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KINETARIUM: Interactive Multiplayer Games for Fulldome Projections

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ABSTRACT KINETARIUM is a new platform for interactive, collaborative fulldome shows for hundreds of people. It enables visitors to intervene spontaneously and in real time in what is happening on the dome, by using their own smartphones. Kinetarium introduces interactivity and gamification to the domes, with the visitors becoming fully immersed in the projection, just as if they were right in the middle of things. Everyone in the audience can participate in the show. Together, the players can go on missions, solve puzzles and discover new worlds – or simply try to crack the high score. In addition to dealing with scientific phenomena, the players experience how difficult the simplest tasks can be when joint decision-making, coordination, team work or compromises are required. That way, the games also teach learning processes about group dynamics or social behavior. The planetariums can thus enrich scientific content with playful and group-dynamic elements and make their program more attractive for a young, gaming and 3D savvy audience.

KEYWORDS Interactive experience; fulldome projection; local mass multiplayer; realtime rendering; immersive; 360° media; serious gaming; collaborative learning; projection mapping.

I. INTRODUCTION – OUR SOLUTION

INSTEAD of being asked to turn their phone off, our audience is encouraged to bring a fully charged phone to the show. Visitors open a website on their smartphone which serves as a controller and enables real time interaction (a large audience is shown in Fig. 1).

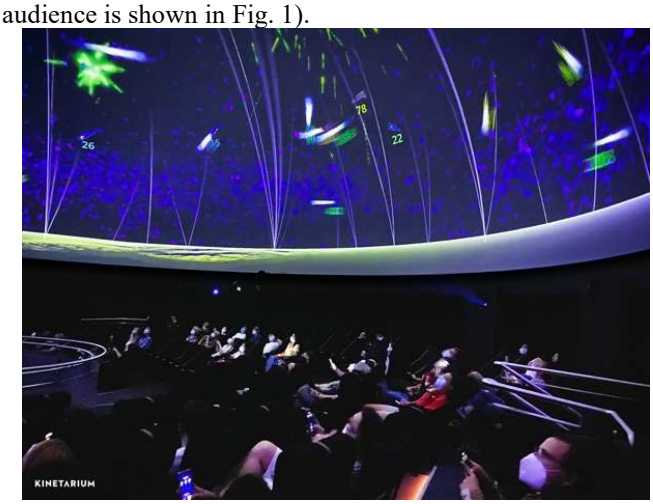

Figure 1. The star dome goes interactive: Kinetarium invites hundreds of players to interact with each other in a physical space

A web server collects all user input and forwards it to the game engine, which updates all game graphics and prepares the new image for projection.

A. LOW BARRIER OF ENTRY FOR THE PLANETARIUM VISITORS

We want to appeal to all planetarium visitors. Therefore, we have taken care not to exclude anyone by assuming gaming experience or technical understanding.

Every visitor uses their own smartphone as an input device, that way they are already familiar with the hardware. The controller is a website, not an app. There is no need to come prepared, no need to install anything. The website is loaded up quickly and can be used right away. No registration required. Any web browser can be used. The controller interface automatically changes to reflect the currently selected game or show (interface example in Fig. 2). Any buttons that aren't needed are hidden. We designed each individual controller to be usable without looking at the screen, since the action happens in the dome.

Figure 2. Direct communication with the projection: use of the controller interface

B. LOW REQUIREMENTS FOR THE VENUE

Any planetarium or venue with a fulldome projection should be able to run Kinetarium. The shows can be controlled by a single person. The Kinetarium client software is very minimalistic and easy to use. It runs on older hardware too, so usually no additional hardware is required. There is no need for any local network infrastructure. A visitor Wi-Fi can be set up, but isn't required as long as the visitors have access to a mobile connection.

C. EDUCATIONAL CONTENT TAUGHT IMMERSIVELY AND INTERACTIVELY

What makes Kinetarium different? Kinetarium is a project that explores the possibilities of fulldome as a collaborative medium: immersive, interactive and live.

Our objective was to:

- Enable each individual visitor to interact with the show and make learning a social event.
- Have a low barrier of entry for the visitors, both technically and in content.
- Have low requirements for the venue, so organizers just need a digital projection system and can use the hardware already available.
- The shows and games should be interactive and immersive containing educational content. They should provide visitors with a shared understanding of problems that we are causing or can only be solved as a collective.

II. TECHNICAL COMPONENTS

A Kinetarium event setup consists of four major hardware components, as shown in Fig. 3: The fulldome projection system (1), a computer running the Kinetarium client (2), a web server (3) that is accessible to the visitors, and mobile devices with the website that works as a controller (4).

Figure 3. Functional diagram of the Kinetarium

A. FULLDOME PROJECTION SYSTEM

The fulldome projection system is part of the planetarium hardware and consists of one or more projectors and computers. This hardware is combined with image splitting software that takes in a circular video signal (fulldome) and distributes it to any number of projectors to form a continuous dome projection [1].

For Kinetarium, stationary (planetariums, science centers) as well as mobile domes (tent constructions, air domes) are suitable. Stationary dome projections offer controlled conditions such as fixed seating, ticket and admission systems, air conditioning, etc. Mobile domes are usually smaller (although insignificant), but can be placed in busy locations such as marketplaces, exhibition halls or festivals.

B. KINETARIUM CLIENT

The real time image that is displayed is rendered on a computer running the Kinetarium client, which is developed based on the game engine Unity. While the engine offers efficient real time rendering, a physics system and features for visual effects, we developed the websocket communications, dome projection cameras, the interface to some existing planetarium software, mass multiplayer input and player management, needed for all the shows and games. This software, written in the default language for unity developers, c#, is at the heart of our development and provides all settings and controls to launch and manage the show, gameplay and sound options.

