ACOUSTICS 2012

Touring a singing sculpture to promote acoustics

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During 2010/2011 acousticians at the University of Salford and the University of Southampton collaborated with artist Luke Jerram to develop, design and tour the acoustic sculpture, Aeolus. Aeolus creates beautiful musical sounds in changing winds, functioning as a giant aeolian harp. Alongside Aeolus, an ambitious outreach programme was designed to compliment the artwork and engage public audiences with the acoustic science behind it. This paper gives an overview of the project's development and public engagement impact. It also discusses the principle workings of aeolian harps and the acoustic design of Aeolus.

1 Introduction

Funded by the Engineering and Physical Science Research Council (EPSRC) and Arts Council England (ACE), the Aeolus project was a large scale public engagement centred around raising awareness of acoustic science by touring the sound sculpture Aeolus.

Figure 1: Aeolus at Lyme Park, Cheshire, UK

Aeolus was conceived and designed by artist Luke Jerram, and developed in collaboration with acoustics scientists from the University of Salford and the University of Southampton as well as partners from Arup, Sculpture Factory, Outokumpu and Vista Projects.

One of the last and largest projects funded from the EPSRC's partners for public engagement programme, the Aeolus project took an an innovative and interdisciplinary approach to promoting acoustics, emphasising the shared history and interconnected relationship of art and science. Aeolus toured the UK in 2011, visiting Lyme Park, the Eden Project and MediaCityUK. Visitors to Aeolus had the opportunity to engage with it on multiple levels, from the immediate enjoyment of experiencing it as a standalone artwork to visiting a nearby exhibition space where they could learn more about Aeolus' development and its acoustics. Upon experiencing Aeolus, many visitors wanted to know how the sculpture produced its beautiful sounds. The artwork inspired a natural curiosity and enabled informal and often lively discussions on the artwork's acoustic properties and acoustics as a discipline.

Hence, the Aeolus Outreach programme was developed and also toured with the artwork in order to satisfy this curiosity and to generate interest in the field of acoustics. The Aeolus Outreach programme included school and community outreach events, workshops, CPD events, interactive demonstrations as well as online educational resources. The outreach team worked with several organisations to deliver the programme, including Manchester's Museum of Science and Industry, The Lowry, The Manchester Art Gallery, The Bluecoat in Liverpool, The Science Learning Centre and numerous schools and community associations.

Figure 2: The Acoustics of Aeolus exhibition at Media City included info-boards, videos, aural renderings of Aeolus with a WFS system and hands on acoustic demos. Here acoustics student volunteers demonstrate Chladni plates and Aeolian harps.

2 About Aeolus

2.1 The concept

Named after the Greek god of the wind, Aeolus primarily functions as a giant Aeolian harp. An early description of the Aeolian harp and its otherworldly sound can be found in Athanasius Kircher's book, the Phonurgia Nova which was published in 1673. The instrument perhaps enjoyed the most popularity during the Romantic and Victorian eras. The wonder of Aeolian harps is that they create music through nature. This fact fascinated the likes of Coleridge and Wordsworth who regarded the harps as conduits for nature's art, and wanted to likewise convey nature's beauty through their poetry. Today, enthusiasts enjoy making Aeolian sounds from a variety of materials and objects ranging from traditional spruce or maple boxes to be placed by windows, to large and elaborate metal sculptures for gardens.

Aeolus is a truly spectacular work of art, comprised of a large stainless steel arch supporting 310, 2 metre long by 0.2m diameter steel tubes that link to an outer ring of 16, 3 metre high listening posts. Figure 3 shows a complete view of Aeolus including listening posts.

Figure 3: Aeolus at the Eden Project, surrounded by 16 listening posts, to which are attached long nylon strings leading to tubes of the arch, enabling visitors to listen up close.

The central arch alone weighs 9.5 tonnes, being 6.1m high with a 9m x 2.8 metre footprint. The listening posts typically fan out to form a circle of a radius of about 20m. Many of the arch tubes link to the listening posts via ~20m long nylon harp wires tensioned to be acoustically active in light winds. The wires pass through wooden bridges held in membranes that form lids for tubes and posts (figure 4). The tubes and posts act as secondary resonators amplifying the string vibration.

