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How Today's Technologies Can Recreate and Help Experience the Ancient Knowledge Repositories: A Case Study Research

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Abstract:

Indian Knowledge Systems (IKS) are timeless as evidenced by each of us, the living descendants of this multi-millennia civilizational ethos. Some of the nuggets of knowledge from millennia ago still guide us in our day-to-day activities or even with our health and wealth management techniques. The knowledge is both deep and vast and as cliched as it may sound, multi-dimensional in its construct. One of the dimensions has to do with the unique body of knowledge with regards to our tangible heritage – temples and monuments. This paper focuses on aligning modern technologies to document and retell the grandeur of those ancient knowledge repositories. We look at emerging technologies like 3D Scanning, VR, AR, 3D Printing to reconstruct our glorious past and retell the History the way it happened (*Itihaasa*). It also provides a critical view of the need for policy building so as to ensure the technology and associated storytelling is beneficial to everyone.

Keywords: Virtual Reality (VR), Augmented Reality (AR), Ancient Monuments, Archaeoacoustics, HeriTech

INTRODUCTION

(For the benefit of the readers, definitions of key terms have been provided at the end of the paper)

Temples are not only marvels of art and architecture but also the embodiments of ancient technologies and a window into our ancestors' ways of working, their tools and their skills. The modern world is yet to understand and appreciate in its entirety the magnificence of these wonders and the depth of knowledge manifested through them. This paper looks at leveraging modern technologies to recreate and experience these ancient knowledge respositories, tools and techniques. Imagine visiting a temple in Virtual Reality (VR) or Augmented Reality (AR), replete with multi-sensory technologies like haptics, olfactory and gustatory devices. This could be leveraged for tourism-discovery on various portals (VR, AR and Web) thereby enhancing

the global marketing of our ancient wonders and reclaiming the *Vishwaguru* title, as well as amplifying tourism revenues for our country. As a part of recreating the temples, there is a need to leverage technologies like 3D Scanning and 3D Modeling. These, in turn, help in preservation of our temples for posterity, storing information of entire temple complexes. Using 3D scanners like FARO Focus Premium 70, a resolution of 0.1mm can be achieved, making the documentation of intricate details of the monument possible. In the event of any damage or destruction, the area can be referred to, in the 3D model, and restored to its erstwhile glory.

Owing to a millennium of invasions in India, a lot of ancient knowledge has been lost. This should serve as a warning to help safeguard and preserve whatever sources of ancient knowledge we have today. Authentic sources pertaining to ancient temple architecture and associated sciences are far and few and for some temples, extinct. Given this situation, it is imperative on us to leverage today's ground-breaking technologies like VR, AR, AI, Blockchain and Quantum Computing to recreate the authentic past in terms of monuments, culture, jewelry, costumes etc. This paper would focus on VR and AR usage in bringing back the monuments to life and touch upon the usability of AI and Blockchain in this endeavour.

Our paper will focus on Temple Architecture, Engineering & Sciences and the role of modern technology in preserving the knowledge for posterity. We will also focus on a couple of challenges viz. Adoption of Technology, the role of Subject Matter Experts and *Sthapathis*.

SCOPE

Renowned *Vishwakarmā* K.P. Umapathy Acharya states that "it is more important to study the spirit of the ancients through their temple architecture and *Vedic* studies than to analyse their '*means of construction'*. Indian architecture will never be a mere construction, it is an inspiration, prophecy and revelation of spirit."[1] Every aspect of temple construction has deep significance and spirituality.

With today's immersive and emergent technologies, it is possible to recreate the entire space in 3D, step by step, thereby recreating the temple architecture and engineering. To add to it, we can enable everyone to experience temples as they used to be in the past, in all its glory. This includes the sights and sounds, costumes, jewelry and the day-to-day happenings in and around temple premises. We must remember that temples were not merely places of worship but were lively cultural centres.

Our endeavour, through this paper, would be to understand "Ancient Temple Architecture and Engineering Design" and "Ancient Sciences" as employed by our ancestors during the development of these magnificent structures. We are also going to focus on how "Modern Technologies can Recreate the Past".

Ancient Temple Architecture and Engineering Design

Āgamashāstra and *Sthāpathyaveda* have within them every aspect of temple design and construction. For example, they include the science behind designating a certain location within a site to host the outer walls of the temple or to select the cardinal directions of a site based on day-dusk shadows[2]. Such depth of knowledge had been transferred from generation to generation and has lasted for millennia. However, this knowledge is at risk of being lost to modern, lucrative professions owing to decline in traditional roles and practices like *Sthāpatya*, *Vishwakarmā* etc. Hence, there is an urgent need to store all aspects of this ancient knowledge, meticulously and authentically. In this paper we are exploring how we can embrace modern technologies to achieve the same.

E-learning modules related to *Āgamashāstra* and *Sthāpathyaveda* with Augmented Reality technology can really transform the teaching paradigm for these ancient sciences. India is the largest consumer of Mobile devices like phones and tablets, across rural and urban India. This makes it a viable medium for us to teach these ancient sciences to a wider audience, either as single-player modules or multi-player modules. The rules of *Āgamashāstra* and *Sthāpathyaveda* can be gamified and looked at, in terms of codified rules within the software, allowing or disallowing certain constructs within the temple construction. This would help the student learn quickly and visually the dos and don'ts of the ancient sciences through an immersive visual media.

Ancient Sciences

There is a need for scientific research into various aspects of Indic Heritage like astrology, astronomy, neurosciences, music etc. When these researches are showcased as visual and aural experiences, it is bound to evince interest in young minds to take to research and contribute to our heritage.

Today's documentaries and short videos or memes have the potential to instil a sense of pride in our ancestors' knowledge but they do not help in its retention in the consumer's memory for application in future. As an example, alignment of the Nataraja Temple at Chidambaram with the Orion Constellation during the *Ardra* festival (*Ardra Nakshatra* is the Betelgeuse of the Orion) establishes the connection between temple architecture and ancient astronomy as well as astrology[3]. It also highlights our ancients' observations of star movements to create detailed star maps which were utilized in various aspects of life like agriculture, besides temple construction.

The date of every festival is determined by the *panchāng* which requires sophisticated knowledge of ancient astrology and astronomy. This is but one aspect of our ancient knowledge that needs to be brought out leveraging modern visual technologies for powerful and retentive education and storytelling. Many other aspects like *Vedapātha* and their impact on human brain needs to be deeply researched by neuroscientists and become a part of the overall immersive experiences. Neuroscientist James Hartzell researched about this very concept and termed it "The Sanskrit Effect"[4].

Modern Technologies can Recreate the Past

Visual Technologies like VR, AR, 3D Scanning, 3D Printing and AI have greatly developed over the last two decades. We have come a long way since the advent of VR in the 90s (and the eventual winter it underwent) and the subsequent collapse of 3D Virtual worlds in late 90s owing to a lack of hardware processing power and bandwidth. Today's high-power GPU (Graphic Processing Units) machines have the power to render the most detailed, high-resolution imagery and videography, either on-premise or on the cloud. This forms a fundamental infrastructure enablement for the realization of 3D visual technologies.

Software engines, leveraging the GPU throughput, can render a photo-realistic scene replete with scenery, shadow, time-of-day simulation, terrain and buildings with unprecedented accuracy. 3D Scanning technology allows documentation of an object or a monument to an accuracy of 0.1mm with texture maps of the monument. Texture maps are digital images of the texture of the monument in various lighting conditions and at different points of the monument. It helps in building a photo-realistic monument in the software engine. The scan data can also include the nearby trees or stones/rocks thereby ensuring data collection of the flora and the environment to recreate an authentic environment in the virtual world. If the structure is broken, there is a possibility to recreate it with the use of this data along with associated ancient documents and manuscripts about temple architecture.

CHALLENGES

Adoption of Technology

This has two aspects, namely, with temple authorities and with consumers at large. In modern times, technology is perceived as a double-edged sword in society owing to the perceived notion that the cons outweigh the pros. Consider the usage of social media. Greater social media usage is associated with poor sleep and poor mental health in adolescents[5]. In terms of heritage, the perception of technology is quite similar.

It is observed that modern devices especially cameras, scanners and virtual reality headsets are not welcomed in traditional temple complexes for various reasons including damage to structures through irresponsible usage. There is a need to sensitize the technology teams to be socially responsible and work with noble intent and mindset at heritage sites so as to maximise the benefits for the temple authorities. There is also a need to sensitize the temple authorities about the tangible benefits of technology and how it could help their future generations.

Adoption of VR and AR technology in consumers is a challenge owing to the nature of the devices as well as pricing. While mobile phones are ubiquitous and therefore they help with proliferation of AR, VR requires head-mounted devices (HMDs) which are not preferred by many. There is a need to increase adoption of such technology with experiences that are more Indic, closer to our hearts and of value to youngsters and elders alike. For example, elders who

may not be in a position to physically travel to these temples can experience them through VR HMDs and receive a near-real experience.

Sthapathi

The knowledge of temple architecture and engineering is limited to very few families in India. It has been observed that a lot of people claim to be *sthapathi* but have no backing from the scriptures mentioned above. This has led to a proliferation of fake temple architects further diluting the sacred spaces in this sacred land. There is a need to create more *sthapathis* in the true sense so that such a treasure-trove of knowledge is not lost or diluted. This paper provides steps and recommendations for the same, thereby augmenting traditional skillsets in younger generation and generating jobs. There is a need to help today's *sthapathis* teach the younger generation in the medium that's attractive to the latter in order to increase memory retention thereby creating the next generation *sthapathis*.

