Outer Wilds

A Game of Curiosity-Driven Space Exploration

by

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Abstract

Outer Wilds is a space exploration game designed to inspire and reward player curiosity. This paper defines the concept of curiosity-driven exploration and discusses our attempts (both failed and successful) to design for it over the course of development. It also delves into the design of *Outer Wilds'* simulated solar system, and investigates how creating a world governed by dynamic forces affects free-form exploration.

Project Description

Outer Wilds is a game about curiosity-driven exploration in a world that changes over time due to natural forces beyond the player's control.

The game is a seamless first-person experience in which players have just 20 minutes to freely explore a miniature solar system as it dynamically evolves over time. After those 20 minutes are up, the sun goes supernova and the the Universe itself comes to an end. However, the solar system is stuck in a time loop where each supernova sends the player back in time to the beginning of the loop. Only by exploring over the course of multiple time loops can players come to understand the history, systems, and secrets of the solar system.

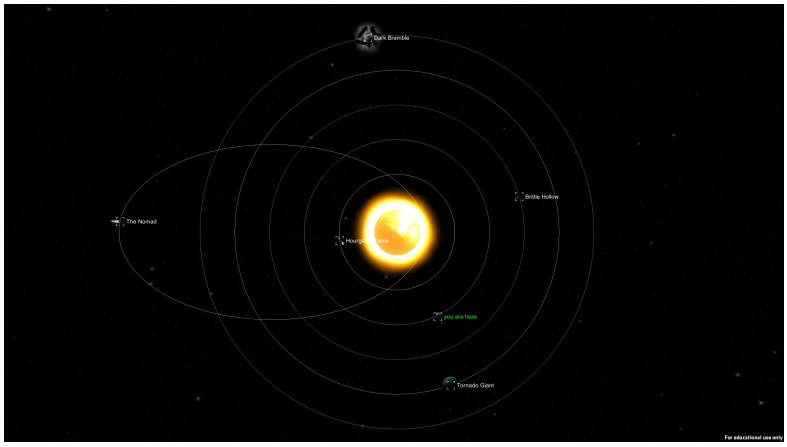

Figure 1: The solar system

The aesthetics of *Outer Wilds* are meant to evoke the feel of a backpacking or mountaineering expedition infused with NASA sensibilities. Equipment is made to look like slightly worn expedition gear, and the planets themselves are subtly alien takes on real-world geographical features and climate zones. The goal is to capture the daring and fragile nature of space travel without making it feel cold, sterile, or impersonal.

With the exception of the introductory sequence, nearly all narrative in *Outer Wilds* is embedded within the world for players to discover as they explore. Each piece of narrative fits

into an overarching history of the solar system, which tells the story of an ancient race (inspired by Anasazi culture from the American southwest) that traveled there millions of years ago in search of an object older than the Universe itself. Piecing this narrative together requires players to both understand the systems that govern the solar system as well as learn to navigate within them as they evolve over time.

Motivation and Objectives

There are many political, scientific, and economic benefits to real-world space exploration. “Through addressing the challenges related to human space exploration we expand technology, create new industries, and help to foster a peaceful connection with other nations.”[1] Even so, I think the most fundamental reasons we explore the cosmos have little to do with these practical justifications. The curiosity to explore distant planets, the courage to delve into the unknown, and the desire to understand the nature of our constantly-evolving Universe are emotional and value-driven motivations that cannot be easily explained on a spreadsheet.[2]

The primary objective of *Outer Wilds* is to capture this spirit of real-world space exploration in an interactive experience. Unlike many games that feature spaceflight, such as PC classics *Elite* and *FreeSpace 2*, *Outer Wilds* does not feature any combat or trading elements. Nor is it primarily a space flight simulator, such as *Lunar Flight* or *Kerble Space Program*. Instead, *Outer Wilds* is a game about exploring the unknown in order to answer questions about the Universe. It attempts to convey these themes by supporting curiosity-motivated exploration and by depicting a volatile solar system that changes over time due to cosmic forces beyond the player’s control.

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[1] NASA, “Why We Explore”, 2013
[2] Griffin, “The Real Reasons We Explore Space”, 2007

Curiosity-Driven Exploration

Humans explore for an incredibly wide variety of reasons. During the Age of Discovery, expeditions were undertaken to discover new routes for the silk and spice trades, to expand empires, to find gold and other sources of wealth, and to expand European knowledge of the world.[3] NASA's website currently has an entire page titled "Why We Explore", which maintains that "Humans are driven to explore the unknown, discover new worlds, push the boundaries of our scientific and technical limits, and then push further."[4] During his 2007 GDC talk on exploration in games, *Far Cry 2* creative director Clint Hocking observed that "Explorers all seemed to explore for different reasons. They all have different drives. Some of them were motivated by money, some by patriotism or nationalism, some of them by more of a pure desire to go where people hadn't been."[5]

In virtual environments, player motivations to explore are similarly varied, depending on both the structure of the game (how much freedom does it allow the player?) as well as individual play style (is the player naturally inclined to explore?). Some players explore the open-ended world of *Skyrim* in order to find new quests that will advance the narrative, some explore to find alchemical ingredients or better equipment, and still others explore just to see what sights the world has to offer.[6]

One of the major objectives of *Outer Wilds* is to create a game that rewards a specific type of exploration, which I'll refer to as "curiosity-driven exploration".

