# Audio Nomad

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## BIOGRAPHIES

**Dr. Daniel Woo** is responsible for Human Computer Interaction teaching and research in the School of Computer Science and Engineering, University of New South Wales. Current projects are focused around the development of user interfaces both in terms of engineering and usability. Audio Nomad is a key research area for his group. His research and commercial background is strongly associated with speech, audio and mobile computing, having worked on projects in the areas of speech recognition, speech synthesis, telephone applications and handheld software.

**Chris Rizos** is a graduate of UNSW; obtaining a Bachelor of Surveying in 1975, and a PhD in 1980 in satellite geodesy. Chris is currently the Head of the School of Surveying and Spatial Information Systems at UNSW. He has been researching the technology and high precision applications of GPS since 1985, and established over a decade ago the Satellite Navigation and Positioning group at UNSW, today the premier academic GPS and wireless location technology R&D laboratory in Australia. Chris is a Fellow of the International Association of Geodesy (IAG), Chair of the IAG's Commission 4 "Positioning and Applications", member of the Executive of the U.S. Institute of Navigation's Satellite Division, and a member of the Governing Board of the International GNSS Service.

**Dr. Nigel Helyer** (a.k.a. Dr Sonique) is an Australian-based Sculptor and Sound Artist with an international reputation for his large-scale sonic installations, environmental sound sculpture works and new media projects. He is actively engaged in collaborative and trans-disciplinary projects that seek to synthesise cultural and scientific practice. He is currently an honorary associate in Architectural Acoustics at the University of Sydney and a Professorial Visiting Fellow at the University of New South Wales working in the area of Virtual Audio Reality. http://www.sonicobjects.com

**Nick Mariette** is a PhD student researching spatial audio synthesis and perception in the augmented reality setting. He developed the multi-channel and binaural spatial sound software components for Audio Nomad artworks. Prior to resuming study, from 1998 to 2003 he worked at spatial audio company Lake Technology, first as an audio software and systems engineer, and most recently as product manager for the Huron spatial audio workstation. Nick also produces live and radiophonic experimental audio compositions, and practices ambisonic surround sound field recording.

**James Salter** is an MSc student at the School of Computer Science and Engineering, University of New South Wales. His research focuses on probabilistic human positioning using existing wireless network infrastructure. He hopes that by developing robust, accurate positioning using existing technology, context aware computing can flourish even in the absence of expensive dedicated positioning hardware. Audio Nomad is an application that benefits from this approach as well as a research platform. James also produces complex but allegedly musical electronic music in his spare time.

## ABSTRACT

Audio Nomad comprises a series of cross-disciplinary art/science projects working on the concept of GPS-driven location-based audio applications. Project outcomes in the form of artworks enable a user or audience to experience a virtual audio world situated within the real world, as a spatial composition of sounds seeming to originate from real objects. Two-dimensional audio spatialization simulates realistic sound sources, and non-spatialized sounds may also be used as location-based content. Conceptually, sound is used to reveal information or create an aesthetic, often composed of a combination of oral histories, archival audio, site-specific historical information, field recordings, and music. The outcome is a culturally significant public sound artwork utilizing this new location-based audio medium – an application of global positioning, audio technologies, and software engineering.

As GNSS technologies become more ubiquitous, Audio Nomad can take advantage of new platforms such as mobile phones. This unique multidisciplinary collaboration has driven the design of tools with great creative potential to provide new alternative location-based services poised to engage and appeal to the imagination of future GNSS users.

## INTRODUCTION

Audio Nomad comprises a series of cross-disciplinary art/science projects working on the concept of GPS-driven location-based audio applications. Project outcomes generally take the form of artworks that enable a user or audience to experience a virtual audio world situated within the real world, so that the user perceives sound content as though it originates from real objects around them. Two-dimensional (2D) audio spatialization is used to simulate realistic situated sound sources, while non-spatialized sound sources may also be used as location-based content. Conceptually, sound is used to reveal information or create an aesthetic, often using site-specific historical information amongst other audio elements. The goal at the outset of this project was to marry technology with art to produce culturally significant public audio artworks utilizing this new location-based audio medium – an application of global positioning, sound design and software engineering.

The Audio Nomad team is a fruitful synergy balancing artistic and technical demands, aimed at pushing the research and development of location-based audio capability. The project has been funded for three years (2004 to 2006) as an Australian Research Council linkage grant with the Australia Council for the Arts (LP0348394). To date, Audio Nomad has deployed the location-based audio concept twice as a ship-based multi-speaker installation: *Syren,* presented at the 2004 International Symposium on Electronic Art (ISEA) on the Baltic Sea, and *Syren for Port Jackson* on Sydney Harbour (March 2006). The team is presently testing a system for pedestrian users (*Campus Navigator*) and conceptualizing one future pedestrian-based deployment before project completion (*Virtual Wall*).