Multi-Dimensional Team of Experts

There are multiple layers to our heritage – history, architecture, art, metaphysics, sound, energy, among others. There are 64 *kalā* and 40 *vidyā* mentioned in our *shāstra*. Therefore, there is a need to create a team of subject matter experts and approach this spiritual, sacred space with a scientific approach and deep knowledge. The paper proposes a plan for the same in terms of people and manpower which could also be codified into immersive course-materials.

METHODOLOGY

For every site, there are two stages of development to realise the multi-sensory, immersive experience – (1) Research Cycle and (2) Design & Development.

Since our heritage, history and culture are multi-dimensional, the retelling of our history warrants a methodology that undertakes multi-dimensional research, covering all aspects of the heritage site.

This approach will enable everyone to absorb it in a relatable manner. Design & Development focuses on the technology-enabled implementation of the outcomes of the research cycle in the form of a VR/AR temple tours, replete with infographics, animation, video and audio along with cinematics.

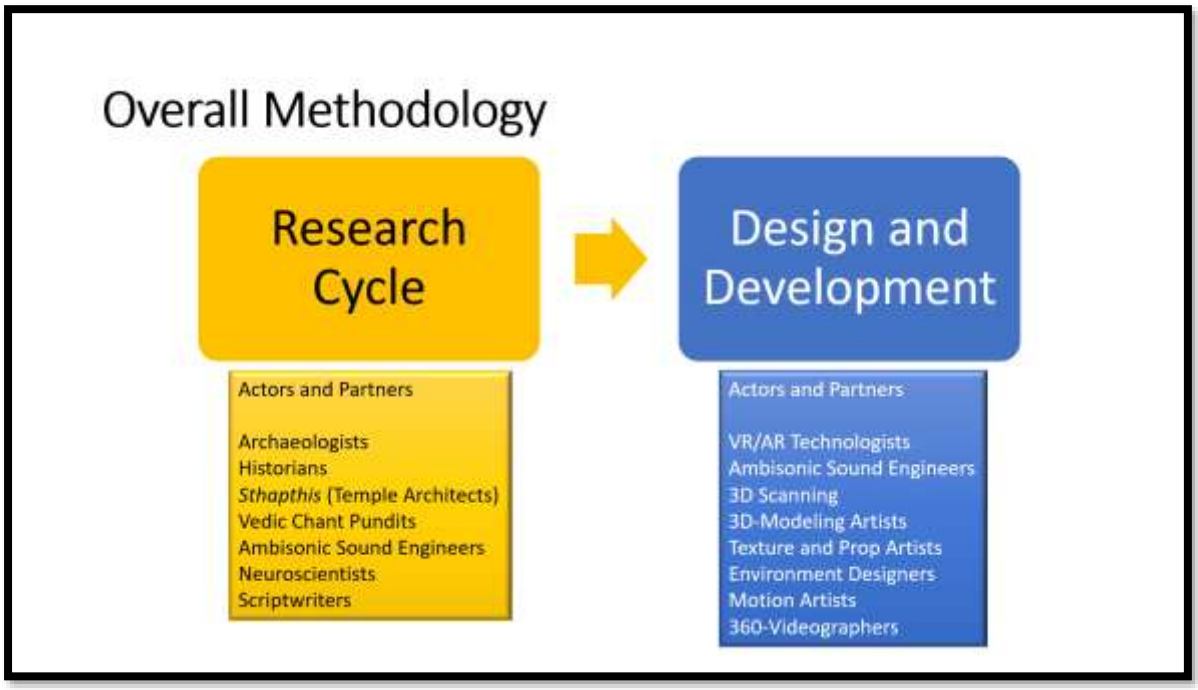

Figure 1: Overall Methodology of Execution

RESEARCH CYCLE

We perform a research cycle with the help of a multi-dimensional team comprising of Historians, *Sthapathis*, Film-makers, Ambisonic Sound Engineers, Neuroscientists and Vedic Chant-healers to initiate our work. This phase ensures tangible outcomes of multi-dimensional approach in terms of assets, infographics as well as a holistic, cohesive approach towards experiencing the site and its history.

Sthapathis quote from *shāstra* and provide revealing information nuggets regarding architectural specifics like pillars' dimensions and motifs' significance, the science behind the deity consecration, the temple's height in relation to the main sponsor's height and many such revelations for our scripting team to include into the overall script.

Other teams during research cycle include Vedic Chant Pundits and Ambisonic Sound Engineers. The Pundits select certain nodal points of the temple for their chanting regime. The chants include the ones dedicated to the main deity of the temple as well as deities that adorn the temples. The recorded sounds are utilized for neuro-research activities to assess the effects of chants on the listener's brain.

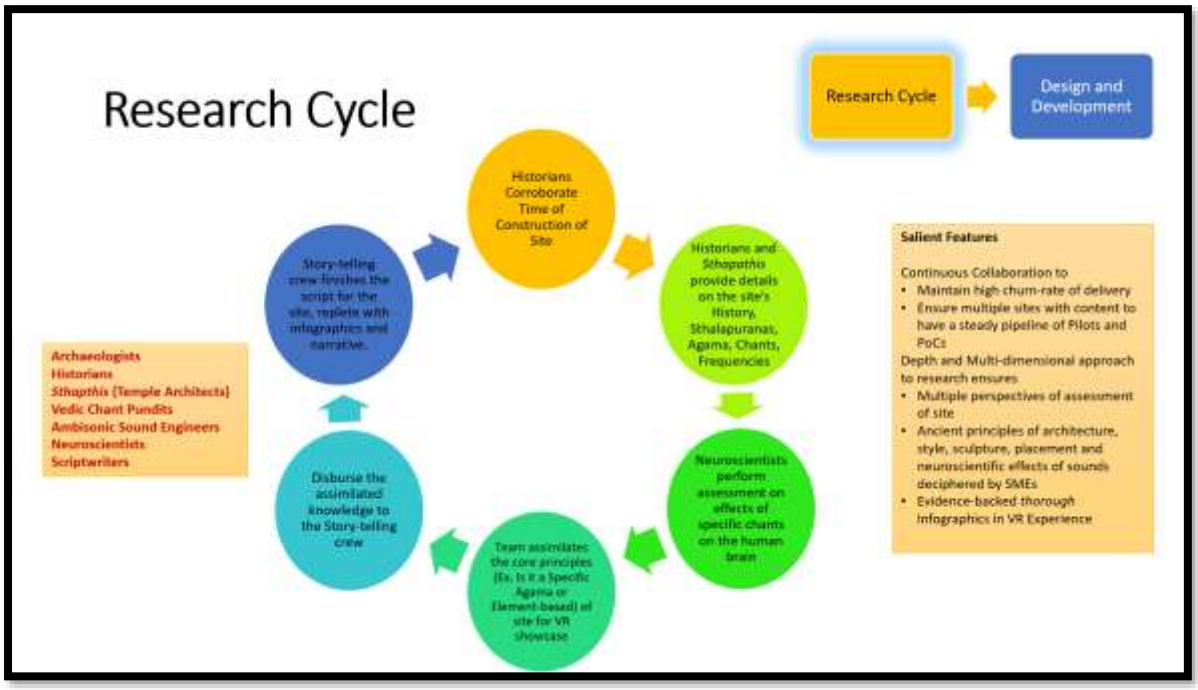

Figure 2: Research Cycle Explained

Figure 3: Vedic Chanting Recorded at Temple

Figure 4: Ambisonic Recording at Brihadeeswara Temple, Thanjavur, Tamil Nadu

Ambisonic sound engineers, using the audio recorder, move around the temple premises to pick areas of particular aural resonance and measure impulse response (IR) at that position. They repeat this process across various nodal points of the temple. Once the details are captured, a map is created with these nodal points marked, for the design & development teams to embed the soundscape at the right points in VR and AR experiences. Sound engineers undergo a training regime on how to extract ambisonics sound and integrate that with the software platform prior to becoming a part of the research team. This output is also helpful in research on archaeoacoustics, the science of sound in heritage monuments.

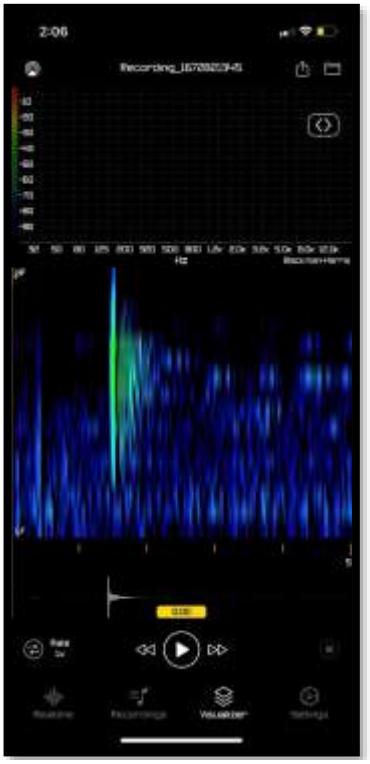

Figure 5: Impulse Response as recorded at Brihadeeswara Temple, Thanjavur, Tamil Nadu

DESIGN & DEVELOPMENT

With the research cycle completed and relevant data gathered, we embark on the design and development of the heritage site as it appears today as well as how it looked in the past. In so far as the latter is concerned, as per Sundstedt et al. (2004), the key practical considerations[5], when undertaking a reconstruction of a heritage site using immersive technology, with a view to investigating how it may have appeared in the past, are

- ✓ Constructing an accurate geometric model
- ✓ Providing detailed surface materials and textures
- ✓ Determining the spectral properties of the ancient lighting materials
- ✓ Creating a light model for flame
- ✓ Rendering the model with physically correct lighting

Latest technologies like LIDAR 3D Scanning capture a site's point-cloud data up to 0.1mm resolution, thereby providing precious data about the site's geometry, both indoor and outdoor. The scanner also stores the data pertaining to the materials of flooring, wall, pillars etc. which helps reconstructing the temple in various visual software engines.