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[3] Briney, "Age of Exploration", 2008
[4] NASA, "Why We Explore", 2013
[5] Ruberg, "Clint Hocking Speaks Out On The Virtues Of Exploration", 2007
[6] Ruberg, "Clint Hocking Speaks Out On The Virtues Of Exploration", 2007

1. “**Curiosity** is defined as a need, thirst or desire for knowledge”.
2. “**Exploration** refers to all activities concerned with gathering information about the environment.”[7]

Using these definitions, curiosity-driven exploration can be described as any situation in which someone chooses to explore her environment (real or virtual) with the primary objective of expanding her knowledge or understanding of it. Although it’s certainly possible for exploration to be motivated by multiple factors, let’s assume that in order to be truly “curiosity-driven”, the expansion of knowledge must be the biggest (or the only) motivating factor.

Examples of Curiosity-Driven Exploration:

- Climbing a mountain to see the view from the top.
- Digging up ancient artifacts and ruins to understand how a culture lived.
- Smashing particles together in a giant accelerator to figure out how the Universe is put together.
- Diving into the deepest part of the ocean to discover what is there.

The common element between these examples of curiosity-driven exploration is that each one starts with a question (e.g. “What’s on the ocean floor?”), and the goal of exploration is to find an answer to that question. Even something as simple as choosing to travel towards a strangely-shaped object in the distance implies the question of “What is it like up close?” (and possibly “What is it?”), and moving towards the object becomes an attempt to answer that question.

[7] Edelman, “Curiosity and Exploration”, 1997

Telling Stories of Distant Places

In order for a game to allow this sort of curiosity-driven exploration, it has to give players something to be curious about. While placing interesting objects in the distance is certainly a good starting point (and one that many games, including *Outer Wilds,* use frequently), there are other ways to pique the player's interest besides direct observation. In particular, *The Legend of Zelda: The Windwaker* has been a huge source of inspiration for the way it encourages curiosity by telling the player stories of distant places.

The Windwaker takes place on the Great Sea, a vast ocean dotted with 49 small islands which the player can freely travel between in her sailboat. On one of the islands lives an old sailor, Lenzo, who loves taking photos (referred to as "pictographs" in the game). Inside his house is a gallery full of framed pictographs of the places and things he has seen during his travels. If you interact with one of the pictographs, Lenzo will tell you a brief story of how he came across the subject of that image, and even gives you directions to a few of them (e.g. "it lies due south of here").

Figure 2: Lenzo's Gallery (*The Windwaker*)

Critically, Lenzo never implies that you should seek out any of the things depicted in his pictographs. Although the statue in the above image is actually part of the main quest required to complete the game, talking to Lenzo does not reveal this larger purpose. In fact, without knowing

about its role in the main quest, and with so many other possible goals to pursue, the only apparent reason to follow Lenzo's directions and sail to the Triangle Islands is to learn more about the mysterious statue. One of Lenzo's comments seems specifically meant to evoke this sense of curiosity - "I wonder if such things still remain out there on the high seas, lonely on the waves?"[8]

A Web of Curiosities

In many ways, the overarching structure of *Outer Wilds* can be understood as an evolution of Lenzo's picture gallery. Every major object, structure, or location players discover in the solar system is part of a web linking these numerous "Points-of-Interest" (or POIs) with four special objects known as "Curiosities". Like the pictographs in Lenzo's gallery, POIs tell players about the existence of interesting things in the world (the Curiosities) and provide them with enough information to investigate on their own (without explicitly telling players to do so).

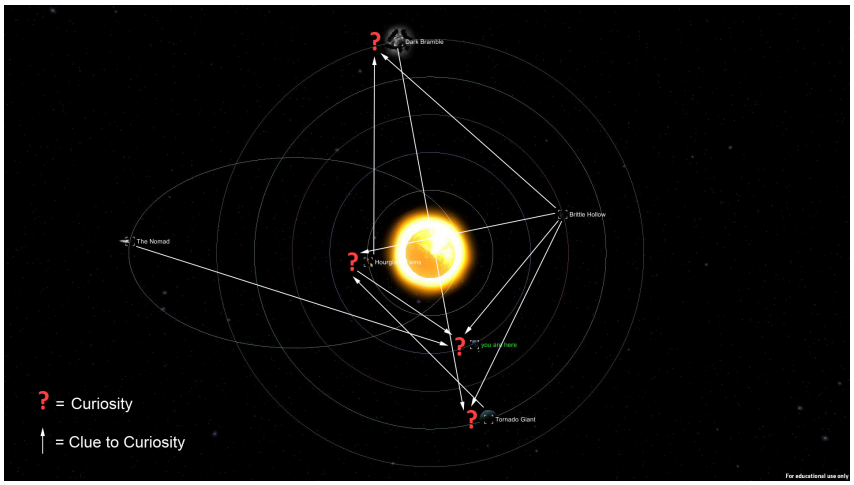

Figure 3: Embedded Curiosity Web

There are only four Curiosities, and each one holds the answer to a major narrative question regarding the history of the solar system. For example, reaching the Curiosity at the

[8] *Nintendo*, 2002

center of the gas giant answers the question of why the device causing the time loop was originally constructed. Each Curiosity exists in either a hidden or hard-to-reach location, and actually getting to one requires an understanding of the dynamic system surrounding it. This is where the POIs come in. Each Curiosity is linked to three Points-of-Interests, each of which is located on a different planet. POIs perform three basic functions:

1. They tell players about the existence of the Curiosity they are linked to.
2. They give players one out of three pieces of information they will need to understand the system surrounding that Curiosity.
3. They give players an audio frequency that allows them to locate the other POIs linked to that Curiosity through their telescope.

