to do that, as well.

For example, "We wanted Moana to be able to take the hair from one side of her head, pull it over to the other side, and have it land in position," Thyng says. "We needed constraints to control the strength of the forces through timing and distance. So, we revamped our collision model and came up with new dynamic constraints."

And now Moana can even slide her hair through her fingers.

To make it easier for others in the pipeline to control the characters' hair, the simulation department provided a general setting

for collisions with the hair in various conditions – wind, underwater, wet, and so forth.

“The shot artists might deviate from the settings, but the settings gave us a good, consistent look for the characters,” Thyng says.

CLOTH AND FEATHERS

The same engine, a fabric solver, moved the characters’ costumes and the birds’ feathers.

The clothes had to move and look right in wind and water, so each costume had three versions: a base version, an underwater version, and a wet, out-of-water version.

“We had lots of layered costumes,” Thyng says. “And our main character wears tapa cloth over a grass skirt. We wanted the simulation to happen within one solve. Our costumes were probably the most complicated we’ve ever done. But, our in-house cloth simulator, called Fabric, is very stable and handles collisions very well.”

For the grass skirt, Technical Director Timothy Richards counted the grass strands in each section of the skirt to develop a size ratio for the sometimes thin, sometimes thick strands.

“Grass skirts are made of strips,” Thyng explains. “So he built little strips – cylinders – and we treated each strip as a piece of cloth for the simulation. It was pretty cool.”

Fabric also handled feathers for the shape-shifter Maui’s transformation into a giant hawk, and for the little chicken HeiHei.

“We broke the hawk’s feathers into types and created geometry that animators could see for the long feathers and the down,” Thyng says. “Then we used deforming geometry solutions and XGen again with the new primitive-type curve bundle to grow primitives off primitives. The cloth solve would work with geometry, curve bundles, or standard primitives based on the type of feather. We tweaked Fabric to make it more stable for the deforming surface. Then we scaled the stuff for the large hawk, to do the little chicken.”

THE CHARACTER OF WATER

Water, which forms the environment for much of the film as Moana navigates her way through the story, was a special challenge. With hundreds of shots in the offing, the *Moana* effects teams concentrated on making art directing and simulating water easier.

“We had to build a whole new pipeline,” Driskill says. “We had probably 1,000 water shots. We wanted to raise the bar artistically. And we wanted to make the system faster and easier to use.”

We see Moana and Maui on a boat in a calm, open ocean. We see Moana interacting with the water. We see the water lapping the shore. We see big waves and small.

To design the camera view for the shots, layout artists used tools that let them place a boat in a rough approximation of buoyant water. The boat would float and would

react to wind speed as the artists dialed in various parameters.

“In a lot of shots, the water wasn’t more important than a ground plane would be on land,” Driskill says. “It was ever present but not part of the action. So, we built an automated wake pipeline. These shots could pass through to lighting without the effects department doing anything by hand.”

Often, though, the water did something more fantastic.

“The ocean is Moana’s friend,” Driskill says. “It interacts with her and with Maui.”

Says Director Musker, “We wanted to do things in animation that we couldn’t do in a live-action film. One thing was making the ocean a character. People in Polynesia talk about the ocean as if it is alive.”

For example, to show the relationship between Moana and the ocean, in a scene reminiscent of the famous water creature (Pseudopod) shot from *The Abyss*, a column of water reaches up and out, and seems to communicate with Moana. West explains how the effects team worked with animation on that shot and others in which the water acted as a character.

“We created a sock-puppet-like rig that the animators used,” West says. “Then we took that rig and turned it into a simulation or simulated over it. Working with character animation to create these characters was a huge deal.”

When the water performs through animation in those types of shots, the team used Side Effects’ Houdini. For shoreline and



The 16-year-old star of *Moana* is voiced by Hawaiian singer-actor Auli'i Cravalho, also a teenager. Moana, the character, is adventurous, strong, compassionate, tenacious – and in search of her true self.

Bill Schwab led the character design for the film. Chad Stubblefield was modeling supervisor. Neysa Bové handled costume design. Hyrum Osmond and Amy Lawson Smeed were heads of animation.

“What was great is that Bill Schwab stayed

with the show for the entire movie,” Smeed says. “We had 90 animators on the show, straight out of *Zootopia*. They would try to figure out acting performances. As we did animation tests, we could show them to him and he would do draw-overs on the characters to make sure they kept their sense of appeal and design. One of our philosophies is that we wanted to collaborate more with all the departments.”

Moana’s traditional costume provided interesting challenges for the effects department, which needed to simulate layers that included a grass skirt.



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open water, they turned to Splash, a system developed for this film.

"We needed a new way to solve water," Driskill says. "Most of the commercially available solutions use one of two principal ways to solve water, and each has strengths and weaknesses. With one, we get fast solves that are easy to work with but can be unstable. With the other, we have more stability, but it's harder to work with and slower. Our technique takes the strength of both and integrates them. It's stable and fast."