Unity (www.unity.com) is designed to create realtime interactive 2D and 3D content [2] and is the basis for our interactive 3D content. It enables us to provide the Kinetarium client for Windows, MacOS and Linux. All textures, 3D models, sounds [3], animations and scripts are combined here, to create an immersive experience. This easy to use game engine allows us to quickly create new content and test new ideas as well as to compile the platform for any operating system. Rendering happens at 60 frames per second. We use a lightweight render pipeline to ensure compatibility with planetarium systems of earlier generations [4].

In order to operate the Kinetarium in a planetarium or fulldome projection space, very few requirements must be met:

- connection to a digital fulldome projection system
- internet access with low latency
- reasonably fast hardware for running the Kinetarium client

A note on hardware requirements: We optimized the Kinetarium client so that most gaming/media PCs and laptops released in the last five years should be able to run it.

C. KINETARIUM WEB SERVER

The Kinetarium web server is a NodeJS server that brokers all connections between the visitors' smartphones and the Kinetarium client. The web server provides the controller website, then collects all input from the visitor's controllers and makes it accessible to the Unity game engine. Both connections are accomplished via websockets to minimize latency (currently around 50ms). We are routing all controller input over the internet instead of a local network. We do this, to keep requirements at the venue as low as possible. The planetarium just needs to make sure, both the Kinetarium client and the visitors have internet access.

Because we're routing these signals over the internet, reducing latency is essential. Under ideal conditions, the web server would have to be very close to the planetarium or venue.

Our first long distance tests show however, that most of our games are rather forgiving when it comes to latency.

Connection bandwidth is almost irrelevant since very little information needs to be sent. This information (coordinates for a joystick position, booleans for buttons, number values for sliders) is sent and received formatted as JSON objects. We have to be careful with the update interval though. In order to minimize input latency, you want to send as many updates as possible. This can quickly choke the web server when it has to handle a lot of connected devices. We found that a maximum of 20 updates per second work well for our games. Of course, the controller doesn't need to send anything, if no input is registered.

D. CONTROLLER

The Controller is a simple website that visitors open on their smartphone at the beginning of the show. The URL is displayed directly in the dome, and can be entered manually or by scanning a QR Code. We chose to use a website as a controller, instead of a native app, because that way we can support more mobile devices with a single code base. Also, an app would have required visitors to install it beforehand, or install it during the event, which would have caused delays and waiting time for others.

The controller website is very small in file size. It is programmed with mostly native HTML, CSS and Javascript and uses Vue.js for all dynamic elements. All images are vector based SVG files, to keep file sizes low. This means it can be quickly downloaded via 3G or LTE network and allows a large number of visitors to get started quickly. We do not require a login but instead assign a user ID that is stored in a cookie on the device. This allows the player to temporarily turn off the device, without losing his or her settings and highscore. Collecting the visitor input data on a webserver has another advantage: since the data is already online, it can easily be exchanged between two planetariums and allows them to play against each other. For example: visitors of a planetarium in Berlin could face off against visitors of a planetarium in Paris or Madrid.

As described earlier, latency must be kept as low as possible. At the same time, battery consumption and the required data volume must be minimized. Interaction has to be possible without having a Wi-Fi connection. With the help of the cookie script, a cookie can be written and read, which stores the player number assigned by the server on the client.

Depending on the selected game or show, the controller interface shows a combination of buttons, joysticks and sliders. Some examples are shown in Fig. 4.

Figure 4. Different controller interfaces depending on game content of the Kinetarium

In order to prevent the light of the display from disturbing the projection, the interface is designed as dark as possible. Sometimes however, a strong background color is used to signal a team affiliation. This color can also be identified by others in the otherwise dark dome room. The input options (joystick and an action button) are very minimalistic to allow a quick start. Ideally, a game can be played without the visitors having to look at their phones screen. This is hard to achieve on a touchscreen though, where users lack the haptic feedback of real buttons.

E. DATA SECURITY

Kinetarium offers high security by data minimization. Players don't register and leave no personal information, not even nicknames. During the shows, they are simply identified as a number. The controller website is loaded via HTTPS. Input signals are sent over an encrypted Websocket connection. This data is sent in JSON format and is stripped down to a bare minimum. After a show has ended and all connections to the server are closed, any information related to the show is deleted.

III. THE CONCEPT

A. INTERACTION IN EDUCATION

Interactive learning is omnipresent in today's world. On the internet, as an app, even as an interactive experience of art in a museum [5]. The transfer of knowledge through interactivity is integrated into our everyday lives – without us even noticing it. We scroll past some examples on social media likely every day.

Nevertheless, interaction has not yet arrived in some places: in planetariums it is a very rare feature, even in the most modern venues. We see a great potential in this area and want to increase successful learning by introducing active participation to the dome.

B. THE PLANETARIUM AS A COLLECTIVE IMMERSIVE MEDIUM

Planetariums allow us to immerse ourselves in distant worlds and could be seen as modern "temples of knowledge". Since the technology is already a century old, it is often forgotten when we think about immersive media. Therefore, the fulldome environment is not a new type of media – relatively new, however, is the widespread use of digital projectors (similar to the ones used in cinemas). Unlike traditional star projectors (hardwired to project a static image of the stars and constellations), these allow any animated content to be displayed in real time.

Since planetariums have always been designed as places of education and excitement, we wanted to use these places to impart knowledge in new – immersive – ways. Why immersive? A common assumption is that they facilitate a deeper experience of stronger emotional impact compared to conventional audiovisual media [6, 7]. It is widely assumed that the immersive experience mediated by media such as fulldome, 360° video, or VR can be explained by an increased realism. Nonetheless, it remains a technically mediated realism that is fundamentally different from the real-world experience. As strong as the emotional impact through immersive experience may be, viewers are aware of the fictional character of this experience is [8, 9].