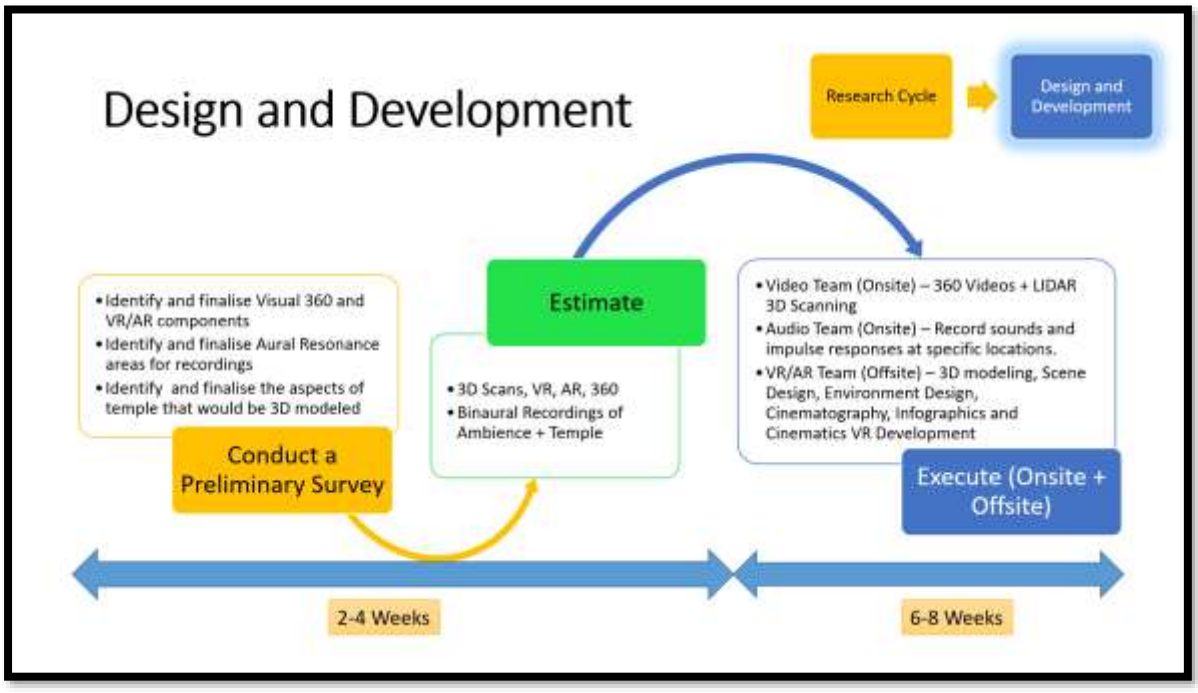

Figure 6: Overview of Design & Development

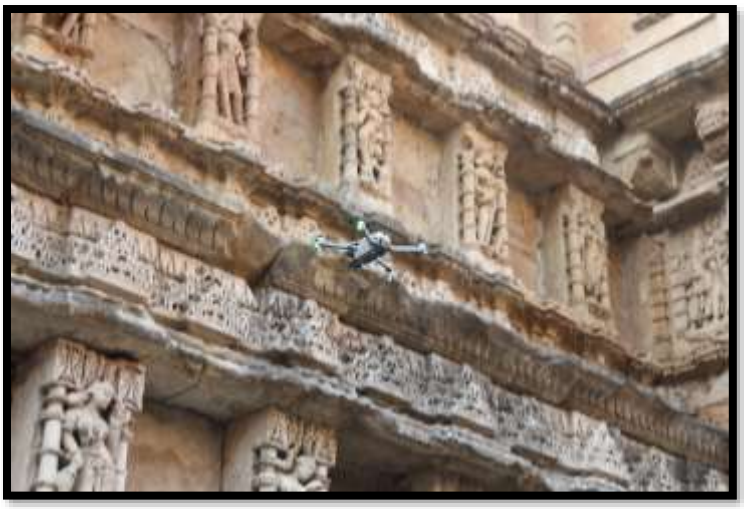

Figure 7: Drone preparing for 3D Scan

(1) 3D Scanning: LIDAR Scanners are mounted on drones capable of carrying higher payloads. This enables aerial scans to capture the surrounding environmental details for posterity. Hand-held scanners are used on ground to capture intricate details of sculptures, pillars etc. in addition to the aerial scan details.

(2) 3D Modeling: The resultant point-cloud and textures are imported into various software like Blender, ZBrush, Unreal and Unity Engine to create accurate 3D models of the entire site

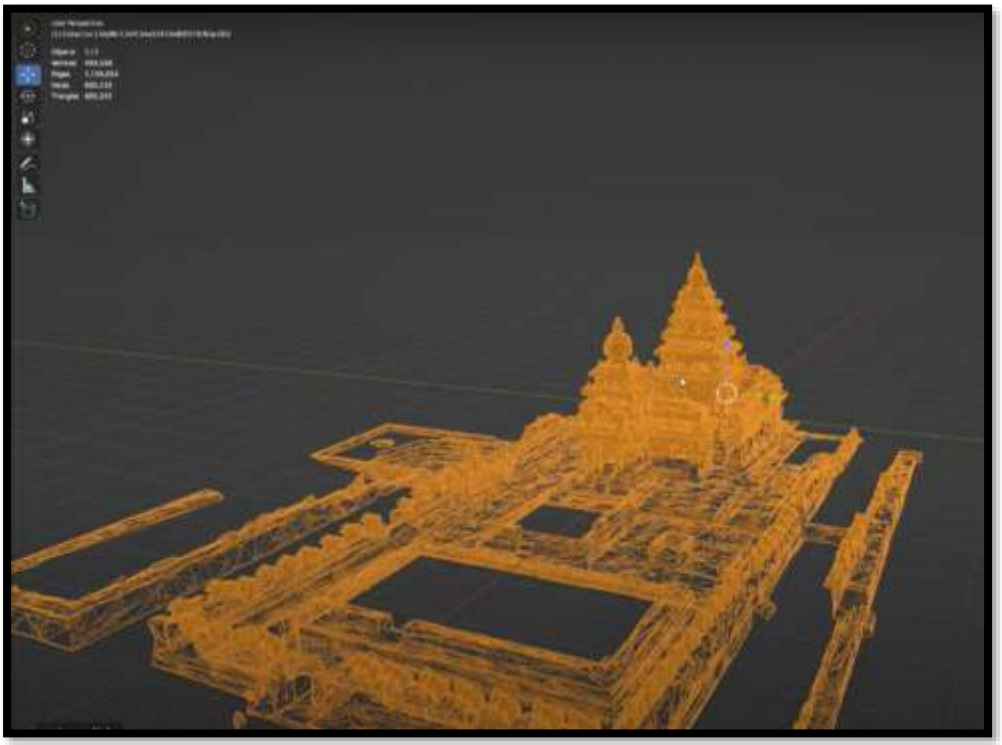

Figure 8: Point-Cloud and Mesh of Temple

Thereafter, the model is tested against various lighting conditions to ensure there is no inconsistency in the collection of data in terms of holes or gaps.

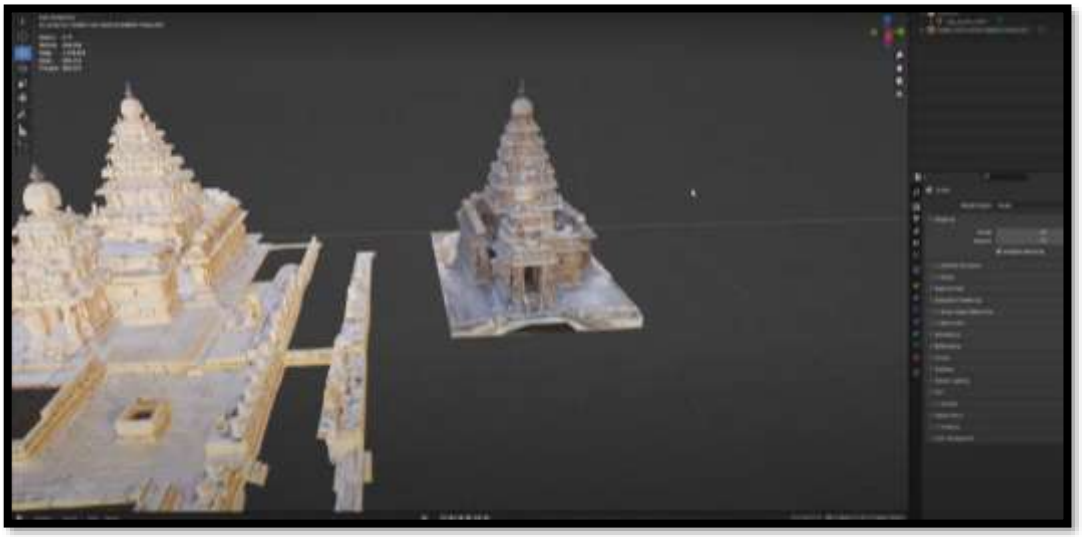

Figure 9: 3D Model in various lighting conditions

(3) Scene and Environment Design: The next step is to replicate the surrounding environment as in reality. This includes buildings, roads and other infrastructure. It also includes the flora at the location and creating 3D models of the tree species.