To render the water, the team built level sets into Hyperion, Disney Animation's proprietary renderer.

"We start with a bazillion particles, then level sets craft a surface at the boundary of the particles that we built into Hyperion to create as much fidelity as possible," Driskill summarizes. "Rather than pre-solve the level set with some pre-set fidelity, the final level set, the choice of resolution, happens at render time."

The team also provided controls for shaping and moving the water to get the type of motion and the look the directors wanted.

"We layered white water on top and could dial in the looks of each layer, pulling out the right color and saturation for each piece of water," Driskill says. "We wanted to raise the bar. There was a recurring theme about how beautiful the water is in the South Pacific. People would say photos weren't doing it justice, that it was prettier in person. So, we aimed for their memory of the water, not a physical representation of the water. We have controls in Hyperion to break from physicality. We dialed in subtleties from shot to shot and sometimes in every frame to have water that was brighter, more saturated, and with reflectivity different from actual water, to give it more blue than what would naturally be reflected from the sky."

PUSHING DATA

The combination of simulation and rendering put extreme demands on the studio's renderfarm.

"We built 70,000 cores in the renderfarm," Driskill says. "But even so, we bumped up against boundaries. We needed a petabyte of temporary space for the water simulation and about ten times as much for simulation storage."

Although the team could distribute the simulation across eight machines, each with 256GB of RAM to achieve the fidelity they wanted, Hyperion couldn't handle distributed rendering. Thus, they created a monster machine that they used as a test bed.

"We built a machine with a terabyte of RAM that we used to test-render some un-optimized shots," Driskill says. "We knew the upper limit on the farm, but people would blow out our memory, and we didn't know by how much. So, when we saw shots that needed more RAM, we'd take them over to the monster machine and find out how far out of whack the shot was."

The complex environments on land pushed the limits, as well. Moana's fictional island of Motunui has more than 60 species of vegetation, including specific coconut trees, breadfruit, and taro.

"We have a pretty mature system for vegetation using XGen and Bonsai, our procedural vegetation system," Driskill says. "We built Bonsai for *Tangled*. It's based on L-systems. But, the scope

and scale in this movie.... We have a song that takes place in a village that has thatched huts with XGen growth, women with long hair in grass skirts, vegetation all around. The geometric complexity is probably ten times that of the city of [Big Hero 6's] San Fransokyo. We had a crazy amount of geometry on screen."

FOUNDATION EFFECTS

Knowing that the effects artists would have their hands full on the show, the team began working on ways to create and package some simulations to make them available to and manageable by more departments. They called these pre-produced simulations "foundation effects." Once created, layout artists and animators could select simulations from a library of foundation effects and add them to shots, and the simulations would move through the pipeline all the way to rendering without the effects department's involvement.

"Foundation effects were a natural evolution," Driskill says. "Early on, layout artists would cobble together shots using simple shapes to give the director an idea of explosions, splashes, and other simple effects that were not story beats. But, directors

wanted to understand the timing and placement earlier in the pipeline. So, for *Big Hero 6*, we gave layout artists placeholder effects assembled from component pieces. Later, effects artists replaced those effects with final effects. With this film, the layout artists had a whole library of fully realized, fully renderable 3D effects that could be placed and rendered in final shots."

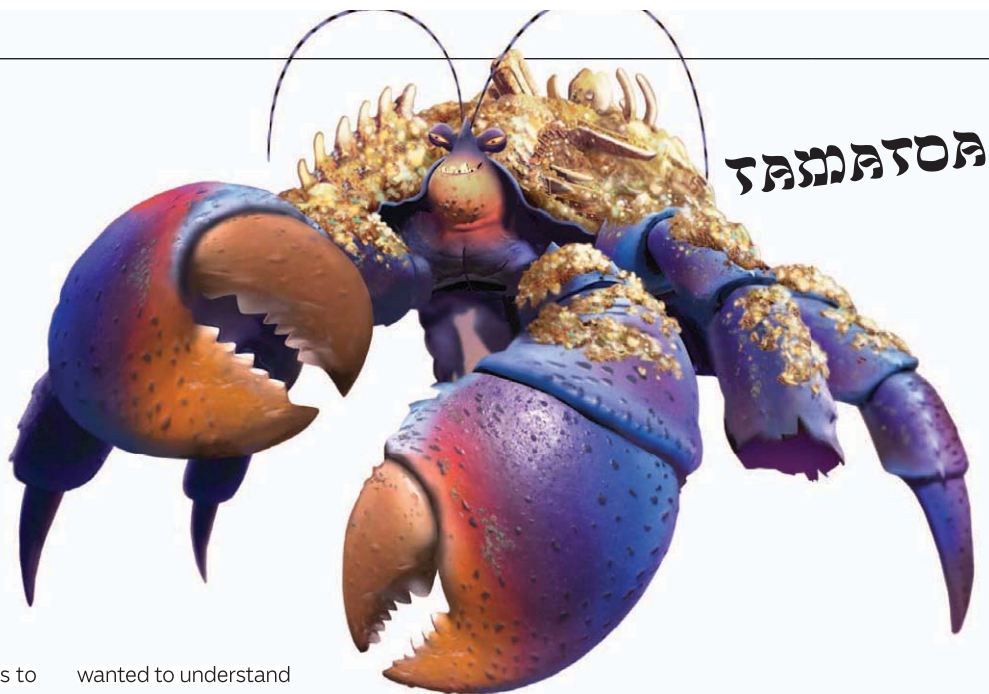
Driskill gives an example of how an animator might use water splash foundation effects.