For example, one of the Curiosities is the ancient device that powers the time loop itself. It lies buried beneath the surface of a planet, and the only way to reach it is to understand the system of planetary alignments that governs an array of ancient teleporters on the planet's surface. After learning about this system from POIs found on other planets, players are able to teleport inside the time loop device, where they learn about its origin and purpose in the world.

The idea behind this POI-Curiosity web is that no matter where the player chooses to explore first, she will stumble across a POI that attempts to pique her interest about one of the four Curiosities. In Henry Jenkins' essay on narrative architecture, he argues that detective stories are a common form of embedded narrative because they "motivate the player's active examination of clues and exploration of spaces and provide a rationale for our efforts to reconstruct the narrative of past events."[9] Although *Outer Wilds* has no murders or conspiracies

[9] Jenkins, "Game Design As Narrative Architecture", 2004

to drive player exploration, POIs are analogous to spatially-embedded clues that enable players to decipher the mysteries of the solar system.

A crucial aspect of this setup is that both POIs and Curiosities are completely knowledge-based concepts. Instead of physically unlocking Curiosities, POIs simply teach players how to reach them through a deeper understanding of existing systems (which means that it is technically possible, although highly unlikely, for players to reach a Curiosity without finding all or any of its POIs). The fact that the Curiosities themselves exist solely to answer major narrative questions (and offer no other tangible rewards) is intended to craft an experience in which the most strongly-supported purpose for exploration is to learn more about the Universe and how it works. This also mirrors the goal of real-world space exploration to "address fundamental questions about our place in the Universe and the history of our solar system."[10]

A World In Motion

Despite being a time-based medium, relatively few games feature worlds that are irreversibly changed by the passage of time. This is especially true of many open-world games, where being allowed to freely explore for as long as desired is a large part of their appeal. Even though the open-world game *Skyrim* takes place in a land under attack by dragons, nothing bad happens if players choose to put saving the world on hold to climb a mountain or collect potion ingredients. While designing a world that clearly waits on player input sidesteps many undesirable and difficult-to-manage situations (e.g., the game does not simply end if players fail to save the world in time), it tends to result in a fairly stable world that necessarily revolves around the player.

Of course, we live in a Universe that very clearly does *not* revolve around us. Real-world

[10] NASA, "Why We Explore", 2013

space exploration tends to be an incredibly humbling affair that constantly reminds us how small and insignificant our planet truly is on the cosmic stage. Like our own solar system, the solar system in *Outer Wilds* is governed and changed over time by forces that do not know or care about the player. The goal of this approach is to create a world that players can come to understand but are ultimately unable to control (much like our own relationship with the Universe).

To achieve this in *Outer Wilds*, we made the entire solar system part of a real-time physics simulation. Rather than design each planet as a discrete “level”, every planet is simultaneously kept in orbit around the Sun via simulated Newtonian gravity. In addition, most planets physically change over time due to local large-scale processes. Some of these processes are fairly random. The planet known as “Brittle Hollow” is gradually broken apart by unpredictable impacts from molten rocks that erupt from its volcanic moon. Other processes are more deterministic. On the pair of planets known as the Hourglass Twins, sand flows from one planet to the other, burying a cave system on one planet as it reveals ancient ruins on the other.

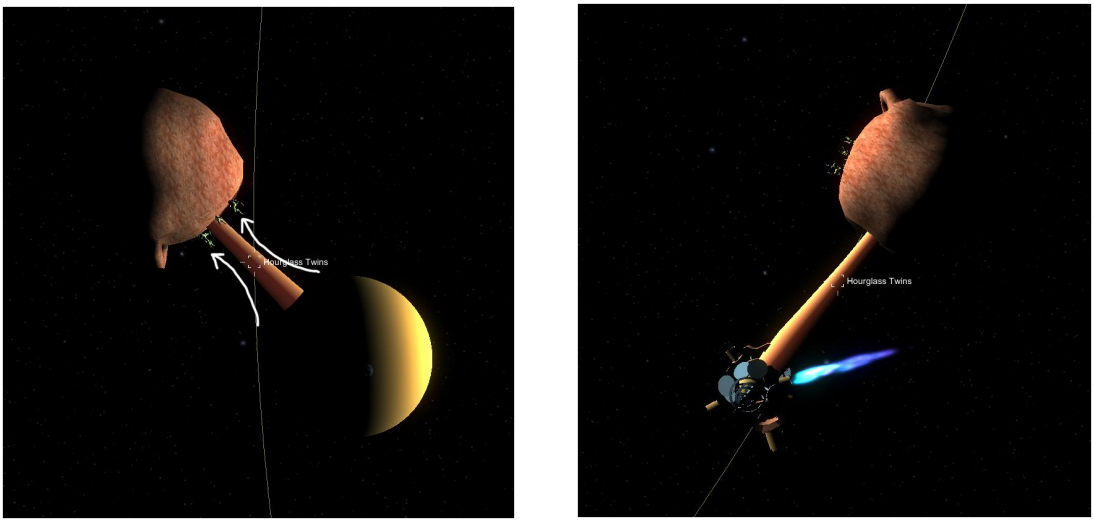

Figure 4: Time-lapse of the Hourglass Twins

The cumulative effect of these systems is a volatile world that dramatically changes over

time. Unfortunately, since many of these systems are either irreversible or unstable (or both), the simulation can only run for so long before it either devolves into chaos or reaches some sort of equilibrium. To circumvent this issue, the simulation only runs for twenty minutes, after which the Sun goes supernova and the entire solar system resets. This is explained within the narrative as a diegetic time loop in which the player's character is trapped.