## CONCEPTUAL AND SONIC OBJECTIVES

Audio Nomad projects place strong emphasis on a highly imaginative, creative approach to sound design and composition that highlights the potential of this emergent field of location-based spatial audio. Unlike conventional sound or musical composition, location based audio requires sensitive consideration of environmental and geographic context.

Pedestrian projects in particular require significant attention to user behaviour and their unpredictable interaction with the content via position, speed and heading in relation to the architectural/urban environment. Conceptually and sonically, the principal challenge of all Audio Nomad projects, whether ship-based, or for pedestrian users is to develop a 'compositional' strategy able to deliver a non-linear but coherent 'field' of location-based audio.

## WORKFLOW AND APPROACH TO CREATE SUPPORTING TECHNOLOGIES

A very important goal of the software engineering work is the development of reusable tools and workflow design for the creation of location-based audio content by non-technical users, not just a one-off implementation for each new work.

From the ISEA experience in 2004 we learned that the art community is usually focused on building exhibits as "one off" development exercises. We came to realise that our approach to develop tools for location-aware audio design was fairly unique in that community and gave us the capability to design location-aware content in an efficient manner that was not specific to one type of deployment environment.

Designing the tools around user needs [1], in this case the principal artist, helped the artist's ability to work efficiently with the tool and lock project focus on real problems. The design was participatory in conceptualisation but incorporated regular usability evaluations to identify both design issues and bugs in the software system.

## AUTHORING TOOL

The editing tool is a compositional environment in which the location of the listener triggers audio as though it were a spatial "playhead". Unlike conventional audio tools where the playhead is directly related to time, location-based audio design has a 2D playhead that could follow a variety of paths.

The editing environment has undergone two revisions. The first prototype, *VectorMap* (Figure 1) was developed specifically for the ISEA deployment on the Baltic Sea. The second prototype, *MapViewer* (Figure 2) is a more general tool that can produce content for both multispeaker and handheld environments. MapViewer adopts attributes expected of a software application used in a more conventional audio production environment.

Understanding the audio artist workflow is a significant aspect of the project. The mechanisms provided to the artist to choose, add, remove, adjust and refine the audio content will impact on the creativity and efficiency of the editing process. Being able to audition the evolving content and experimenting with different combinations is a key factor for success.

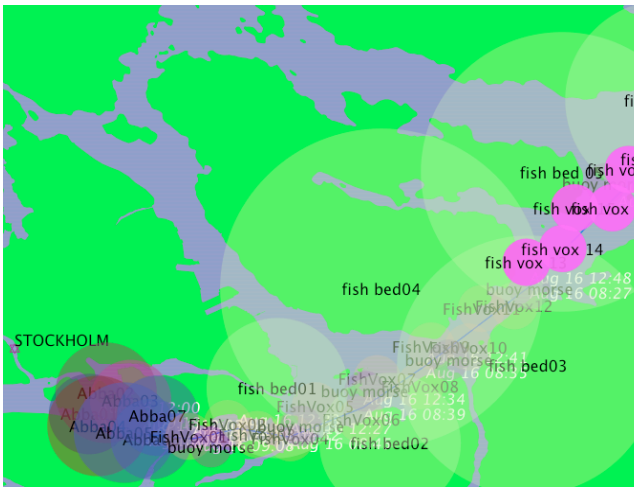


**Figure 1 – detail view of VectorMap software used to create *Syren* content for ISEA on the Baltic Sea**

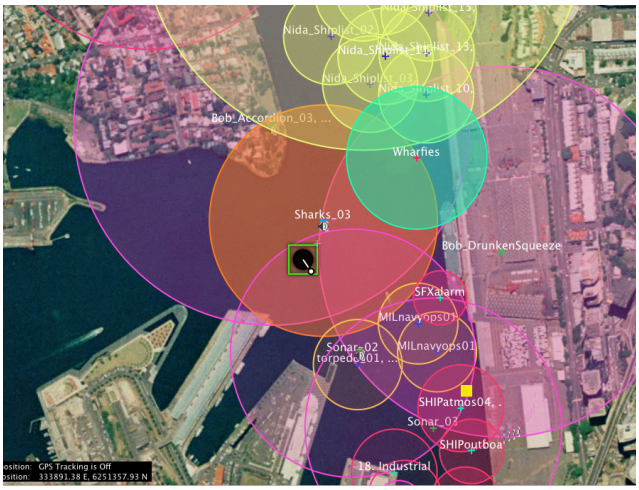


**Figure 2 – detail view of Map Viewer software used to create *Syren for Port Jackson* content, with the square cursor at centre representing the ferry's position**

The aim of the tool was to create "flow" [2] so that the artist could concentrate on audio design not the pragmatics of interacting with the tool. The artist is focusing on the interrelationship of sounds to the landscape, which is a 2D map-based editing surface. Being centred within a speaker array that is representative of the final configuration removes the guesswork when designing the audio experience.