IV. CURRENT SITUATION

A. VIRTUAL REALITY MULTIPLAYER DEVELOPMENTS

Since Virtual Reality (VR) is the most known immersive medium – a comparison with fulldome is therefore obvious. VR is also popular amongst educational experts, as it enables very immediate, intensive learning. There are different concepts and projects to provide a shared experience with multiple headsets.

Some examples are:

- Yullbe (www.yullbe.com/yullbe-pro) is a collaborative Virtual Reality experience for up to thirty-two people playing simultaneously. Participants are equipped with backpacks, hand and foot trackers and a VR helmet to move through a 200 m2 space. As a group of up to four people, a task is to be solved together [10].
- Spree Interactive (www.jointhespree.com) also offers multiplayer Virtual Reality. The "SPREE Arena" is a multiplayer free-roam VR attraction available in six player and ten player configurations. A VR headset and additional controllers are required [11].
- EVA (www.eva.gg) offers Virtual Reality e-sport experiences. The players are equipped with a VR headset, a backpack computer and a connected rifle. Two to twelve people can roam an arena of up to 994 m^2 [12].

While all concepts offer participants an immersive multiplayer experience, they restrict their freedom of movement and comfort due to required equipment. The games are limited to a hand-full of participants while others are waiting in line. For the "organizers" there are several hurdles as special equipment is needed and has to be obtained and set up first.

B. FULLDOME MULTIPLAYER DEVELOPMENTS

The planetarium scores with its generous space under the dome and still offers benefits, even when compared to stateof-the-art VR headsets. First and foremost, it turns virtual space travel into a social experience, instead of an isolating one. You can watch planetarium shows with hundreds of people, limited only by the size of the dome and the number of seats.

Some types of planetarium software allow the presenter to show and highlight specific topics in real time. This form of real time interaction allows a presenter to, for example, hop between planets or to steer through the galaxy. Since the audience usually isn't actively participating, this has no immediate effect on their experience. "Dome experiences can be developed in wildly diverse content areas including art, science, music, engineering and many others" [13].

In the fulldome environment some concepts and game developments introducing interactivity already exist. An Overview is shown in Table 1. Students at the "Mediendom" of the University of Applied Sciences in Kiel, Germany (www.fh-kiel.de/kultur/mediendom) have developed several games for the dome [14]. These are mostly limited to two to four players using Xbox 360 controllers. The competitive fulldome game "XUR" for example, where two players can navigate on the dome in a "jump and run" style. During an event, the vast majority of visitors would have to watch instead of actively participating [15].

Few fulldome game concepts (like www.360touchit.de) allow all visitors to join in via their phone, but have to install an app first. To cope with the large number of players, a competitive system of elimination is used. As a result, players who are quickly defeated have to watch the longest part of the event [16].

Table 1. Overview of immersive multiplayer developments (selection) [1]:

Medium	Name	Genre	Input device	Max. number of players
VR	Yullbe	Team	Tracked body movement	32
VR	Spree Arena	Team, family-friendly	VR Controllers	10
VR	EVA	Co-op or PVP	VR Controllers	12
Fuldome	360Touch.it	Competitive survival	App for iOS devices	253
Fuldome	XUR	Platformer, jump and run	Xbox 360 controller	2

V. CONTENT AND INTERACTION

A. GENERAL CONSIDERATIONS ON FITTING CONTENT

Since we enable a large group of people to interact with one another, problems that can only be solved as a group are particularly interesting. Game genres where the main focus is on one single or a few characters are not suitable for us. As described at the beginning, we want to use the platform for interactive learning.

We initially focus on scientific or socially relevant topics, for example:

- space debris in earth orbit
- swarm intelligence and swarm behavior
- overfishing of the oceans
- climate change as a social dilemma
- the spread of viruses or false news
- democracy and democratic processes/citizen participation

These complex topics can only be understood by an individual one step at a time. With our platform they can be discovered and understood cooperatively in a playful way. To take advantage of collaborative learning, both social, psychological and academic. Visitors are challenged to cooperate, which i.e. promotes critical thinking and establishes a positive atmosphere [17].

B. SOCIAL DILEMMA – GAME THEORY

Game theory analyzes a wide range of situations as a game in which "individuals make decisions that will influence one another's welfare" [12] So for our case it offers some concepts that apply well to larger groups.

For example, the (over) use of common goods – the socalled "tragedy of the commons" or "social dilemma". This concept can be adapted to a Kinetarium show: A freely available but limited resource (space in earth's orbit, CO2 quotas, etc.) must be used efficiently by everyone and is threatened by overuse, which also threatens the users themselves. What is best for the individual player, is not best for the group. The players need to consider their options and, if possible, develop a strategy together. This is where cooperation plays a crucial role.

C. COOPERATIVE GAME CONCEPTS

Cooperation results in synergies that simplify solving a task. The individual player does not seek an advantage over the others. In addition to dealing with scientific phenomena, the players experience how difficult the simplest tasks can be when joint decision-making, coordination, team work or compromises are required [18].

Team building games such as soccer, pong, etc. also fall into this category. Inspired by Atari classics and sports, these concepts serve to find a common strategy and promote communication. Here, too, a special feature of the Kinetarium plays a major role: the players are in a physical space. This means communication is not restricted to an audio or video channel. Participants can simply call out to fellow players, see, feel and hear them.