Figure 10: 3D Modeling of Local Flora

The terrain is created based on the point-cloud. It includes depth perception as well as gradient in the environment. The software also ensures lighting constructs follow the laws of physics and provide the optimal shadows. The same can be programmed as well, requiring advanced knowledge of behaviour of light.

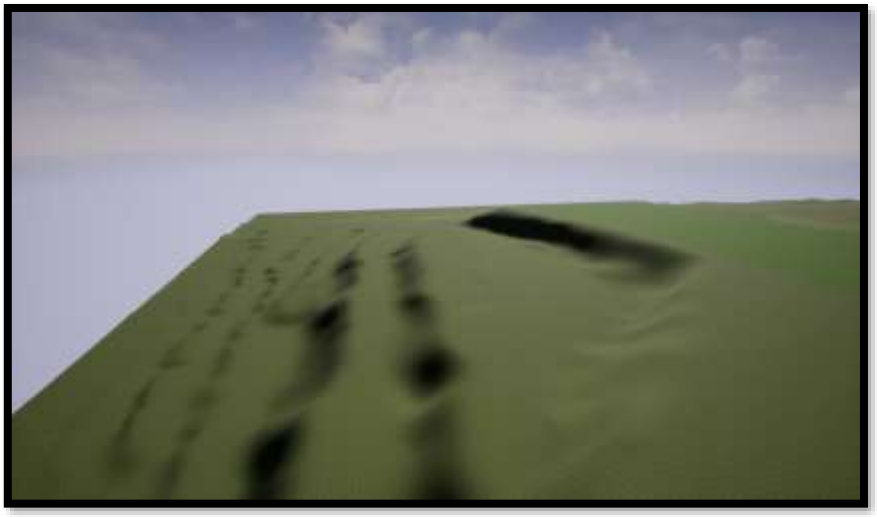

Figure 11: 3D Terrain Topology

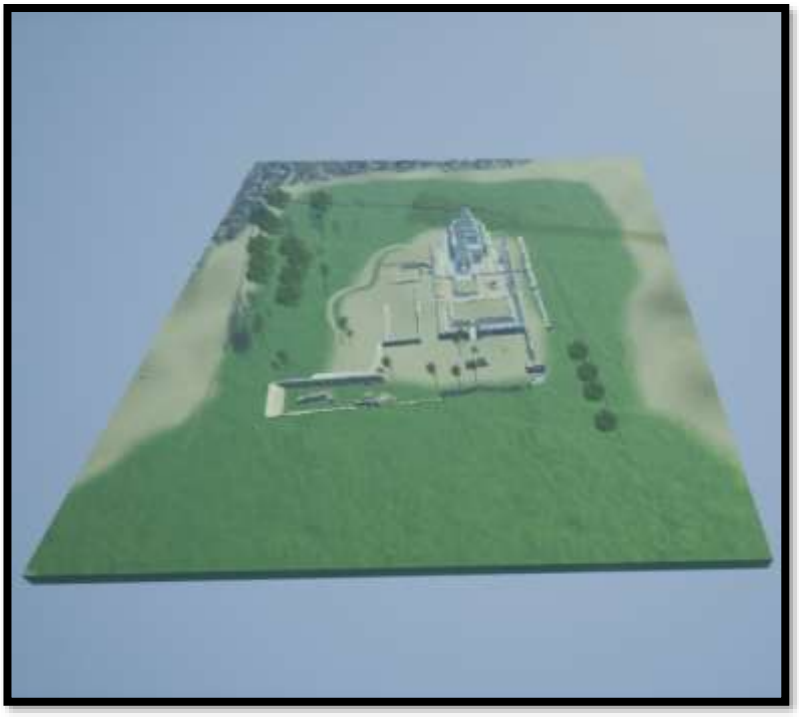

Figure 12: Final 3D Model of the Temple and the Environment

(4) VR/AR Development: Once the model is ready and workable on the software, we proceed to create the entire experience in terms of User Interface, User Experience, Icon Design, Colour Scheme, Fonts, Infographic Texts, Cinematic Videos with Audio Narrative which would require cinematography and syncing as well. Software package is designed for particular Head-

Mounted Devices (HMDs) in case of Virtual Reality and on target mobile devices in case of Augmented Reality. The development process is iterative where every asset is integrated into the VR/AR software and checked for FPS and other metrics to ensure optimal performance under all conditions. Interactive Design elements are iterated for best visual design and performance. This is a critical phase of the development as the hard work and attention to detail undertaken in earlier phases comes to life in this phase. This is pretty much the way people will experience the temples in VR/AR. Ambisonic Recording undertaken in the initial phase is plugged into VR development and additional programming carried out for the most natural ambisonics sound experience.

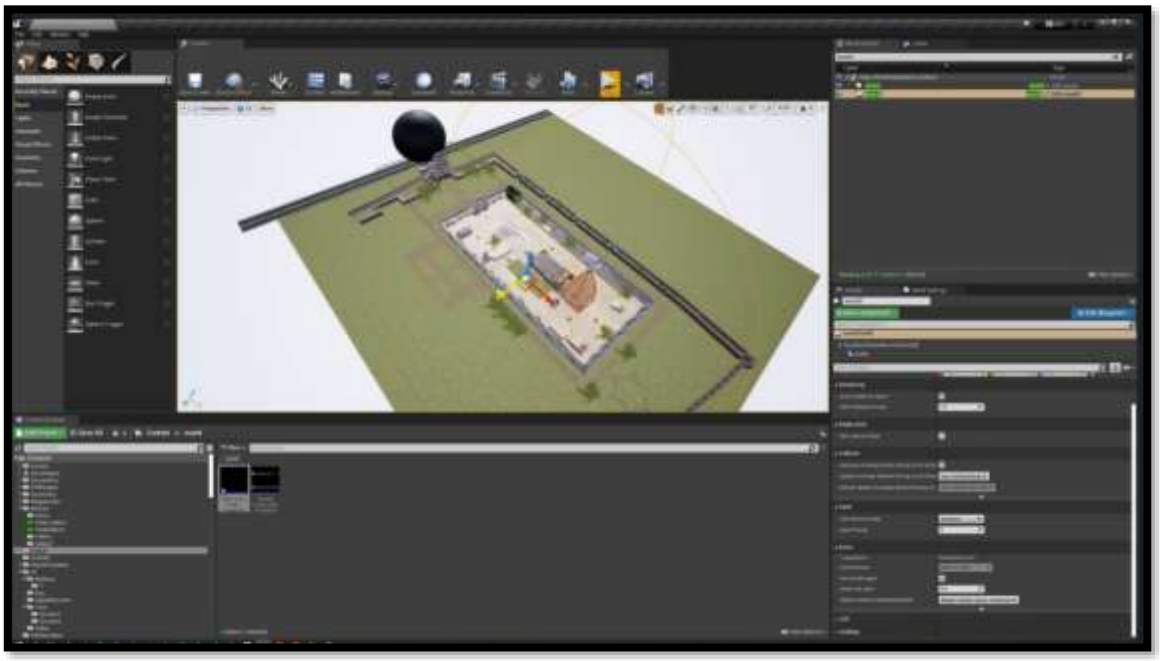

Figure 13: 1Ambisonic Sound Design in Software Engine

The black ball at the entrance of the temple complex is considered the sound source. The projections with various elevations from this source denote the angular displacement of the sound with respect to the movement of the actor across the temple complex. This is an iterative process to obtain the optimal and cohesive directional sound reproduction within the engine. Intricate sound design for every corner of the temple would involve intricate programming and projections to provide that near-real experience.

Graphic elements like buttons, fonts, colours constitute user interface. They are an important aspect of the overall interaction design and need to be created keeping in mind aesthetics and functionality. Here's an evolution of the floor icon for a teleporting experience.

Figure 14: Evolution of Icon Element

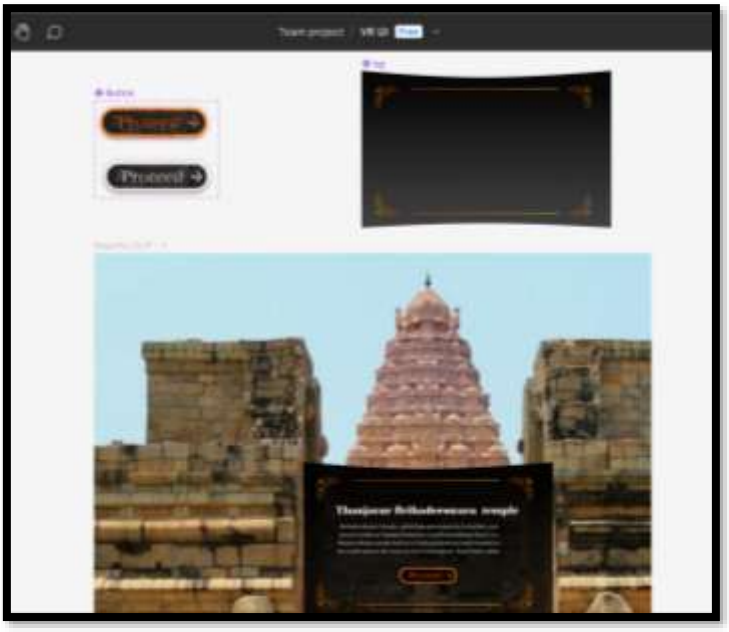

Figure 15: Buttons and other UI Elements

Once the interaction design and user interface elements are frozen, we get into realizing the storyline that was handed over by the scriptwriting team during the research cycle. A visual storyboard or mood board is created that highlights navigation, the areas of focus during navigation and placement of videos within the entire navigation to ensure the resulting VR/AR experience is smooth and with all the research information plugged-in.