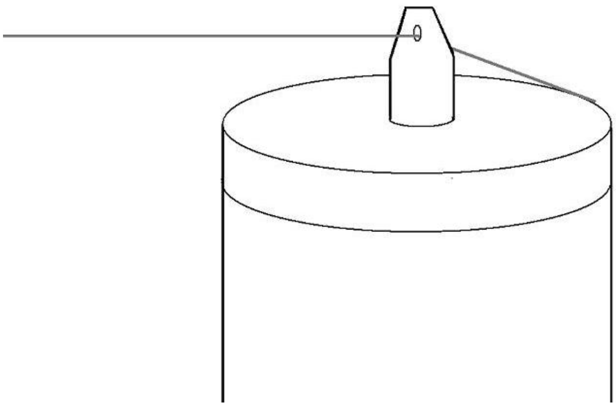

Figure 4: The membrane and bridge of a tube that holds a harp wire, thus coupling aeolian string vibration to the air column of the tube.

The sounds Aeolus creates are the result of the Kármán vortex street effect. As wind blows across the strings, alternating vortices pull the string periodically. The frequency of excitation can be shown to relate to wind speed v and string diameter d via equation 1

$$f \propto {}^{v}\!/_{d} \qquad (1)$$

As the string is excited into motion the frequency of excitation locks into one of the discrete modal frequencies of the string to create an audible resonance. As wind speed changes, the string moves up and down a harmonic series and so responds with consonant intervals in a very musical way. The effect is most prominent with gentle steady laminar wind flow in a direction perpendicular to the string. If multiple strings are set at different directions and tensioned with diatonic relationships to each other, the resulting sound is dynamic and very musical.

As well as its striking Aeolian effect, Aeolus has other notable aural effects. For example, when someone stands and speaks in a particular spot under the arch, Aeolus reflects and focuses the sound back. The resulting comb-filtering creates an unusual echoing sound that surprised and intrigued many visitors to the artwork. The tubes themselves also resonate with the low frequency sounds around them creating an appealing conch like effect for visitors who put their ears close up.

2.2 The acoustic design

The challenge for the project team was to facilitate the best acoustic experience given the constraints of cost, robustness, portability, and Jerram's desire to design a sculpture that was not only aurally but visually spectacular and intriguing.

The dimensions of the steel tubes were chosen to create a beautiful internal mirroring effect. Light from the outside world is collected, inverted and presented to participants standing within the arch (figure 5).

Figure 5: The visual effect of standing under the arch.

Forty tubes were designated to be secondary resonators for Aeolian harp wires, each capped at the top end with a clear membrane holding a bridge. This acts to couple vibration to the tube's air column. Initially the possibility of also using some tubes as flutes was explored, however a series of wind tunnel experiments showed this required slots drilled into the tubes, which compromised the visual effect and resulted in sounds that were neither special or complimentary to the Aeolian effect. Although the steel of the tube's themselves had a beautiful, bell like, natural structural response, it was believed these structural resonances would not be easy to exploit.

Long thin tubes with membranes are not optimum secondary resonators, as they offer a closed/open pipe input impedance profile with very narrow discrete air column resonances separated by wavelengths of roughly 1/4 , 3 /4, 5/4, etc. Despite acoustic design constraints, the air columns of the tubes give some broadband amplification that proved adequate. Figure 6 shows the experimental setup for an analysis of a tube's acoustic response when its bridge of membrane is tapped with a Type 8202 tuned hammer and sound recorded at 1m with an omni-directional microphone. Figure 7 shows the corresponding acoustic force transfer function with its narrow air column resonances and underlying broadband response.

Figure 6: Experiment set up to explore air column and structural responses of tubes required for Aeolus.