D. COMPETITIVE GAME CONCEPTS

We analyzed different competitive game concepts when we started the development. But noticed, that for our educational focus, collecting points and an individual player's score should fade into the background. It was more important for us, that the players work to achieve a common goal and to set up a high score together, not that everyone plays against everyone else.

With a combination of collaborative and competitive elements, we want to bring the principle of "coopetition" into the world of education in an entertaining way – "edutainment". Making use of the benefits of cooperation and competition to enhance the audience's gaming and learning experience.

E. LEARNING THROUGH EXPERIENCING – LEARNING THROUGH GAMING

Most planetariums are set up to present educational shows. Entertainment and music events are common, but usually aren't in focus. We design our content accordingly. While it would be easier to focus solely on gaming, we try to make educational shows that incorporate interactive elements.

We create shows that are family friendly and are fun for a wide range of ages. They are also designed to work with drastically different visitor numbers. Some planetariums have 30 seats, others have over 300. Our shows try not to set any limit.

For a show or game to be fun for everyone, it must be reward focused [19] It must not punish mistakes too harshly, otherwise it might be frustrating for less savvy players. And while we do include some competitive elements, our focus is on collaboration and team play.

We try to offer a new perspective on scientific topics. The audience is invited to become scientists themselves, actively discovering and curiously learning things. Instead of explaining why fish swim, players get to play the fish, and see for themselves. Instead of explaining why reducing CO_2 emissions is hard, the players have to stop climate change themselves – "… gaming has the potential to support the co-construction of knowledge, as games can provide joint entry points and stimulate discussions and negotiations" [20].

That way, the games also teach learning processes about group dynamics or social behavior [21]. The planetariums can thus enrich scientific content with playful and groupdynamic elements and make their program more attractive for a young, gaming and 3D savvy audience [22].

F. WHAT ELSE IS POSSIBLE?

Other possible event formats could be polls and opinions, experiments in mass psychology and sociology, and live data collection as well as music visualizations and interactive artworks.

The Kinetarium is also conceivable in the field of collaborative serious gaming, that provides functionalities for intuitive management, visualization, and analysis of geospatial, hydrological, and economic data to help stakeholders in the decision-making process, e.g., when preparing for and responding to hydrologic hazards [23].

Great untapped potential of serious gaming certainly also lies in inclusive approaches, for example, promoting IB (inclusive business) [24].

VI. SHOWS AND GAMES

At the moment 10 shows and games on various social and scientific topics are available:

- In Orbit: space debris in earth orbit
- Smart Swarm: swarm intelligence and swarm behavior
- Element Run: characteristics of elements in the periodic table
- Total Turbulence: wind speeds and their effects
- All Against Darwin: the balance in an ecosystem
- Quizgalaxy: multiple-choice quiz
- Soccer: one team vs. another
- Paint the Dome: artistic fulldome graffiti
- Dong: cooperational game keeping a ball in the air
- The Button: a social experiment

Video footage of the shows can be found at our website under www.kinetarium.space/en/shows-games.

A. IN ORBIT – AN INTERACTIVE JOURNEY (42 MINUTES)

The visitors depart on a journey around earth's orbit as shown in Fig. 5.

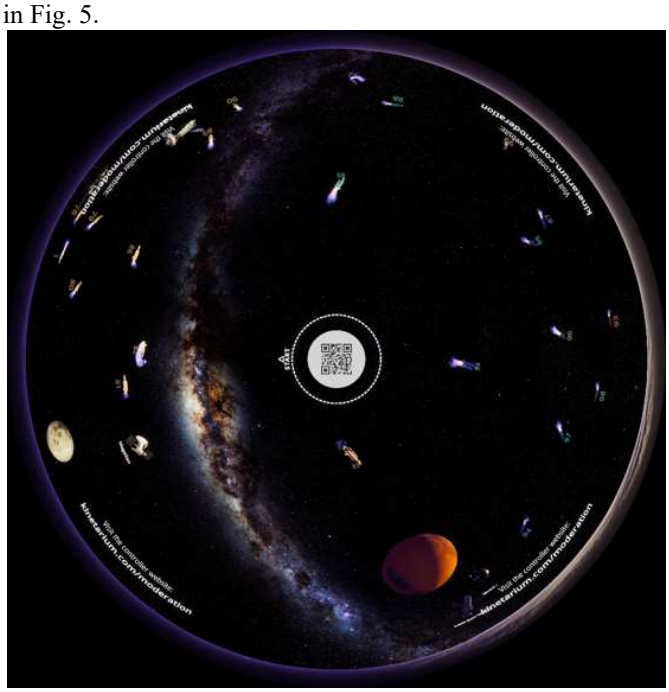

Figure 5. Dome master image of the Kinetarium show "In Orbit", the images need to be very dark to achieve good contrast in the dome

They discover how mankind began to explore space and learn how many everyday applications satellites have today shown in Fig. 6.

Figure 6. "In Orbit" – Satellites in everyday life: Visitors can fly their rockets to the hotspots and learn more about different applications of satellite technology

In interactive and cinematic sequences, they discover what happens to the satellites when they stop working properly. These useless satellites – i.e. defective or technically obsolete ones – are an alarming sight. Over the years, several thousand of these have accumulated, along with fragments or debris from collisions, burned-out rocket stages, empty fuel tanks and other junk left behind during space missions. They form a belt of debris around earth, making space travel increasingly hazardous.

By integrating live data into our projection, the visitors can see how many objects are actually buzzing over our heads at any given time. They can not only witness this as a viewer, but experience it for themselves: the cluttered orbit makes it increasingly difficult to steer their own spaceship and avoid collisions in the process.

B. SMART SWARM – ONLY TEAMWORK HELPS WHEN FACING BIG FISH (VARIABLE DURATION)

In "Smart Swarm", the players turn into a school of fish and learn about the harsh reality of underwater survival, experiencing the importance of collaboration: with the controller each player can control their own fish.