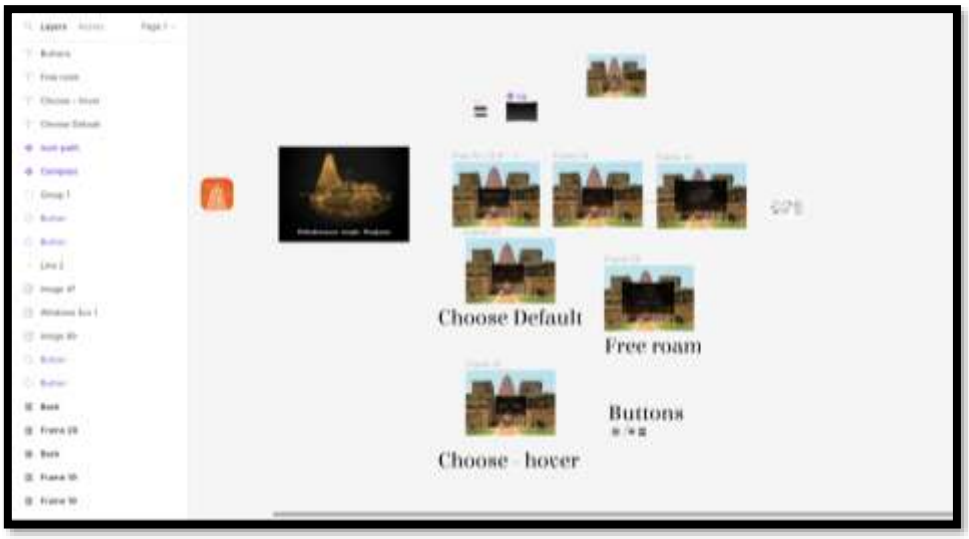

Figure 16: Converting Script into Storyboard

The storyboard is provided to the development team for the actual software development to replicate the storyboard and the graphical experience elements. All infographics, texts, videos, voice-overs for narrative are executed in parallel to the software development.

The final phase involves testing the software and eventual packaging on target devices like HMDs (VR) and Mobile devices (AR). This is an iterative process and involves rigorous defect detection, tracking, testing and closure. Defects are categorised according to the area of impact – visual design, UI elements behaviour, controllers-related, movement-related, performance-related etc. Usually, in software testing, the UI related defects are categorized as cosmetic and low-priority for fixing. In our case, no such classification exists as the entire experience is primarily visual.

Testing on multiple devices removes any ambiguity in the package behaviour and ensures uniform experience for users irrespective of their devices. Multiple device-based testing also ensures consistency in colour perception and model renders and behaviours.

Once the software is tested and found stable, we commence packaging on iOS, android or on HMDs with necessary firmware updates, software patch updates etc. A final round of sanity testing is performed to ensure all flows work as expected and is now ready for release to the user.

ANALYSIS

Following the methodology described above, we created a prototype VR experience about the Nandi Monolith at Lepakshi, Andhra Pradesh. The experience was accompanied with sound and infographics on the history of the location (Ananthapur district) and how today's dry and arid region was once a thick forest with numerous water bodies. We also covered the significance of Nandi via narrative and infographics. We created 2 versions of the prototype – one with infographics, narrative and sound and another one without any of these elements – a pure visual experience.

Figure 17: Prototype VR Experience of Nandi at Lepakshi
(https://www.youtube.com/embed/_ET3Bl5CuZo)

We built full-fledged experiences of four sites – Shore Temple at Mahabalipuram (AR), Brihadeeswara Temple at Thanjavur (VR), Rani ki vav at Patan (AR) and Harminder Sahib (Golden Temple) at Amritsar (VR). Every aspect of the methodology including research cycle and design & development was followed during the making of these experiences. The Trailers associated with these experiences are being shared here to get a glimpse of the actual VR and AR experiences.

Figure 18: Video Trailer for the Shore Temple Experience Released during G20 in 2023. It shows 3D Rendered temple with waves animation. The final experience is in AR with large 3D printed model of the monument

(https://www.youtube.com/embed/6zagVIFOQMA)

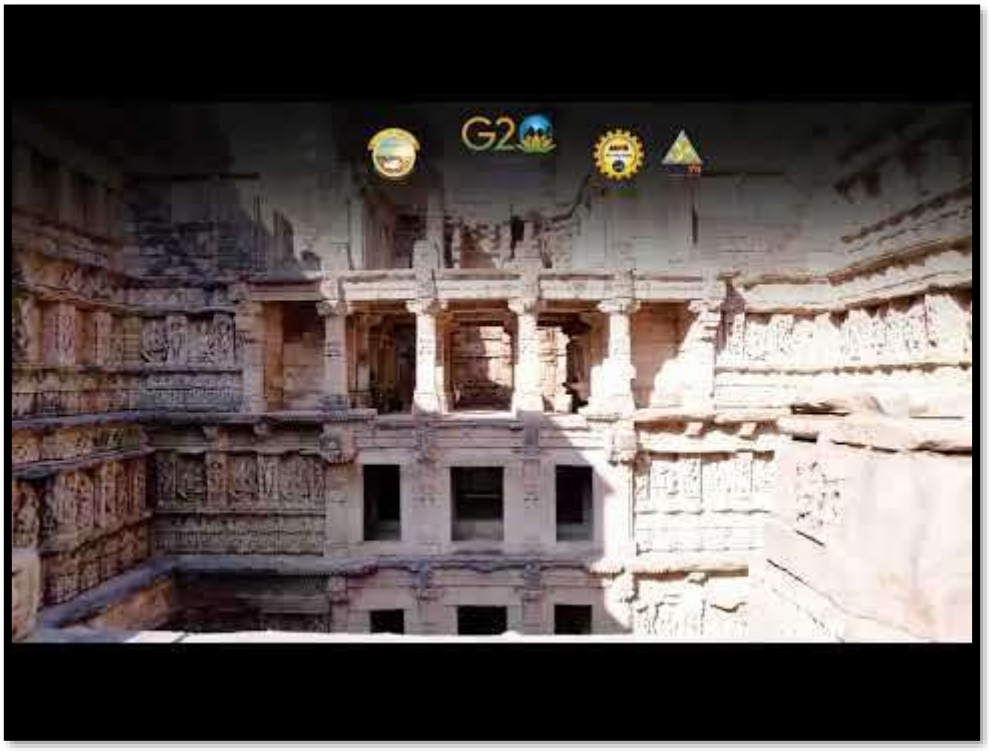

Figure 19: Video Trailer for Rani ki Vav Experience Released during G20 in 2023. It shows 3D rendered step well with water storage principles in animation. The final experience is in AR with large 3D printed model of the monument.

(https://www.youtube.com/embed/EEHy4Vscylw)

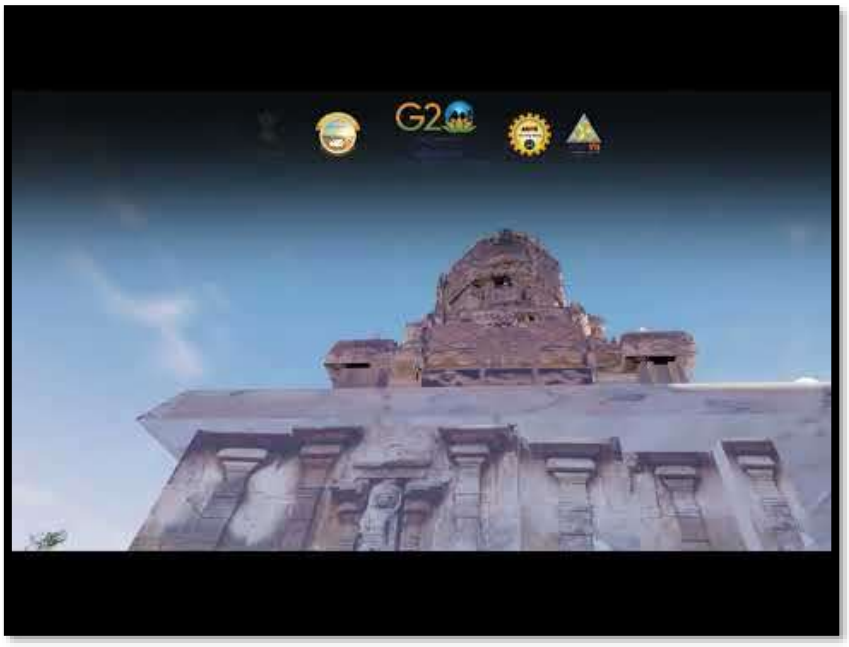

Figure 20: Video Trailer for Brihadeeswara Temple, Thanjavur released during G20 in 2023. It shows 3D rendered temple with temple courtyard scenery. The final experience is in VR
(https://www.youtube.com/embed/WB_oll8m7yc)

Figure 21: Video Trailer for the Harminder Sahib Experience released during G20 in 2023. It shows a night scene of the Golden Temple with Historical events of Amritsar. The final experience is in VR
(https://www.youtube.com/embed/MN1exlEly4s)

We leveraged the prototype experience as well as these full-fledged experiences as case-studies at various public events to gauge the market appetite for heritage experiences and feedback on the technology including the hardware, among many other facets that are outlined in the "Key Findings" section.