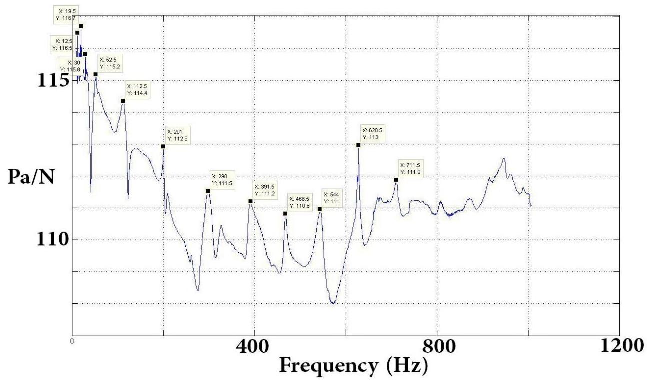

Figure 7: Force transfer function microphone/hammer

There was an initial concern that wind speed thresholds would be too high for clear weather conditions. However, following outdoor experiments with long nylon wires, the Aeolian effect not only worked well with wind speeds just above a gentle 4mph, but also gave the best sustained and most musical response. Sites were chosen to give Aeolus exposure to laminar, un-buffeted wind flow for prevailing wind directions.

Critical to an optimum response was an appropriate choice of wire diameter, membrane material, bridge material and perhaps most importantly, string tension. Below a tension of 50N the strings did not respond well. Electric fence tensioners proved to be the ideal tensioning solution. They are small, robust and able to provide the wide tensioning range necessary for Aeolus to create sounds. It proved crucial that string tension was properly maintained throughout a tour given strings would naturally loosen when settling in or after windy nights.

In order to ensure Aeolus could withstand harsh weather conditions, a variety of tube membrane materials and bridges were tested. Tests concurred that vacuum formed PVC of 0.75mm thickness gave a good response whilst being robust enough to cope with expected vertical forces from bridges. Tests also showed that 1x6cm cylindrical dowels proved as both effective and remarkably robust bridges. Violin bridges, with their rocking design and bridge hill resonance gave marginally better responses with lower wind thresholds, however their delicate nature made them an inferior choice.

The acoustic design of Aeolus was a compromise, however, the final result yielded beautiful sounds on clear days even in very light winds.

Figure 8: Aeolus at Media City, Salford, UK. As Aeolus could not be covered up at night or in bad weather its acoustic components had to be robust enough to stand all conditions

3 Evaluation Strategy

The Aeolus project had a comprehensive evaluation strategy that ranged from tallying numbers of visitors to detailed surveys designed to assess the quality and impact of engagement, especially with respect to raising the awareness of, and interest in acoustics. In addition to evaluating responses from visitors to the artwork, evaluation data was also gathered during outreach activities such as school visits or one off events.

Throughout Aeolus' installation periods, teams of volunteers from the National Trust, Eden Project and The Lowry invigilated the artwork. These volunteers were trained by the Aeolus team to provide background information about Aeolus and to direct visitors to the nearby exhibition where they could find more details about Aeolus' acoustic properties and try out hands on experiments. Invigilators were also responsible for sampling visitor opinions via specially programmed handheld tablet PCs. Opinion data was evaluated with respect to total visits to provide a statistical extrapolation of responses with reasonable confidence.

Three questions regarding visitors opinions were asked in addition to basic demographic information.

Did you enjoy the sculpture?

Are you curious about how the sculpture works?

Does the sculpture make you want to learn more about acoustic science?

Visitors rated their experience of the artwork and desire to learn more about its acoustic properties with a simple star rating system, as follows:

1-5 star rating system with the following values

No answer	0
No/ Negative response	1
Not much	2
Indifferent	3
Yes/Positive response	4
Yes, very much/ very positive response	5

Figure 9 shows sampled responses.

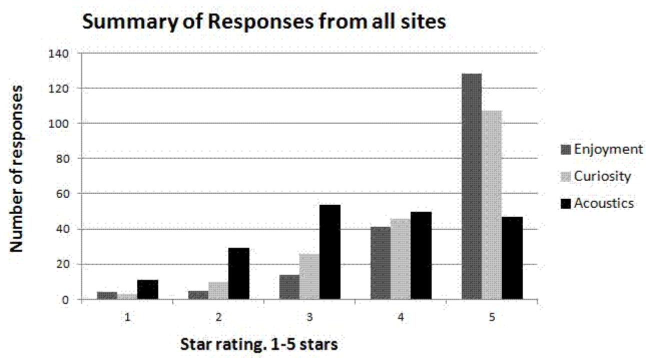

Figure 9: Sampled responses of visitors to Aeolus. Graph shows sculpture was well received affecting enjoyment and inspiring curiosity.