The school is held together by an invisible force, so all players have to cooperate to control the school as a whole. The goal is to eat food, for which you get points. If one fish eats, it counts for the whole school.

After a certain number of points collected, predators appear – sharks (Fig. 7). Survival can only be ensured by coordinating and calling out instructions.

If one fish is eaten by a shark, the whole school dies (Fig. 8). After a countdown, the game starts again. During this countdown, helpful hints are displayed. The highest score achieved is saved as a high score and can be cracked in further events.

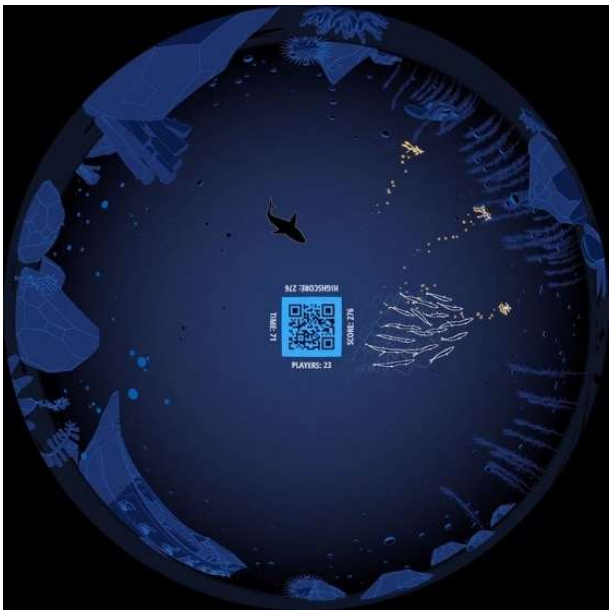

Figure 7. Dome master image of the show "Smart Swarm"

Figure 8. "Smart Swarm" game over screen with the humorous message "You're shark food"

C. ELEMENT RUN – A GAME OF ELEMENTS (VARIABLE DURATION)

There are currently 5 different levels available, each with two pairs of elements and the intro to find into the game. With a single button on the controller, each visitor can switch between these elements (the personal ball). In the levels are various obstacles, including trapdoors, magnets, fire, water, etc. These can only be overcome if you switch to the right element at the right moment, which then, for example, is not magnetic or does not react with water. In the upper part of the dome helpful hints and background knowledge are displayed. The level "Electricity" can be seen in Fig. 9 below.

Figure 9. Dome master image of the show "Element Run" – in the level "Electricity" players have to switch between Copper and Phosphorus

The level of difficulty increases from level to level. In levels four, five and six you have to pay special attention to your fellow players, for example, not to trigger a reaction with them (Fig. 10).

In this way, various physical and chemical properties (some of which are rather unknown) can be discovered in a playful manner: for example, argon as a noble gas that is not flammable. Element Run will soon be expanded with more levels and element pairings.

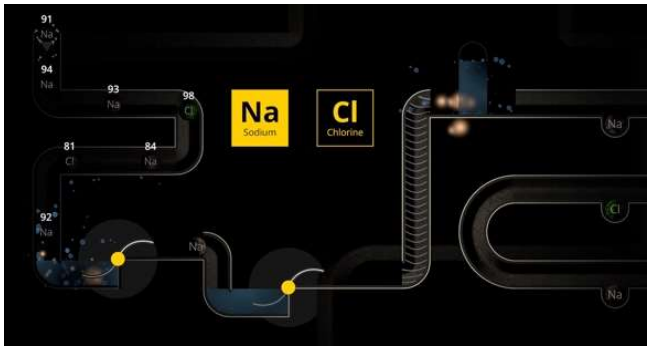

Figure 10. In the level "Table salt" players have to switch between Sodium (Na) and Chlorine (Cl) and have to consider that Na and Cl cause a reaction when they collide

D. TOTAL TURBULENCE – MAKING WIND TOGETHER FOR BEGINNERS (APPROX. 15 MINUTES)

In "Total Turbulence", players are invited to influence the weather by generating wind together. They can generate wind currents that are visualized on the dome. With these, they are challenged to keep kites in balance, bring down buildings, and to get a feeling for wind forces along the way. Generating wind until the coal-fired plants shut down and powering entire cities, shown in Fig. 11 below.

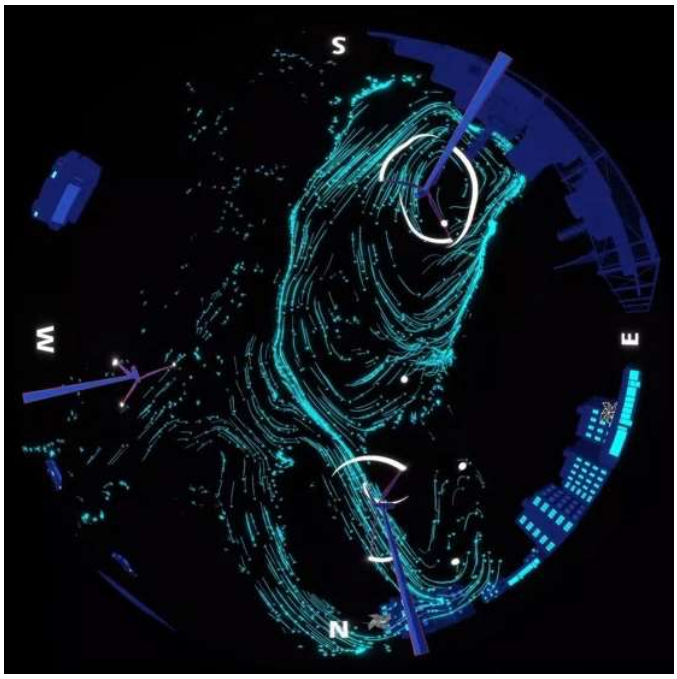

Figure 11. Dome master image of the show "Total Turbulence" with players powering lights in a city skyline through wind energy

The different levels are organized in wind forces according to the beaufort scale. Each level has a different color scheme and scenery (Fig. 12), allowing the players to create unique visualizations. There are also little things to discover and points to collect in each location.