KEY FINDINGS

Has technology of today enabled ancient sites to come alive? Has technology helped people relive the past? Our analysis is multi-dimensional as is the case with all things related to heritage and history. We perform our analysis across the following dimensions:

- ✓ End-users
- ✓ Technology
- ✓ System
- ✓ Community

End-users

The main intent of deploying immersive technologies and deep research into our heritage and history is to make the learning appealing and enjoyable for our end-users. Additionally, the need to instill a sense of pride and self-worth in our younger generation, the future of our nation. With this in mind, we present some of the audience-responses, behaviours and recommendations based on our work across multiple projects presented to the public at various locations across India.

In the year 2022, at the Bengaluru Technology Summit, a prestigious industry event, we setup a space for the audience to partake in our VR experience across 3 days. The experience was a prototype of the Nandi Monolith at Lepakshi, Andhra Pradesh, having no sound and no explanation of the significance of the site. Our intention was to test the curiosity in the market for heritage experiences, with a sub-optimal prototype. The audience would see the Nandi Monolith and surrounding environment in a 2-minute walk. Will it engage the audience? Will the experience be something that they haven't witnessed before? Will they want more?

Our hypotheses with respect to the market appetite for heritage experiences was proved right. The space had the longest queues at the event, with people getting their friends and families the next day to partake in the same, sub-optimal, experience. Elders, students, teachers and people from diverse communities enjoyed the experience and opined that this should be the mode of learning history in schools and colleges and for tourists to learn about the monuments.

Some users provided constructive feedback such as "the experience is very basic and can be much improved" or "there is only one site. Work should be done on more places to depict the diversity of our nation".

In the year 2023, as a part of the G20 Presidency of India, we were commissioned by the Ministry of Education, Govt. of India, to create VR and AR experiences of heritage sites across India and display them at various G20 delegate events at Chennai, Amritsar, Bhubaneswar and Pune. As a part of the Education Working Group (EdWG) of G20, four priority issues were identified for deliberation[6]:

- Ensuring Foundational Literacy and Numeracy especially in context of blended learning
- Making Tech-enabled learning more inclusive, qualitative and collaborative at every level
- Building Capacities, promoting Life-long Learning in the context of Future of Work
- Strengthening Research, promoting Innovation through richer collaboration and partnerships

Would VR and AR appeal to the masses to engage in tech-enabled learning and bringing in a sense of inclusion for all, the world over?

The events had, on an average, 90 foreign delegates partaking in our experiences of Indian heritage sites. Some of the notable countries included Spain, US, Germany, Netherlands, Saudi Arabia, UAE. They enjoyed the experiences and were enamoured by the depth of knowledge of our ancestors in the fields of water conservation, temple construction, sciences and architecture and philosophy.

Schools, colleges, researchers and the public were invited for 2-3 days per event, to visit various spaces like ours. The crowd management at our space used to be a challenge. In fact, on the last day of the respective events, we would cordon the space so that we could pack up our equipment and transport it back to the Ministry of Education. Many people would request for an experience at the last minute, politely declined by us. That reinforced the hypothesis that there is curiosity and thirst in the audience for heritage experiences.

Some incidents from these events are unforgettable. For instance, in Chennai, a student walked up to put on the VR headset and before doing so, removed his shoes (circled in the image below, in orange) and folded his hands. He witnessed the Brihadeeswara Temple.

Figure 22: Experiencing heritage sites in VR - Barefoot

Figure 23: A school student in Chennai experienced both VR and AR and enjoyed them

Figure 24: Kids partaking in VR Experiences of Heritage Sites

Across all locations, we witnessed long queues and an innate curiosity to know how the experiences were built. Many students, in under-graduate studies, wanted to join us to build these kinds of experiences. Many of the video testimonials recorded at these events mentioned this is how history should be taught so that people get to know better about who they are and where they come from.

Technology

One of the thoughts that come to mind when we hear the word "Technology" is "Cost". Indeed, technology is expensive. More importantly, devices that we own become obsolete the day it is sold to us. Such is the speed of development and evolution of technology. With state-of-the-art immersive technologies, the scenario is no better, if not worse. Immersive technology is rapidly evolving, perpetually in search of photorealistic experiences and compact hardware. That said, the realism possible today is phenomenal, as compared to visual technologies in the 90s or early 2000s. To add to it, the 3D scanning technology has matured and delivering on its promises of providing high-quality scans. In this section, we will focus on the issues faced by the development team in the usage of these devices as well as building the experiences.

(1) 3D Scanning: Most of the 3D Scanners in the market are from Europe and USA and are tested in various conditions conducive to those regions. In our case, 3D scanners were not operational at high ambient temperatures. It would stop scanning and switch off until cooled off. This led to an invaluable loss of time for the team to scan the heritage sites. Additionally, it pushed our schedule owing to delayed post-processing as a result of delayed scan data delivery.

Figure 25: 3D Scanners being cooled down to resume operations

The second issue was with respect to the data retrieval processes undertaken by the 3D scanner providers. We had recorded Brihadeeswara Temple scans across a period of 4-5 days and the same needed to be rendered on cloud, by the providers. After weeks of inaction, it was brought to our attention that the site is too large and that the software is not capable of scanning such heavy workloads! Clearly, the lack of Indian data and systems for robust testing of these products came to the fore. Our team devised a way to push smaller area scans to the providers

and we could receive the data in quick time. But, this added to the overall development effort as the models needed to be stitched together, imported one by one, and assimilated in the same lighting conditions in the software.

Overall, 3D scanning technology is phenomenal as it provides a digital twin of the physical premises. We have data pertaining to the exterior of monuments to a resolution of 1mm. In fact, some of the experiences included museums inside these monuments. With little or no effort in post-processing the data, these museums were photorealistic and were highly appreciated by one and all. On the other hand, the unpreparedness of the products in Indian conditions and for large scale data is worth a consideration for these products' future development.

(2) Virtual Reality: VR as a technology came to the fore in Mid 90s. The technology has not yet reached the mass consumption levels, the world over. That said, the ancillary technologies for VR like 3D Scanners, High-processing Hardware (GPUs) and Network infrastructure (5G) have all come together to make VR a high-fidelity, rich visual experience. The price of a VR HMD has also come down to a reasonable rate for considerable uptake in the world market.

Our VR experiences were powered by High GPU Gaming Laptops (NVIDIA RTX 3060 series) with the HMD being the visual display unit. Usually, HMDs come with their own processors but they are not powerful enough to render heavy (TBs of model data) and rich visual content (photorealism with water waves, for example).

One issue we faced was with the optimal polygon count (or polycount, in short) in the experience. While our 3D models had a polycount of 70,000,000 to 80,000,000, high-end VR experiences can only tolerate 7,00,000 to 8,00,000 polycounts. This means a direct loss of resolution and quality and needs a fine balance to ensure the realism of the experience is not broken. This, we believe, is a pain-point that's worth considering to be fixed by the HMD providers globally. There are some HMDs that perform much better but they are made in countries that are geopolitically not in alignment with India. Today's standard way of solving it is by performing a retopology (retopo in short) using software like Blender or Maya. The intent is to bring down the polycount without eliminating sufficient, crucial architectural data. Another method is to ensure dynamic loading of the experience so that all the memory and processing is utilized for the current scene and as the user moves ahead, dynamic render of the next scene occurs. This saves processing power to a great extent but requires coding to ensure dynamic loading of the scene. With every head movement, this method will be triggered and optimizations performed, without compromising on the latency to ensure the consumer gets a seamless experience.

The team developed a program sequence to control the texture and flow of water in the pond at Harminder Sahib, Amritsar (popularly known as the Golden Temple). It took considerable testing to make it perfect. In the end, everyone who experienced it was blown away!

While VR provides visually rich experiences, ambisonic sound compliments it with rich, immersive sound – directional sound, crucial to bring a sense of embodied cognition in the viewer. With ambisonic sound, training and post-production is key. The sound engineer needs to assess the best location for IRs and other sounds such that the same is translatable in VR experience. Software engines handle ambisonics quite well and provide configuration and customisation capabilities to the development team.

True to our multi-sensory experience approach, we brought in haptic experiences also like feeling a stone-wall and the water surface. They largely work on force-feedback yielding vibrational sensory experiences to the user. But they largely miss codifying the texture, material and temperatures. These parameters are of paramount importance in providing a realistic multi-sensory experience. As a result, the experience was disappointing but our team is working to constantly improve it beyond what the product provides.

In summary, technologies today are really advanced and provide way more opportunities than they did in the past. The landscape has matured and both hardware and software are constantly upgraded and able to meet the challenges of the software developers. Today's animations are photorealistic and allow teams to convert their visual and aural dreams into reality.

System

System, for the purpose of this paper, includes the people and processes in various Govt-run bodies. As a part of heritage site visits, there is a need to interact with and seek permissions form various authorities like the ASI (Archaeological Survey of India), Local Police and other District Authorities.

(1) Archaeological Survey of India (ASI): The first step is to seek permission from ASI to shoot at heritage monuments which fall under their purview. This is done by applying online, one site at a time. While online application is a great boon and eliminates yet another means of corruption, for large-scale projects across multiple sites and states, individual applications and their follow-ups to fruition is a labourious task and an operational hassle. Keeping in mind, the bigger picture of potential proliferation of heritage tourism with cutting-edge technologies, these processes could operate in bulk at the authority level, thereby allowing teams to focus on their work rather than these hassles.