**Editing in-situ**

For both ISEA and Sydney Harbour testing runs were conducted before the actual events. For ISEA we had the opportunity to take a short cruise the day before the conference. Sydney Harbour, being in our home city enabled us to spend two test days on a much smaller boat. The editing tools were used in the field to fine tune content that had already been specified. Seeing the visual reality against the augmented audio experience is a necessary part of producing high quality outcomes.

## *SYREN* FOR INTERNATIONAL SYMPOSIUM ON ELECTRONIC ARTS

*Syren* was presented as a ship-board exhibit at the 12th International Symposium on Electronic Art (ISEA) in August 2004 [3], [4]. *Syren* produced a continuous, spatialized soundscape that augmented the landscape of the Baltic Sea with location-based audio over a forty-one hour journey between Helsinki, Mariehamn, Stockholm and Tallinn (Figure 3). Listeners on the upper deck of the ISEA cruise ship (Figure 4) heard sounds rendered on a multi-channel speaker array so as to appear to originate from the location of visible geographic features and other positions along the journey, using custom Audio Nomad-developed software that enabled the artist to place location-based sound content over on vector map of the Baltic. A handheld GPS provided both position and direction data for the software system, built on Mac OS X, to render the soundscape from the current point of view of the ship on the map.

The Baltic Sea is a long way from Sydney, Australia and it was not feasible for a major resource commitment to be deployed to the northern hemisphere before the actual presentation at ISEA. The need to design at a distance made it necessary to create a flexible design environment that could dynamically update content should unanticipated situations arise. An unexpected situation did arise when the boat docked at a different port in Stockholm. The real-time nature of the user interface allowed immediate repositioning of audio without having to halt the playback system.

Digital mapping data from the relevant hydrographic authorities, paper-based navigation charts and a position data from the shipping company were obtained. This collection of reconnaissance provided a good estimate of where we were expecting to be. However the editing tools were not limiting the audio design to a specific path dictated by the position data. The path data was used as a guide to help the artist focus attention on the known course, rather than creating content that would be never heard since it was never coincident with the ship's course.

**Figure 3 – view of *Syren* ISEA, showing two speakers and Baltic Sea landscape**

**Figure 5 – *Syren for Port Jackson*: the ferry Regal, showing the DGPS antenna, with Sydney city in the background**

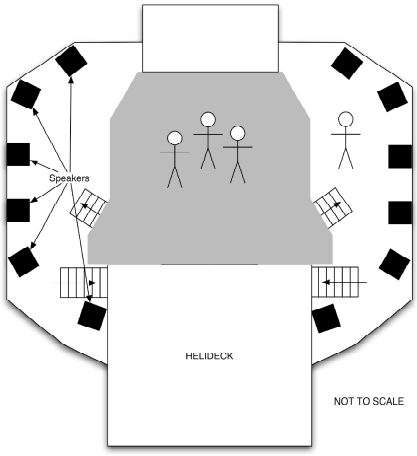


**Figure 4 – Upper deck layout on the Opera cruise ship, for *Syren* at ISEA, depicting grey central audience area surrounded by 12 loudspeakers**

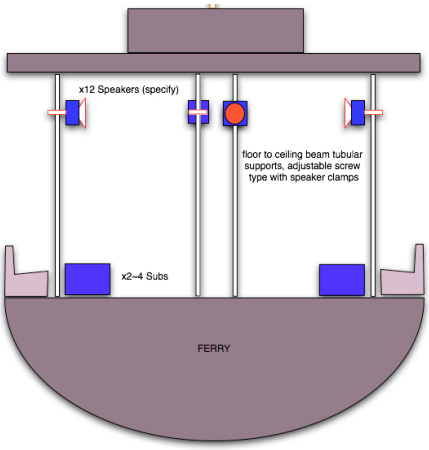


**Figure 6 – *Syren for Port Jackson*: Layout inside the ferry Regal, showing loudspeaker placement and seating**

### *SYREN FOR PORT JACKSON*

In March 2006, *Syren for Port Jackson* (*Syren PJ*) presented essentially the same concept deployed on Sydney Harbour (Figure 5, Figure 6) as an exhibit in conjunction with the New Constellations conference at the Museum of Contemporary Art. *Syren PJ* presented spatial audio relating to the contemporary and historical, natural, built and cultural environments surrounding Sydney Harbour. For *Syren PJ*, the content authoring software (MapViewer) was redeveloped to use orthophoto images as the background upon which the artist can lay out location-based audio content.