"When the coconut-shelled Kakamora fell into the water, an animator could animate the splashes at the same time," Driskill says. "The splashes would end up in the

final rendered frame without a visual effects artist having to touch the shot."

In addition to water splashes, foundation effects included waterspouts, smoke, pyroclastic plume, steam, cooking smoke, torches, and more. The artists used them in simple shots and for the more dramatic lava witch Te Kā.

"We had 13 artists working for eight weeks in Houdini creating effects we knew would be in this film," West says. "Some were fluid sims, some particle sims, some were volumes. Mostly they were over black, but sometimes we would put Moana or Maui next to them for scale, or put them in a boat. We worked with the production de-



Maui, voiced by Dwayne Johnson, is large, arrogant, confident, and a charming trickster. He walks with a swagger.

"We pushed his proportions to convey power and charm," says Mack Kablan, animation supervisor for Maui.

He has two characteristics that make him especially unique: Using a magical fishhook and animation that pushes the character from one form into the other, he transforms into other characters – an iguana, a shark, a lizard, and a hawk.

Secondly, he is tattooed with miniature versions of himself. These mini Maui's sometimes spring into action, becoming Maui's alter ego and conscience.

"The tattoos presented an interesting opportunity for CG animation to work with traditional animation," says Hyrum Osmond, co-head of animation for the film. "To be working in the trenches with Eric Goldberg, that was unique."

Goldberg animated the 2D tattoos on Maui's body. Head of Characters and Technical Animation Carlos Cabral's team devised a method to blend the layers of 2D animation into the 3D character's skin without stretching as the character flexed his muscles.

"We'd define regions where Eric could animate and go back and forth between 2D and 3D," Cabral says. Skin sliding and volume preservation maintained the integrity of Maui's anatomy.



MAUI'S VARIOUS TATTOOS SOMETIMES COME TO LIFE THROUGH 2D ANIMATION.

HEIHEI



signer and sent them to the directors for approvals. The directors took a leap of faith to approve them out of context."

The effects couldn't react with a character or the environment, but they could be placed, moved, and sometimes scaled.

"Animators could re-time them and move them — steam vents, splashes, things like that," West explains. "These were real effects. Any Te Kā shot would have dozens of smoke plumes, and many would be foundation effects. Layout artists could look at a library of 20 splashes and pick one. Character animators used them, as well. During the Kakamora attack, the animators placed little squibs every time the arrow hit a desk. The effects worked in the scene. They worked in the render."

MAGICAL EFFECTS

In addition to hair, cloth, and water effects, there were other types of visual effects throughout the film.

"We had a lot of bread-and-butter environmental effects," Driskill says, citing two. "Feet had to interact with the sand or it looks wrong. We also had lava."

For both these effects, the team re-purposed the snow pipeline from the 2013 feature *Frozen* into a sand pipeline, and by giving the particles material properties that made them act in a viscous manner, created Te Kā's lava.

There were also magical effects. During some scenes, Moana sees bioluminescence that helps tell the story.

"In one shot, the bioluminescence is on placid water, and in another, we needed it to look like it's in more active water," West says. "We used a rig to generate the swirl. Gravity doesn't affect the magical particles as it would in the real world, but they needed to look like they would in real water."

Another magical effect produced the opposite kind of image, an ash cloud.

"That was a collaboration between the effects and the look departments," West says. "We used a particle simulation in Houdini. Both the ash cloud and the bioluminescence needed to be effects based on a rig that various artists could pick up and use, and both were magical. But one was a huge swirl of ash, and the other was beautiful and life-affirming."

With any animated film, but perhaps especially one as large as this, the attention tends to fall largely on the directors, the voice actors, the designers, and the animators. But the team that makes the impossible possible deserves much of the credit, too.

"We kept facing challenge after challenge, but we pushed ourselves to make something beautiful to put on the screen," Driskill says.

And so they did.

The journey from *Big Hero 6* to Polynesia sent *Moana's* visual effects team into unexplored technical and artistic realms, resulting in unforgettable images that could not have been accomplished a few short years ago. It's no surprise that many are calling *Moana* Disney's most beautiful CG film thus far. ■

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