Exploring the 4th Dimension

The fact that each planet irreversibly changes over the course of twenty minutes means that it is practically impossible to explore the entire solar system during a single playthrough. Similar to other heavily time-dependant games like *Majora's Mask* and *Way of the Samurai*, *Outer Wilds* is intended to be a long-form experience comprised of multiple playthroughs. This setup effectively adds an extra dimension to exploration by making "when" players explore just as important as "where". After all, Brittle Hollow as it exists at the start of the time loop is a very different place from the shattered husk it becomes after twenty minutes of meteoric bombardment. The Hourglass Twins are also a good example. If players arrive during the first half of the time loop, they can explore the underground cave network of the first twin before they fill with sand. If players choose to explore the Hourglass Twins later in the time loop, they can investigate the ruined towers on the other twin which are gradually revealed by the draining sand.

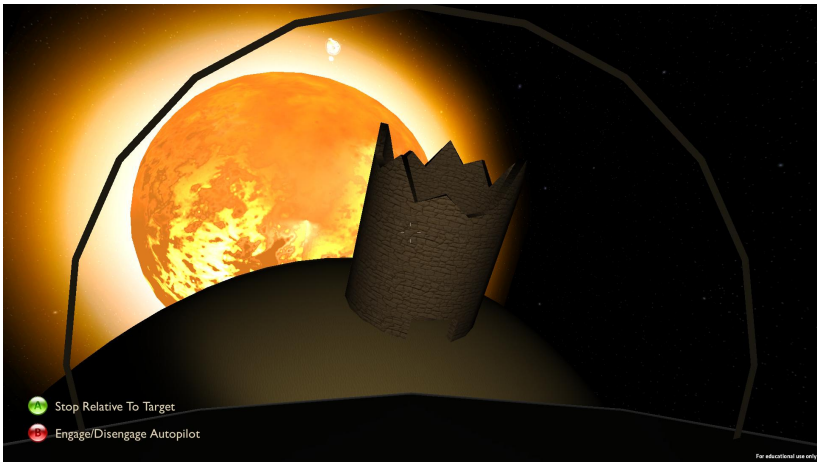

Figure 5: A tower being revealed on the Hourglass Twins

Since these large-scale changes occur continuously as the result of procedural forces, they give each playthrough a certain unpredictability (and occasional serendipity) that comes from navigating a dynamic physics simulation. We like to think of it as trying to explore inside a storm. During our playtests so far, some of the strongest player responses were prompted by the more procedural aspects of the world. Several players responded in shock and surprise as they watched the giant sand funnel on the Hourglass Twins suck their ship off of the surface. Another player accidentally fell through a black hole, but managed to use his jetpack to reach a comet that just happened to be passing by before his oxygen ran out. Still another player was excited to witness a tornado in the gas giant lift an entire island into the atmosphere. Even though most of the Curiosities and POIs have yet to be implemented, the existence of these dynamic systems seem to go a long way towards making the solar system a space that is engaging to explore in and of itself.

Knowledge Over Agency

Although players are free to explore wherever (or whenever) they wish, they have very little agency to affect the forces that drive the solar system. All they can do is understand how

each force or system works and learn to deal with it. This parallels the POI/Curiosity system, which is also completely knowledge-based. Together, they create a world that rewards exploration for the sake of knowledge and understanding as opposed to more tangible rewards.

This concept of knowledge-over-agency has been a driving influence for several major design decisions, such as the behavior of the sand that flows between the Hourglass Twins. The question we faced very early one was whether the player could trigger this transfer, or whether it was something that happened automatically over time (beyond the player's control). We decided to go with the latter because it supports the idea that there are forces at work beyond the player's control, which means the player must to adapt to the world and not vice-versa. This decision set a thematic precedent for all future systems-related decisions, leading to the current solar system in which players must learn to explore within systems that are beyond their control.

This theme also influenced the overarching narrative of the game. Originally, the goal of the game was to find a way to stop the Universe from ending. This changed to the goal of understanding *why* it is ending (among other questions). Even the narrative climax of the game is knowledge-based, where players finally discover what the thing older than the Universe actually does. Conveniently, this mentality meshes nicely with the nature of time travel as depicted in the narrative. Since the player's character is stuck in a time loop where only her consciousness travels back in time, memories and knowledge are the only things that could possibly persist between time loops (barring a sufficiently-contrived plot device).