Secondly, there are different rules or norms at the local ASI level. While some ASI authorities allow full access and help clear the crowds for an accurate 3D scan (any presence of objects and people impede the output of the scan and therefore, its quality), others chose to ignore the same. By and large, the ASI authorities are very helpful and cordial. Our 3D Scanning team would leverage the ASI offices for network connectivity, essential for scan data. It must be noted that not all ASI locations have high-speed internet. The team had to travel to the nearest city to ensure the scan data was processed. This increased the timeline of scanning a site to a few more days, adding to the operations cost and additional hassles.

ASI could benefit from looking at bulk-site approval processes for organizations entrusted with documenting heritage monuments. Secondly, there needs to be basic amenities like high-speed internet provided at the local offices.

(2) Local Police: One needs to seek permissions from both the ASI and the local police authorities for usage of drones at heritage sites. Again, the experience was mixed. While some local police authorities were very efficient and quick in providing approvals for timely shoots, some local police authorities didn't provide the approval until the very last day following high-level escalations. Flying drones is not permitted beyond a certain number of hours during the day time. It was also noticed that some of the heritage sites were not open during those hours. This led to a major reshuffle in planning the shoots without the drones, thereby leading to a loss of scan data. More importantly, a lack of data for heritage site preservation and digitization. In some places, it was not known as to who the approving authority was, leading to greater time-delays.

Drone-permissions, as a process, could be streamlined at the national and state level, including contact details of authorities and the next-in-line.

Community

Community refers to the researchers, archaeologists, historians, temple priests, titular kings of cities, subject matter experts associated with particular heritage site(s) as well as ground personnel and tourists and the local community. As stated earlier, a large section of the community welcomes technology into sacred sites, once our noble intent is made known to them. Many in the community despise the use of technology and qualify it with damage done to structures by tripod stands and other hardware. As a passionate team fully focused on heritage sites, we took utmost care in not violating any rules or laws and ensured zero-damage to the sites.

We were unable to scan and record the interior of the temples due to absence of permission. We tried sensitizing the titular kings and the priests on the usage and benefits of technology but we understand that this requires a shift in mindset. As a result, interiors of the site are not digitized. We completely understand that the *garbagriha* should not be approached at all but the rest of the interiors could have been captured for digitization and preservation. Again, the approval needs to be given on a case-to-case basis keeping in mind the track record of the team and its intent. In fact, some end-users wanted to explore the interiors and were a tad bit disappointed that it was not possible.

Figure 26: Utmost care taken at heritage site to ensure zero-damage. Image shows equipment being deployed at various parts of heritage site, including corners and elevated areas.

POLICY PERSPECTIVES FOR THE FUTURE

We propose the following policy and administrative steps to streamline the process of content development for heritage, the skill development required for it along with administrative programs that can be organized at various levels from college/university to Central/State Govts.

a. Identify key policy and administrative guidelines

- **National Education Policy (NEP)** should leverage technology to bring back emphasis on Heritage. Technology can enable students to learn about History and Heritage in an immersive manner as explained above with e-learning. Many researches in the past have established the efficacy of visual learning over text-based learning, in terms of retention and recall. Therefore, immersive, visual technology could be a powerful

medium of information dissipation that has the potential to disrupt the learnability of youth as well.

- **Archaeological Survey of India (ASI)** should look at setting up Immersive Experience Centres at select heritage sites to engage visitors with in-depth VR/AR/360 experiences of the site, including time-travel to its past. Tourists, local and foreign, are largely unaware of the significance of the sites. To top it, an inconsistency in the information of tourist guides at these location means that the tourists get little or incorrect information. With these immersive experience centres, authentic information can be provided to the tourists thereby bringing in a shift in their mindset with regards to Indian history, arts, culture and heritage.

- **Skill Development** in the field of VR/AR and immersive technologies is essential to scale up content development and proliferation, given the multitude of sites in India and associated cultural ethos. Today, engineering colleges largely ignore this field of study. While lakhs of students are churned out every year as market-ready, their skills in this emerging technology are nominal or non-existent. Upskilling and reskilling the current workforce and students will go a long way in creating an ecosystem for content development in the field of heritage.

- **National Digital Tourism Mission (NDTM)**, as a policy, is well-intentioned and well-drafted. The focus on startups being a part of the entire ecosystem and the conception of UTI (Unified Tourism Interface) much like today's UPI is indeed revolutionary. Heritage Tourism startups and industries should be made a part of the early formulation of NDTM with pilot projects. The authorities at Tourism Department, Govt. of India, need to be made aware of emerging, immersive technologies and their potential.

b. How to operationalize above suggestions

Here are our recommendations on **Skill Development**:

- ✓ Universities should call for public discourses, paper presentations, talks at a state and national level. Institutions should have regular conferences to source heritage knowledge keepers and heritage knowledge givers and help them network with each other.

- ✓ All Government projects involving Culture, Tourism ministries should have a list of these knowledge keepers and givers to source from. Currently, this is broken and has a potential to further debilitate the cause of upholding the functioning of our heritage and culture.

- ✓ Training students in Universities on Industry 4.0 (Virtual Reality, Augmented Reality, Blockchain, AI, Metaverse etc.) with internships with startups and other companies working in heritage technology (**HeriTech**) vertical, thereby creating skilled manpower and generating jobs. Youngsters are encouraged to build a career in this niche field.

- ✓ State and Central Govt. to ensure funds within Startup India or statewide initiatives to have a funding allocated for **HeriTech** vertical so that startups could make use of them to build content. Content development is part of producer economy and is traditionally expensive in India.

- ✓ Hackathons to be organized at university level as well as Govt level for various initiatives of Culture Ministry and Tourism Ministry.

Some of our suggestions on operationalizing immersive technologies within **NEP**:

- ✓ NEP already includes the need for using immersive technologies in schools in its formulation as noted in sections 24.4(d) and 24.5.

- ✓ Allocation of funds for targeted course-content in immersive technology for schools is a must. Expecting this to be done as a part of CSR or Section 8 company defeats the purpose of providing world-class course-content for the students.

- ✓ Inherently, the technology is expensive and the content development is largely visually-centric which opens up the realm of subjectivity in terms of content aesthetics. There is a need to ensure content development is undertaken as per the research cycle and design & development methodology outlined in this paper.

- ✓ Pilots at select schools with course-content development and feedback across primary and secondary education would go a long way in faster implementation of immersive technologies as a part of NEP.

Here are some thoughts on operationalizing **ASI** recommendations

- ✓ Setting up Experience Centres at select heritage sites with the content already created could be considered as pilot execution.

- ✓ Culture ministry and ASI should allocate funds for proliferation of heritage tourism not only at the regional level but for global tourism as well. Many VR-based tourism portals exist in US, UK, Australia which can be leveraged to provide rich, immersive content of our heritage sites for tourists to discover and visit India.

- ✓ ASI should look at using scanned 3D models for preservation and protection of the monuments. The content should be stored at a central location, easily retrievable and usable by the staff for swift, corrective action when needed.

- ✓ ASI policies on heritage site shoot permissions should be relooked at, to help increase efficiency of the content development teams. It has to be noted that the content development teams focused on heritage look for permissions in bulk so as to cover a

large number of sites within given time and resources (people and equipment). This needs to be deliberated as a policy change.

- ✓ ASI should help in crowd management and control during such shoots as these are activities of national importance that are being carried out. These shoots help digitize the heritage sites and preserve them for posterity. In the case of natural calamities or any mishaps which cause harm to these sites, the digitized data would act as a reference to restore the damaged areas of the site. A case-in-point was the reconstruction of cathedral at Notre Dame, France.

Figure 27:3 Restoration of Notre Dame made possible due to 3D Scanning Data
(https://www.youtube.com/embed/sQmlxPVtOGk)

Here are some suggestions on **NDTM**

- ✓ Tourism ministry should look at heritage tourism as the fulcrum of NDTM and enable onboarding and empanelling of startups and agencies working in this field.

- ✓ Tourism revenues in India today are comparable to some of the major cities of the world. Much needs to be done in increasing the revenues. Heritage tourism, especially of temples, is an under-tapped aspect of tourism revenues and it would augur well for the Tourism ministry to invest in creating experience centres as part of Incredible India campaigns across the world.

- ✓ Investments by Culture and Tourism ministry in the order of billions of rupees into creating a metaverse for temples and heritage sites would ensure we future-proof our

ancient past with modern technologies. This should not be reactionary but rather a planned, deployable policy initiative. China recently announced similar plans at a cost of $6.9Bn[7].

c. How it benefits and to whom

- **Culture and Tourism Ministry** – These policies could ensure technology would initiate heritage content proliferation. It could benefit the Tourism department in terms of alternate channels of revenue, and as a tool for Tourism Discovery, thereby increasing foot-fall in India for these heritage sites. ASI could leverage the 3D models for their research work as well as plan maintenance works across the sites.

- **Students -** For students, learning History would be enjoyable and immersive with high recall of memory. For young adults exploring their History and Heritage and wanting to visit places of interest, this would be very helpful, with potential cultural exchanges between India and other nations which evince interest in this program. Additionally, skill development programs across the nation would ensure the next generation is equipped with all the technologies and skills to take on the metaverse revolution.

- **Elderly -** For the elderly who may be unable to travel but have a yearning to see places of worship or places of heritage and tourism, this technology would be a boon, enabling them to travel and see places despite their physical condition. The opportunity is more powerful when it comes to senior citizen NRIs and their yearning to experience the heritage of India.