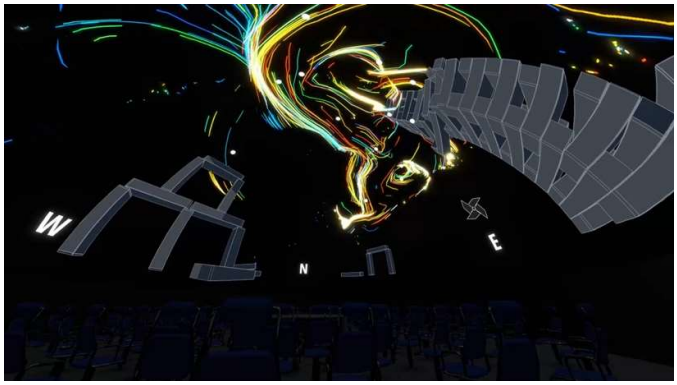

Figure 12. At wind force 12 players are able to bring down entire buildings by creating a hurricane, the scenery has changed, wind currents are visually more harsh and angular

E. ALL AGAINST DARWIN – FEED OR BECOME FOOD (VARIABLE DURATION)

Players start as a small caterpillar and must eat various berries to grow (Fig. 13). The more they eat, the "bigger" the caterpillar grows. It becomes harder to control the long caterpillars and not bump into the other players. If two caterpillars meet, they pupate, but only if they have eaten enough before. After some time, butterflies hatch, the number and size are dependent on how big the caterpillars have become. The player then starts again as a small caterpillar. If the caterpillar has not found food, it cannot pupate and starts again after a short time.

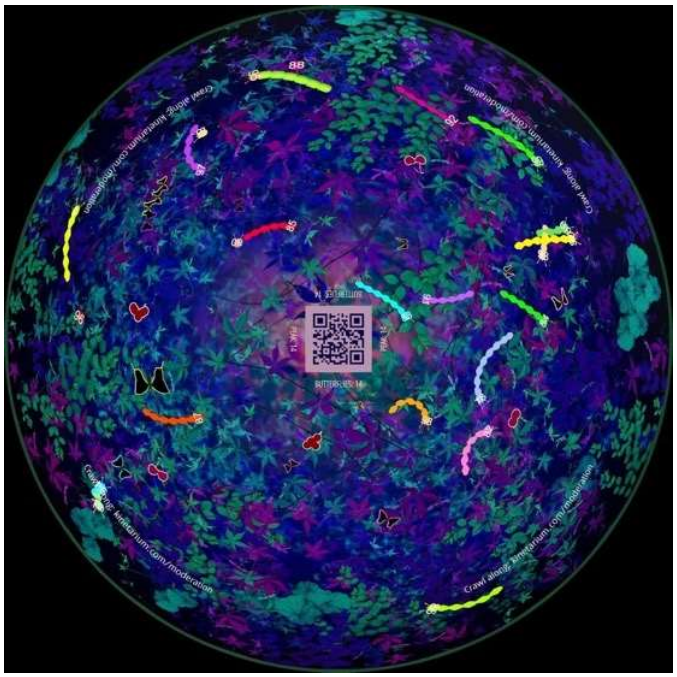

Figure 13. Dome master image of the show "All Against Darwin"

The goal of the group is to create as large a population of butterflies as possible. However, as the population of butterflies increases, predators are attracted (Fig. 14). These specifically try to catch the caterpillars and butterflies. No matter what length the caterpillars have previously reached, they do not become butterflies if caught. Therefore, it can be advantageous for the population as a whole, for each player not to pursue their own goal and become as long as possible, but to pupate intentionally. A playful turn on the game theoretical dilemma: what is best for the individual, is not best for the group.

Figure 14. The predator (a blackbird) is depicted as a dark shadow flying quickly across the dome

F. QUIZGALAXY – SPACE: INFINITE QUESTIONS (VARIABLE DURATION)

The "Quizgalaxy" is a multiplayer multiple-choice quiz that challenges the participants to demonstrate their knowledge on space, i.e.: How many planets are in our solar system? What is a supernova? Who was the first man in space?

The quiz serves as a warm-up for the visitors prior to the show and at the same time allows the host a feel for the audience's prior knowledge. One question and four different answers are displayed, only one of which is correct. After 30 seconds, players must have their answer logged into the controller. After 10 seconds the correct and wrong answers are displayed, as well as a short hint or additional background knowledge about the question. Points are collected per correct answer, a highscore shows the leading player numbers on the dome (Fig. 15).