Prior Art Review

Many existing exploration-focused games can be loosely grouped into two categories. There are "open-world" games, such as *Skyrim*, which treat exploration as something optional to

do between objective-driven missions. On the other side of the spectrum exist largely goalless exploration games such as *Proteus* and *Noctis*, where the only objective is to freely navigate a virtual world. The world of *Outer Wilds* exists somewhere in between. Although players are initially set loose to explore without anything resembling a goal or objective, the POI-Curiosity web is a collection of concrete (albeit optional) clues and objectives waiting to be discovered. Despite their similarities, POIs and Curiosities differ from *Skyrim's* quest system primarily in the way in which they are communicated to the player. Whereas *Skyrim* directly tells players what to do (e.g. "Inform the Jarl of Whiterun about the dragon attack on Helgen."[11]), the POIs in *Outer Wilds* merely inform players of their affordances within the world. For example, while most tornados on the gas giant lift objects into the sky, there is a POI that tells players about the existence of a tornado that pushes objects downwards. It is left up to the player to use that information in order to reach the Curiosity at the center of the planet.

Outer Wilds' time-dependent nature is largely inspired by *Majora's Mask* and *Way of the Samurai,* both of which feature worlds that change in dramatic and irreversible ways over time. Just like *Outer Wilds'* time loop, both games require players to complete multiple playthroughs in order to see everything their worlds have to offer. The key difference between these games and *Outer Wilds* is that the time loops of *Majora's Mask* and *Way of the Samurai* are completely deterministic - that is, their worlds consist of scripted events that always happen at specific times. By learning when these events occur (and what future events they affect), players can intervene in order to manipulate their outcomes. One of the most pivotal early design choices on *Outer Wilds* was to focus less on using the time loop to create these precise schedules of events, and more on using it as a way to create large-scale irreversible systems for players to explore and understand. Whereas *Majora's Mask* and *Way of the Samurai* are about

[11] *Bethesda Game Studios*, 2011

experimenting with causality, *Outer Wilds* is about learning to navigate and survive within a dynamic system.

Outer Wilds draws much of its thematic and aesthetic inspiration from the films *Apollo 13* and *2001: A Space Odyssey.* These films inspired the game's fairly realistic portrayal of space travel as well as its theme of fragility. Space travel in *Apollo 13* feels like a truly dangerous undertaking, where the fragile Apollo capsule is all that protects the characters from the void of space. Unlike many popular space flight games such as *FreeSpace 2*, *Outer Wilds* accurately represents space as a frictionless zero-gravity environment. Although this makes space travel far less intuitive for players, it also makes it feel much more realistic and dangerous. This model of spaceflight also allows us to create situations in which the player must exit her ship in zero gravity. These situations convey an intense sense of fragility, and are directly inspired by the scene from *2001* in which Bowman chases after Poole's body, which is rapidly drifting away from their ship and into the void of space.

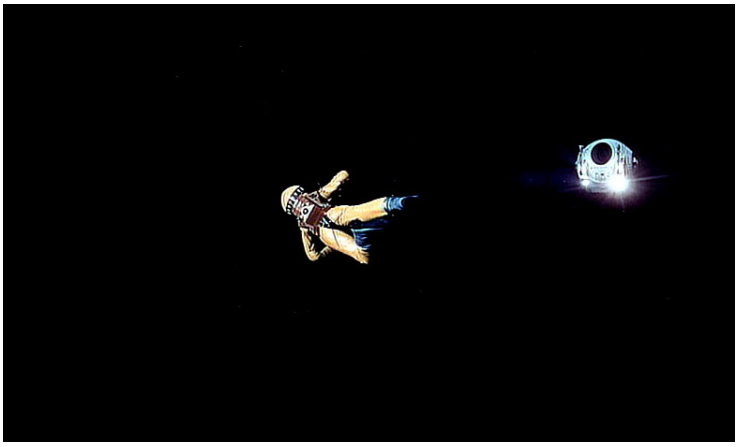

Figure 6: *2001: A Space Odyssey*

In addition to space travel, *2001: A Space Odyssey* also influenced the embedded narrative of *Outer Wilds.* Similar to how *2001* tells the story of an expedition to find a mysterious alien artifact of cosmological significance, *Outer Wilds* tells the story of an ancient alien race in

search of a mysterious object older than the Universe itself. In fact, we often used referenced *2001's* monolith scenes when designing the parts of the game that involve the mysterious object itself.

Process and Evaluation

A Flawed Introduction

The core elements of *Outer Wilds* - the embedded web of POIs and Curiosities and a world governed by dynamic forces - are both complex concepts for players to understand. Before they can uncover POIs or even attempt to reach a Curiosity, players must first learn how to navigate the world's dynamic systems (many of which are extremely dangerous). This in turn requires a certain level of proficiency with the moment-to-moment telescope, probe, and spaceflight mechanics.

Creating an introductory sequence to ease players into this complexity (while simultaneously introducing the world and setting the proper tone) has proved to be one of the most difficult design challenges of the entire project. While the specifics have gone through many iterations, the intro sequence has always begun in a small alpine village (situated in a crater on the third planet from the Sun) and ended with the player lifting off in her spacecraft to explore the wider solar system.

Below is an outline of our very first iteration of the intro sequence. Players were required to complete all ten steps (in order) before they were allowed to lift off and explore the rest of the solar system.

Original Introductory Sequence

1. Roast a marshmallow.
2. Use the telescope to observe distant planets in the night sky.
3. See an alien object fall out of the sky and crash on the other side of the village.
4. Leave the starting area and walk down to the village.
5. Talk with the Outfitter to obtain probes.
6. Use a probe to take a picture of the crashed alien object.
7. Show the Outfitter the picture to obtain a jetpack.
8. Use the jetpack to reach the crash site.
9. Discover the alien map of the solar system, which reveals the true scope of the world and its many possible destinations.
10. Return to the Outfitter to gain access to the spaceship, then lift off to explore the cosmos.