- **Partially Visually Impaired** - The power of visual learning is beyond doubt. This would be beneficial to the partially visually impaired people, young and old. There have been pilot projects and researches conducted worldwide and in India with Virtual Reality for partially visually impaired. Sensations of light of different intensities (colour/brightness in visual language) convey different details to the partially visually impaired. They have suggested using audio narrative with highly descriptive commentary that could describe what is being seen as well as haptic devices for a sense of touch-and-feel. This could benefit them to learn and visualize History like never before.

- **Prime Minister's *Panch Pran*** – When PM Narendra Modi ji announced the *panch pran (5 oaths)*, it was a call to shift every individual's mindset. Aspects like Decolonising Minds as well as taking pride in heritage are the fulcrum of the *panch pran.* With this technology and the policy suggestions above, it can indeed have a large-scale impact on the younger generation in decolonizing minds in the days and years ahead.

- **Heritage Keepers** – Last but certainly not the least, this technology and suggested policy changes would proliferate jobs and services in the heritage sites sector (temples)

ushering in a wave of economic independence in the lives of heritage keepers who are today dwindling or seeking other jobs, owing to lack of monetization opportunities in the sector. This has resulted in lost knowledge and abandonment of our *shāstra* for lucrative jobs in the industry sector.

Leveraging today's technology, we could definitely look at high degrees of inclusivity in education, research and tourism & culture proliferation in the field of History, arts and heritage.

FUTURE DIRECTION

Technology has evolved to bring visions to reality, literally. With Digital twins of buildings and malls, technology today provides the ability to visualize aspects of art, architecture and engineering to great detail with hyper-realistic visuals and sounds. This paper has attempted to provide methods to realise this potential for ancient monuments – one of the key ancient knowledge respositories. While some policy recommendations have been highlighted in the research paper, here's a summary of issues across various aspects like technology, funding, cultural resistance along with probable solutions or recommendations for further research.

Firstly, there is a **lack of data** pertaining to the number of people practicing traditional roles like *Sthāpathya*. A focused approach on preparing a registry with relevant information and access points would help in actionizing plans related to their well-being and development. A detailed list of traditional skillset needs to be prepared and reviewed by traditional experts prior to executing the survey.

While **policies** like NEP and NDTM are in place, their implementation needs attention. The paper has provided certain tangible actions for the same. The paper also wishes to acknowledge the SHRI (Science and Heritage Research Initiative) by Dept of Science and Technology (DST), Govt of India. Relevant synergies between academia and industry could be harnessed for viable execution of projects and programs related to heritage in India.

Cultural resistance has been noted in this paper as a limitation. It's understandable as a generational trait but needs attention and a consistent approach. Future exercises and surveys could pave the way for the methodology of addressing this limitation. This impedes an otherwise robust economic development of the temple and its surroundings i.e. the opportunity to bring back the ancient temple economy paradigm. Consistent approaches in sensitization to the temple trusts and authorities could help beyond the surveys and exercises.

Currently, the **skillset** required to operate the hardware or even develop the 3D content is sparse. Skillset development is required in the areas of technologies like 3D Scanning, 3D Model Development, Animation, Content Development, Environment Design, Lighting Artists, Rigging Artists, Motion Capture Mechanics, Ambisonic Sound Recording and Rendering, among many other visual, immersive technology segments. The WAVES initiative by the I&B Ministry is a step in the right direction, especially, with the first ever institute that

would teach above mentioned skills – Indian Institute of Creative Technology (IICT) in Maharashtra. More such initiatives are needed for rapid skill development and scaling across the country.

Culture and Heritage has attracted very little industry interest in terms of an industry vertical or a line of business. While CSR **funds** include heritage as a recognised vertical, few industries opt for it. There is a need for sustained value-proposition of culture and heritage for society at large. Researches should be undertaken at scale, in this realm to underscore the significance of our civilizational relevance in today's world. Culture and Heritage requires government funding as primary source of investment and financing for projects. The potential of HeriTech is huge as highlighted in this paper but needs infusion of large-scale funds. Any new initiative or mission on a grand scale requires government support and focus. While some section 8 companies and trusts are sustained by donations and private funds, the author recommends a Fund-of-Funds for Culture and Heritage Startups (LLPs or Pvt Ltd) which work on deep tech like VR, AR, AI, 3D Scanning etc, as these are capital intensive and have high potential of scaling and global presence. These startups could usher in the Indian Soft Power through cutting-edge technology for global outreach via new media, in addition to seminars, conferences, books, journals, music, dance etc. There is a need to sustain risk-taking startups that operate in a hyper-niche segment like culture and heritage. Fund-of-funds from the Govt of India would help bring up such promising startups across the nation, generating employment and ensuring high-talent pool is deployed for Indian cultural endeavours as against the mainstream startups.

One of the limitations of the technology is its **cost**. A large part of the cost is borne out of the expensive hardware equipment, mostly imported. For example, a LIDAR 3D Scanner is priced at ₹10,00,000-₹17,00,000, VR HMDs are in the range of ₹50,000-₹2,00,000. There are HMDs that are manufactured by Indian Startups but they can't afford to bring their price down owing to high manufacturing costs with low margins. The PLI scheme from the Govt of India has helped usher in the hardware manufacturing startups but more needs to be done, before Indian startups replace the industry leaders, be it from USA or from China. Hardware startups in the realm of 3D scanning, 3D printing and VR/AR could be given greater concessions to manufacture at scale and create world-class hardware in the years ahead. Deeper research and reporting need to be undertaken in this regard to understand the industry's needs and pain points and address the same.

There is great scope in harnessing HeriTech for the younger generation but it requires a multi-pronged approach with focused actions across outlined areas, spanning from cultural awareness to technology investments and industry development. This is a greenfield space which needs to be harnessed and sustained as a national mission, to catapult India on to the world stage as the strongest soft power in the world.

CONCLUSION

Technologies today are mature and scalable, unlike technologies of 80s or 90s when 3D modeling and Metaverse had failed. It is, therefore, an invaluable opportunity for technologists, scholars, researchers, academicians and Govt authorities to come together and help reclaim our ancient knowledge repositories, our heritage, and re-anoint Bharat and its civilizational grandeur as the *Vishwaguru*.

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DEFINITIONS OF KEY TERMS USED

Āgamashāstra is a Sanskrit term that describes the manual for worship, temple building and rituals, among other things, within the traditions of Hinduism, Buddhism and Jainism

Ambisonic Sound is a high-fidelity audio system that reproduces the directional and acoustic properties of recorded sound using two or more channels

Archaeoacoustics is a sub-field of archaeology and acoustics which studies the relationship between people and sound throughout history. It is an interdisciplinary field with methodological contributions from acoustics, archaeology, and computer simulation

Garbagrihā is the sanctum sanctorum of a temple

HMD (Head-Mounted Display) is worn on the head and has a small display optic in front of one (monocular HMD) or each eye (binocular HMD)

Kalā is the Sanskrit term for skilled crafts like fine arts and performing arts

LIDAR (Light Detection and Ranging) is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth

Panchāng is a Hindu calendar and almanac, which follows traditional units of Hindu timekeeping, and presents important dates and their calculations in a tabulated form

Point-Cloud is a set of data points in a 3D coordinate system—commonly known as the XYZ axes. Each point represents a single spatial measurement on the object's surface. Taken together, a point cloud represents the entire external surface of an object

Shāstra is the Sanskrit term for precept, rules, manual, compendium or book or treatise in a general sense

Sthāpathyaveda is an ancient system that involves the connection between people and the buildings in which they live and work

Sthapathi is a Sanskrit term that refers to an architect, sculptor, metal worker or a master craftsman

Vedapātha is the recitation of the *Veda*. There are multiple variants of *Vedapātha* like *Ghanapātha* which have ensured lossless transfer of oral knowledge across generations for millennia

Vidyā is the Sanskrit term for knowledge.

Vishwaguru is a Sanskrit phrase and idea which translates to world leader or global guide or teacher

Vishwakarmā is the deified ancient architect. Members within his lineage are referred to as *Vishwakarmā*, to this day

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Brief Profile of the Author:

Ajit Padmanabh is the Founder and CEO at Who VR. He is a passionate techie with over 2 decades of experience in various technologies including AI and was with Infosys for 18 years. His startup, Who VR is one of the 3 companies in the world focused on Digital Heritage, using technologies like VR, AR to recreate our Heritage. They are on a mission to put India on the world stage in terms of tourism, arts and culture and expose the world to the richness and depth of our ancient architecture, ancient sciences & arts and metaphysics.

Ajit is also a TEDx speaker and has given numerous talks on HeriTech across IITs, IIITs and other colleges across the country. He is also a panelist on Republic Digital.

He is a self-taught guitarist and composer. Known as World Void Web, he creates symphonic rock instrumental music with spiritual-historical themes and has released two albums "Think Void" and "Voider Perspectives", available on all music platforms.

Statements and Declaration: I declare that I have no conflict of interest with my places of employment or anybody else in publishing this paper. Some sections of this paper (including a couple of photographs) also appear in one of my previous articles which has been published in a book titled "Glimpses of Art and Archaeology of India and South Asia Felicitation Volume of Padmashri K K Muhammed" (https://www.ibpbooks.in/glimpses-of-art-and-archaeology-of-india-and-south-asia-felicitation-volume-of-padmashri-k-k-muhammed/p/62514). I hold the copyright to that article. I also warrant that the manuscript is my original work and does not infringe on any rights of third parties.

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