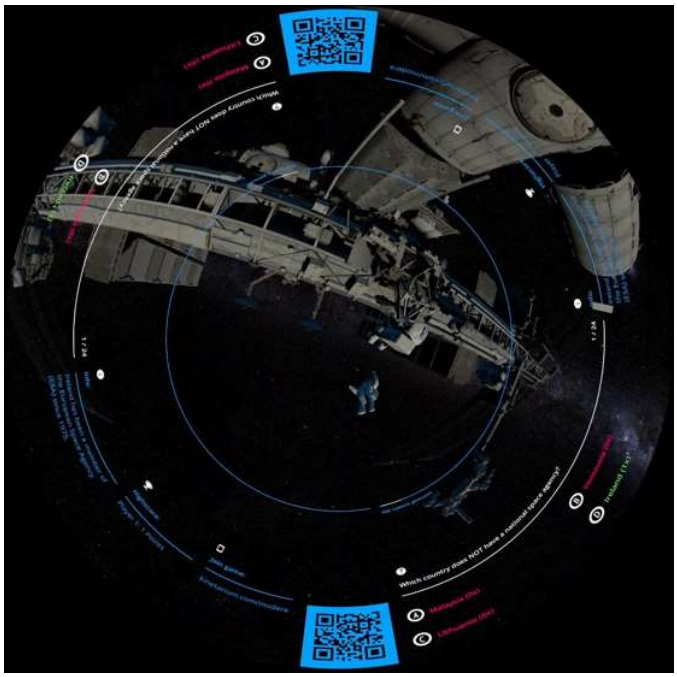

Figure 15. Dome master image of the show "Quizgalaxy"

The quiz can also be customized for any individual topic. Custom questions can be imported (JSON) and individual background graphics (PNG images in the 1:1 "domemaster" ratio) can be stored and used.

VII. RESULTS AND LEARNINGS FROM EVENTS

The purpose of this section is to describe the feedback we have received on previous events. This data should be considered not only qualitatively but also quantitatively.

After a Kinetarium event, the visitors are invited to fill in a feedback form (www.feedback.kinetarium.com). There are six different questions to be answered that allowed answers are on a fixed scale from 1 (not at all) to 4 (very good):

- How did you like the interactive event?
- How quickly were you able to find your avatar on the dome?
- How understandable were the game instructions in the show?
- How well did you get along with the controller on your smartphone?
- How understandable were the game instructions for the controller on your smartphone?
- Would you recommend the interactive event?

In addition we had predefined answer options (multiple choice) and complete user-defined text fields. The visitors had the possibility to skip certain questions. The data was collected at 15 different events since a prototype screening in 2018 until 2021 and is shown in Fig. 16. A total of 457 people completed and returned the questionnaire.

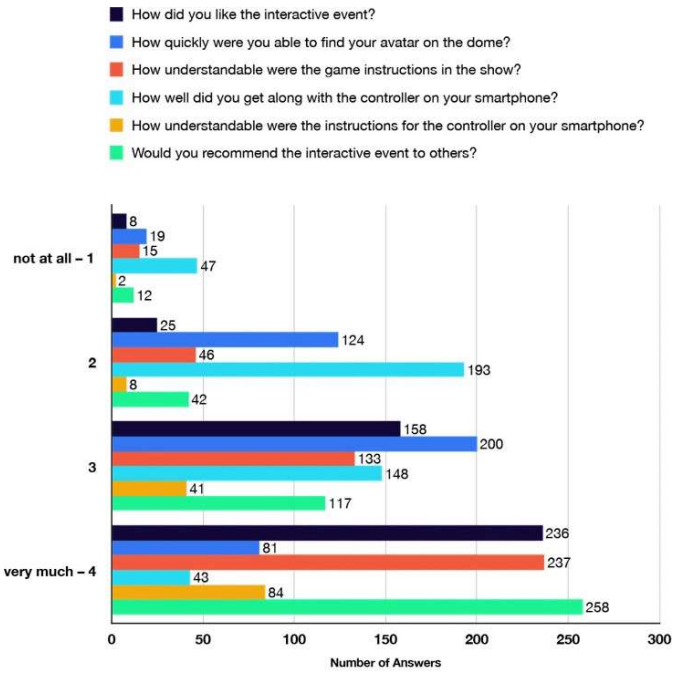

Figure 16. Feedback for the 6 different questions (in total numbers per answer)

A. INTEREST

Regarding the evaluation, it can be said that the general interest of visitors in interactive content is high. 52% of all respondents said that they liked the event very much (4 on the scale) and 56% recommended it very highly. 35 % liked the event and 26% would recommend it (3 on the scale). We could observe on site that especially after a learning phase of about 20 minutes, many visitors were gripped by ambition. In our events with an earlier prototype, however, some found the information content too low. The key here is to find the right balance for each audience. Since the interactive phases of the event take up quite a bit of time, the informative, didactic phases quickly come up short.

B. CONTROLS

Getting along with the three-dimensionality of the controls still seems to be difficult. The two-dimensional control that the joystick offers is very limited in the three-dimensional space that the dome projection represents. Here, 42% of viewers said they couldn't get along well with the controls (2 on the scale) and 10% not well at all. In the same context, a total of 31% of the players said they could not find their avatar quickly at the dome or not quickly at all (1 and 2 on the scale). According to our observations during the shows, we noticed that especially the younger visitors would usually find their way around the dome very quickly. A few visitors had difficulties with the connection or the controls. But after a short period of getting used to the system, almost all visitors were able to play along.

VIII. CHALLENGES

A. SHOWS AND GAMES

We try to strike a balance between gaming and education. The correct mix for each event can differ drastically, depending on the venue's philosophy or the current audience. Planetarium visitors have drastically different expectations, education and experiences. Most likely, Kinetarium needs to offer a broad spectrum of events.

Cooperation is at the heart of what Kinetarium is. To enable hundreds of people to cooperate is a game design challenge that we will keep exploring. These mechanics need to work for small groups, just as well as for large ones.

B. REPLAYABILITY

Video game players are already familiar with many of the concepts of the Kinetarium, so controls and game principles hardly need to be explained. However, one major motivating factor is missing: that of personal progress. Each individual player improves within an event, but can take little of it home in the long run. The only thing left to do is to visit another event, which may be weeks in the future or may not happen at all.