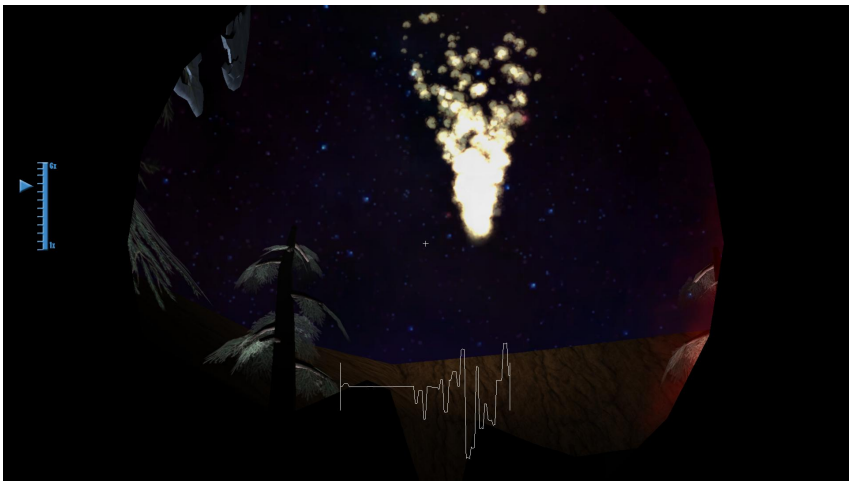

Figure 7: A Stranger Comes to Town

On paper, this introduction seemed to cover all the essentials. It introduced the gameplay arc of using the telescope to spot something from afar, then using probes to get a closer look, and finally using flight mechanics to travel there in person. We decided to center the entire sequence around the investigation of a crashed alien object because we hoped players would be

curious to know what it was and where it came from (questions that could then be answered by exploring the solar system). We also chose to make the villagers actively disinterested in exploration in order to emphasize the importance of the player's own sense of curiosity. For example, the Outfitter actually tried to convince players that the crashed object was not worth investigating, which was written in hopes that players would want to prove him wrong.

In practice, this approach proved to be fundamentally flawed both as a gameplay tutorial and as a thematic and narrative introduction to the world. The most immediate problem with this approach was that the alien object fell out of the sky before players had a chance to fully explore the village and orient themselves within the world. We essentially tried to use the "Stranger Comes to Town" narrative archetype, but we made the mistake of introducing the stranger before the town. As a result, many players completely forgot about the crashed object once they started exploring the village (which, from their perspective, was just as strange and unknown as the crashed object). In fact, most players eventually had to ask what they were "supposed" to do next. I still cannot decide what was worse - the fact that this question represented the antithesis of curiosity-driven exploration, or the fact that the introduction's rigidly linear progression meant that it had an answer.

Problems also arose in terms of narrative structure. Players had no sense of who their character was or what his or her motivations might be. Why did they start by roasting a marshmallow and then look through their telescope? Why did they want to go into space? In addition, due to our decision to make the villagers disinterested in exploration, players described them as "cold", which ultimately prevented the village from feeling like home the way it was intended to.

The original introduction also failed to teach players the basics of spaceflight (arguably the game's most central mechanic), which resulted in nearly every playtester accidentally flying

into the Sun shortly after takeoff. Instead, the intro taught secondary mechanics (like the telescope and probes) in very restricted situations that did not accurately reflect how those mechanics would be used for actual exploration. For example, players learned to use probes by taking a picture of a specified target, which is a far cry from their intended use as a way to safely poke and prod at unknown systems and environments.

Welcome to the Space Program

Rather than try and patch what was clearly broken, we decided to rebuild the introduction from the ground up. While it seems obvious in retrospect, that first iteration demonstrated that before players can be curious about distant places or new systems, they must first understand the space they are in. This inspired the complete removal of the alien object that crashed in the old introduction. Instead, players are now introduced to the world as a member of the village's space program, and the entire introductory sequence revolves around the idea that the player's character is preparing for her first voyage into space. Not only does this provide a diegetic reason for teaching players spaceflight, it sets up both the player's character and the village, and gives players a chance to become oriented in the world before blasting off to explore the rest of the solar system.

Much like the original introduction, the new one starts players next to a campfire beneath a starry sky. However, rather than being forced to roast marshmallows or look through a telescope, players are immediately free to explore and interact with their surroundings. In fact, the only task that is absolutely required to complete the introduction is to learn the launch codes from a character at the observatory. In place of explicit linear objectives, the village is filled with completely optional content that focuses on instilling curiosity and teaching players about spaceflight and the systems that govern the world. To facilitate this, characters in the village are

far more enthusiastic about space exploration, and either wish players good luck or tell stories about distant places. One character teaches players to use their telescope (without telling them what to look at), while another character challenges players to complete a zero gravity training scenario.