By tallying positive responses of visitors to Aeolus, we estimate 91% enjoyed the sculpture, 80% had a raised curiosity and 51% had a raised interest in acoustics science. One can extrapolate with 95% confidence from verified visitor numbers that 48.9K+/-2.5K enjoyed it, 43.0K+/-2.4K were curious as how it worked and 27.4K+/-4.4K had a raised interest in acoustics.

The wider impact of Aeolus was due to numerous outreach activities including school and community workshops which offered the means to develop Aeolus themed outreach resources for adoption by teachers and science educators. Notably with the aid of the National Science Learning centre, CPD training days were provided for teachers allowing them to tryout workshops resources aimed at Key Stages 1 / 2 and 3 / 4. The recorded responses were extremely positive with 95% of teachers expressing a commitment to incorporate the content within their lessons, meaning a potential outreach to schools of >10K. Workshop activities were also extremely well received by participants from a wide demographic.

The sculpture also enjoyed wide and diverse media attention including national coverage in The Telegraph, Mail Online, Financial Times, Flybe Flight Magazine, Design Week and The Guardian as well as numerous regional newspapers and online sites.

Table 1 : Reach of project based on verifiable numbers of people who took part in activities.

Aeolus Public Engagement Activity Summary	Numbers
Visits to Aeolus and Science of Aeolus Exhibition (Confirmed, we believe true number much higher)	53703
Estimated number of readers of press materials (web & print)	15398920
Number of plays for Aeolus related web multi media (videos & audio)	36346
Website hits (outreach site & aeolus.org.uk site)	10400
Community Activities (festivals, event days, etc)	882
Other workshops and talks	738
In-School Workshops by Aeolus Team	470
Estimated number of primary and secondary students reached through dissemination of project activity resources	4200
Participants on CPD Training (Teachers and sci-comm training for PhD)	60 (>10K student reach)
Visitors to Aeolus Exhibition at RWA	4189

Figure 10: An Aeolus themed lesson in a primary school where children learn about the science of sound and vibration with reference to the sculpture, aeolian harp demos and handmade devices such as tonoscopes.

5 Conclusion

The Aeolus Project sought to inspire curiosity and wonder about sound, inspiring further interest in the diverse discipline of acoustics through the exploration an otherworldly work of art. In collaborating with a variety of partners including leading artists, engineers and acoustic scientists, the Aeolus project was able to demonstrate the interdependent relationship of science and art, therefore helping to make acoustic science accessible for audiences who might not ordinarily engage with acoustic concepts and to encourage visitors who might appreciate science or sound to visit an artwork they might not have been otherwise inclined to enjoy. Aeolus had a considerable amount of coverage in the press and broadcast media, reaching over 15 million people. The artwork was installed in 3 prominent locations and was visited by more than 53,000 people. Over 2000 people took part in the Aeolus Outreach programme’s community and school events. Many teachers commented that while acoustics was an entirely new subject for their students, the workshops utilisation of kinesthetic, aural and visual materials made the sessions fun and easily accessible. The workshop activities developed through the Aeolus Outreach programme are now being incorporated into the Science Learning Centre’s learning resources, enabling thousands of students throughout the UK to learn more about acoustics with acoustic tonoscopes and aeolian wind devices. In addition, Aeolus is continuing to tour the UK, with its next installation to take place this spring in Canary Wharf in London. The project therefore has created a lasting legacy, in the form of both a beautiful acoustic artwork and creative learning resources.

References

[1] Aeolus-outreach.com

[2] Science and the Public, A Review of Science Communication and Public Attitudes to Science in Britain, Office of Science and Technology, Welcome Trust

[3] Public Attitudes to Science, 2011, BIS, Ipsos MORI, Social Research Institute