So far, Kinetarium has been designed and developed as a local application for several hundred players under a common dome; a logical next step is the networking of several domes worldwide.

C. INTERACTION

Kinetarium games should be as accessible as possible. We need to make sure everyone can quickly pick up on how to open the controller website and how to use it. This will always be a priority.

Another game design challenge is that of each individual player's impact: for any game to be fun, every player needs to have the feeling that their decisions matter. To promote cooperation however, collective decisions must cancel out individual ones. This also applies to graphics: every player needs to see some kind of impact, but the collective actions are the ones that need to be highlighted.

D. TECHNICAL CHALLENGES

Planetariums are organized in very diverse ways: as museums, as private companies, as educational institutions, as non-profit organizations. This results in very different financial possibilities and requirements on the show program.

An interactive planetarium program should always have the lowest possible technical and operational requirements so that it can function in most planetariums. Usability of the system must be simple enough that it can be performed by anyone without training.

When preparing Kinetarium for a global market, we have to consider controller input latency. To keep latency within a reasonable range, multiple web servers will have to be set up around the globe.

E. COMMUNICATION FOR A NEW TYPE OF EVENT

We discovered that it is difficult to promote this new event format. There are several challenges here: on the one hand, potential visitors need to understand what they can do in an event in the first place. A classic movie poster, for example, works by showing the content as the topic of the poster. People don't need an explanation on how a movie theater works.

Since planning the first event, several forms of media have been used to promote Kinetarium events and introduce the project. We have a dedicated subpage on the planetarium's Stuttgart website, and the events can also be found in the printed program booklet including a short description. In the city of Stuttgart, we were also able to advertise some events

with various posters. Social media channels have been maintained on Instagram, Twitter and Facebook. Various postings give an overview of what the Kinetarium is and how the interaction works. Video footage of events and illustrations are primarily used for this purpose. In addition, photos and videos taken while testing in the dome show a behind-the-scenes look.

In our feedback form mentioned earlier we tried to evaluate how visitors became aware of the event as shown in Fig. 17. Online advertising and classic advertising with posters and booklets seem to have had a similar impact. This can be attributed to the diverse age and media consumption habits of planetarium visitors.

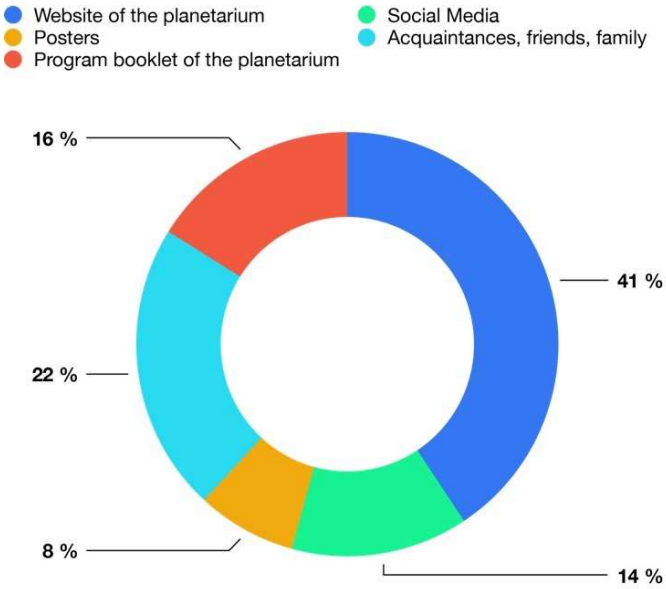

Figure 17. How visitors became aware of a Kinetarium event (in percentage)

IX. VISIONS AND PERSPECTIVES

Once these challenges are solved, a wide range of possible applications opens up, e.g. league games within a worldwide community, Escape Room applications, etc. The development of globally functioning interaction principles can in turn generate novel game ideas and application scenarios.

Another consideration for the further development of Kinetarium concerns the use of a streaming service e.g. Google or Amazon. Instead of a downloadable Kinetarium client that runs locally, the fulldome image could be rendered in the cloud and streamed to the venue. Providing the image for the dome projection via streaming would bring a few significant advantages: even less setup required by the venue, virtually no hardware requirements, and the ability to expand and update the content offering at any time.

The widespread use of high-performance smartphones with mobile internet connection enables visitors to interact easily and spontaneously via a familiar device. Availability of the mobile internet at even higher transmission rates enables live interactions without latency, which will get significantly better with the 5G standard. Another possibility to further increase the use cases of our technology, is to offer Kinetarium for non dome-shaped projections (Fig. 18). Anywhere there is an audience and a projection, Kinetarium can offer spontaneous and engaging interaction to everyone in the room.

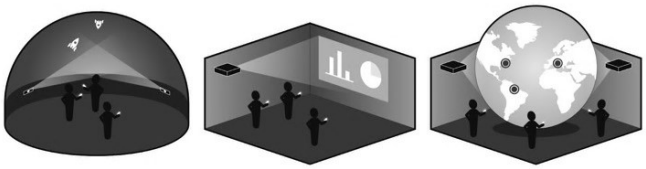

Figure 18. Dome, wall, sphere – possible projections surfaces for the Kinetarium

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Our show “In Orbit” was developed in close collaboration with the Planetarium Stuttgart as well as the German Aerospace Center Stuttgart (DLR).

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The Show “In Orbit – an interactive journey” has been awarded with the SILBERSALZ Science & Media Award in the category IMMERSIVE SCIENCE and the Horsetooth International Film Festival Award in the category Another Dimension.

Kinetarium is a registered brand of halbautomaten Kommunikationsdesign GmbH, Silberburgstraße 183, 70178 Stuttgart.

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