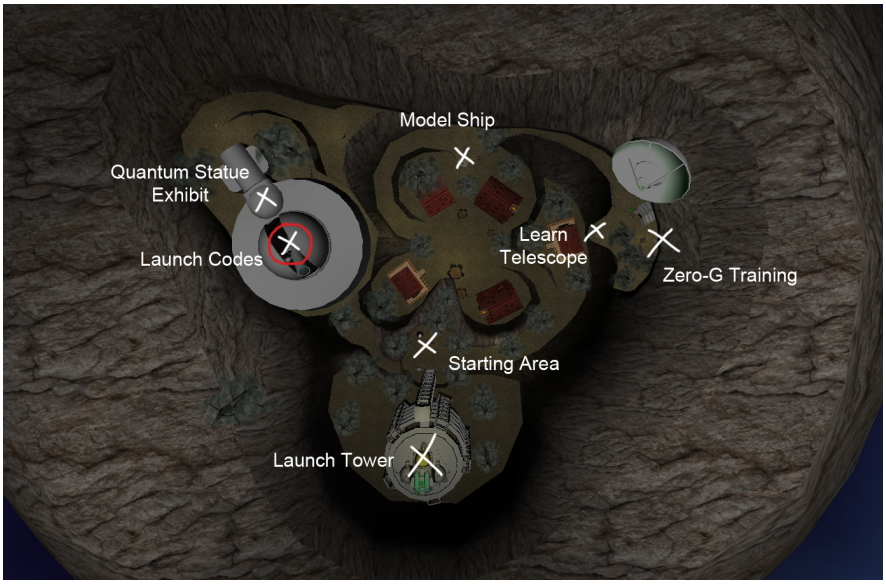

Figure 8: Revised, non-linear village layout

Even from our first few playtests, it is clear that this new introduction is a dramatic improvement over the original. After completing the zero gravity training scenario and flying the model spacecraft in the village, players are now far more successful at piloting the full-sized ship after liftoff (as evidenced by fewer trajectories into the Sun). Since the introduction is more open and only has one required objective, fewer players have to ask what they are supposed to do next. In fact, most of our playtesters take time to talk to villagers, practice in the zero gravity chamber, and look at exhibits in the museum before seeking out the launch codes and lifting off.

Even the villager dialogue has seen success in encouraging player curiosity. One character in the village tells players that he would love to explore the “gnarled, thorny planet” that can be seen in the sky on certain nights. After talking with this character, three separate

playtesters decided to look up at the sky to see if they could spot the planet he was talking about (which, by a stroke of luck, was actually in the sky on all three occasions). Although it is a very simple example, the resulting positive reaction from the playtesters demonstrates the possibility and value of rewarding curiosity.

Building Models of Complex Systems

One of our biggest decisions in creating the new introduction was to re-incorporate a concept from one of the game's oldest prototypes. In this particular prototype, players flew (and more typically crashed) several model rockets before being shown a full-sized rocket and asked to climb inside. Not only did flying the model rocket from a third-person view help players understand the scaled-up version from a first-person view, it also gave flying the full-sized rocket a greater sense of weight (as evidenced by players' initial reluctance to climb inside).

I had initially intended to incorporate this idea into *Outer Wilds'* introduction, but decided to remove it due to fears that it would distract players from investigating the crashed alien object. After it became clear that our original intro sequence failed to prepare players for space travel, we decided to bring back the model rockets as part of the revamped introduction. Not only is this new addition consistently a hit with playtesters, it is clear that they understand it as a model of the full-sized ship they will eventually lift off in.

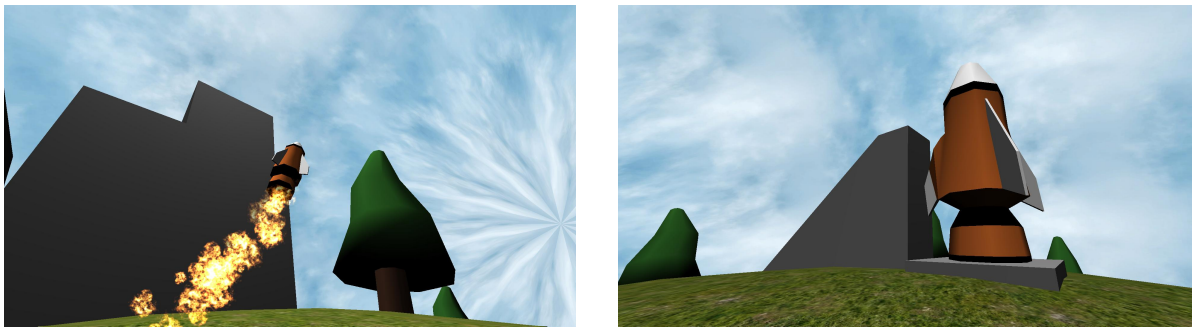

Figure 9: Prototype - model rocket vs. full-sized rocket

This concept of using models to represent larger systems has since become one of the major tools we use to create a world that tells stories about itself. While designing the new introduction, we decided to build a science museum inside the village observatory. This science museum is a collection of exhibits that reference various places and systems that actually exist somewhere in the solar system. For example, one exhibit is a quantum statue that changes shape whenever the player is not observing it. This statue is actually a model of the Quantum Moon, which exhibits a similar sort of quantum behavior on a much larger scale.

Designing A World That Changes Over Time

Creating a solar system governed by dynamic forces has proved to be exceptionally challenging. In addition to designing complex three-dimensional spaces, we have to consider how those spaces will change over each twenty-minute playthrough. The approach we have found to be most successful is to design each planet around a single major system that changes over time (like the sand that flows between the Hourglass Twins). Although each major system is always designed with an initial experience in mind, the nature of the physics simulation often limits our ability to force systems to work exactly as intended. Although the gas giant was originally envisioned with floating islands that would orbit the planet in its upper atmosphere, we soon realized that air resistance would actually cause these islands to spiral into the core during the first few minutes of the game. While we could have simply removed the effects of drag on the islands (which would have lead to new problems regarding the player's own drag and relative motion), we decided to keep working within the existing fluid system. We eventually realized that the same drag that caused the islands to sink could be used to keep them afloat if we placed the islands between two fluids of differing densities. Experimenting with this system in-game ultimately lead to the concept of the spherical ocean that now embodies the gas giant. To make

this system change over time, we introduced ocean currents and roaming tornados (both created with fluids) that interact with the islands in unpredictable ways.

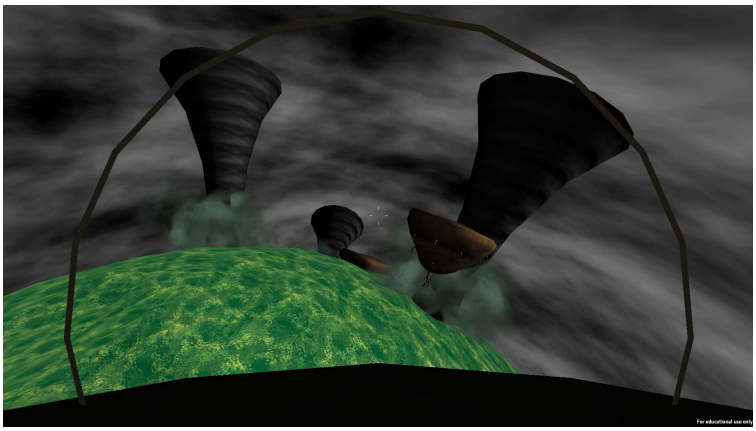

Figure 10: Tornado lifting an island inside the Gas Giant

This approach of rapidly prototyping each planet's overarching system allows us to identify and take advantage of the strengths of the physics simulation while simultaneously reducing the need for custom workarounds (like ignoring drag on only some objects). The resulting system becomes the canvas on which we can then design specific level geometry and create POIs and Curiosities that take advantage of those systems. For example, we decided to place POIs on the islands inside the gas giant after observing how they were tossed around by the tornados (in order to increase the likelihood players will come into contact with that system). Overall, we have found that this approach of first creating a dynamic system, and then designing content to take advantage of that system's behavior is a highly successful way to combine procedural and handcrafted content.

Future Extensions

As of this writing, we are just starting to implement the web of POIs and Curiosities discussed earlier in the paper. Based on what we learned from revamping the intro sequence to

better reward curiosity, we are confident in our approach of using POIs to reveal the affordances that players can use to reach Curiosities. Even so, extensive playtesting will be required to determine how much information each POI should reveal, not to mention whether or not players are actually motivated to investigate each Curiosity.

Should this project ever gain a large enough audience, I think there is potential to build a community of players around the unpredictability caused by the time-dependant and physics-driven nature of the game. Judging from the sheer number of extremely improbable events that have transpired during playtests, I think players would be interested in recording and posting their feats and misadventures within the game. For example, one player decided to jump out of his space ship mid-flight and yet somehow managed to land on Brittle Hollow intact using only the jetpack. Another player decided to push the model rocket all the way across the village, carried it up to the ship in the launch tower elevator, got it inside the ship using the tractor beam, and flew across the solar system to finally deposit it on the Hourglass Twins. These types of exploits are largely possible thanks to the dynamic physics and systems at play, and I think players would be interested in sharing their own improbable experiences with a larger community.

Conclusions

Although curiosity has proved to be a difficult concept to pin down, I believe we have discovered a number of useful techniques that either support or reward curiosity-driven exploration. From our iteration of the game's introductory sequence, we learned that you cannot expect players to be curious about a distant or new element in the world before they understand their local environment. Not only is it extremely difficult (and perhaps impossible) to control what players are curious about, in doing so you run the risk of transforming their curiosity into the need

to fulfill an extrinsic requirement (like our attempts to make players curious about the crashed alien object). One approach that seems to successfully encourage curiosity is to populate the world with things that reveal affordances elsewhere in the world without telling players what to do. This allows players to ask their own questions about the world, and increases the chances that those questions have answers.

When designing a world around large-scale dynamic systems, we discovered that it is important to first make an extremely rough prototype of each system, because they often behave in unpredictable ways that influence gameplay. Although the gas giant's dynamic systems were initially designed on paper, the decisions that lead to the creation of its spherical ocean were all based on observations of run-time behavior.

The primary purpose of *Outer Wilds'* large-scale dynamic systems is to create a world that changes over time. Interestingly, these systems also seem to reinforce the project's other goal of curiosity-driven exploration. Even though the majority of POIs and Curiosities have yet to be implemented, players are already curious to investigate the physical systems themselves. One playtester spent several minutes trying to figure out exactly how the quantum statue works, while another proposed multiple hypotheses to explain the behavior of tornadoes in the gas giant.

In the end, I imagine *Outer Wilds* merely scratches the surface of the many possible ways to design for curiosity-driven exploration and worlds governed by dynamic forces. I think the game does successfully reveal the potential of both concepts, especially with regards to exploration-heavy experiences, and I hope that our approach is a useful trail marker for the next travelers who venture into this territory.

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