### CAMPUS NAVIGATOR AND VIRTUAL WALL

*Campus Navigator* and *Virtual Wall* are both works-in-progress that deploy location-based spatial audio for pedestrians listening on headphones. The hardware platform is presently a handheld computer using an integrated GPS receiver, with head-mounted antenna and digital compass to determine the user's current position and orientation. Campus Navigator will provide an artistic location-based audio guide for the University of New South Wales campus, as an initial trial of the solution for a handheld platform.

## VIRTUAL WALL

*Virtual Wall* is an augmented audio reality artwork proposed for the Mitte in Berlin. The project will trace the physical course of the now absent Berlin Wall through the predominantly re-built city centre with a complex location sensitive soundscape formed from a mixture of historical material (oral histories and public speeches for example) with fictional audio narratives, music and ambient effects. *Virtual Wall* will operate in the space between the public and private lives - balancing material from public broadcast sources with intimate stories and characters.

Narrative themes will be developed from historical and cultural research and we anticipate forming partnerships to undertake both the background research and generation of content (recorded as multi-lingual voice narratives). Spatial and architectural 'keynote' objects are also important compositional elements.

### Complexity, Time and Space

The construction and the experience of *Virtual Wall* will occur within both a time domain and a spatial domain. Whilst the experience of audio is by nature temporal and generally continuous, the experience of a spatially constructed soundscape is far less predictable, particularly when the user is free to choose where to walk at any time. Further to this, the content of the work itself will address historical and contemporary time periods, adding further complexity, requiring compositional decisions about how to design interactions between user time and position, and content time and location.

Although the work is spatially bounded (albeit in a large area some 4,000 metres by 400 metres) and has a principal vector in the path of the wall, the compositional structure does not impose a spatial hierarchy or even propose an explicit spatial structure. Spatio-temporal complexity is generated by both the pace of walking through the physical landscape (and ipso facto through the soundscape) in combination with the temporal duration of individual sound events and their position which may be fixed in absolute space, coupled to a trajectory or positioned relative to the participants position.

### Technical and Research Challenges

*Virtual Wall* proposes a range of complex technological challenges. Our proposed project area is a 4km section of the wall running either side of the new Parliament building (for example, Figure 7) and thus needs to incorporate a huge amount of audio data, distributed over a large geographical area.

The compositional environment needs to address not only creative requirements, but also the pragmatics of cueing and guiding the users over a large geographical terrain, focused on the path of the vanished wall (a sharply defined linear track). Only a few 'natural' limits exist to where a participant can walk (e.g. the river) but many competing points of interest will lie outside the project's geographic scope, therefore sound behaviour compositional designs must be developed to indicate the project boundaries and retain the auditor's interest.


**Figure 7 – Berlin, adjacent to the Brandenburg Gate: one of the proposed sites of *Virtual Wall* audio content**

Position determination that is reliable and accurate enough is a potential problem that may be addressed by using alternative technologies to GPS, discussed in a later section of this paper. Wireless LAN may also be employed to stream the many hours of audio required by the geographically large active deployment area, which may not fit onto mobile device storage.

## MULTIPLE DEPLOYMENT CAPABILITY

A core aim of Audio Nomad is to produce outcomes spanning multi-speaker ship-based deployments through to the handheld version for pedestrian use. The development approach has been to focus on one design tool that could generate content for multiple platforms.

The second Audio Nomad software system, MapViewer, is scalable to several different deployment platforms of varying processing power and mobility. MapViewer, running on Mac OS X, can itself function as both studio and laptop-based design tool, or as a deployment platform primarily for ship-based multi-speaker installations. Content developed using MapViewer can be also be deployed to a mobile device for individual pedestrian user playback. Deployment content data is packaged as an XML document and compressed mp3 sound files, which can be transferred to the mobile device using a memory card. Devices interpret the content and render it according to their processing capability. Currently, the sole deployment platform is Pocket PC. The Audio Nomad team is also developing a custom mobile playback device, and mobile phones or mp3 players may be targeted in the future.

## CHALLENGES OF PEDESTRIAN

Compared to shipboard location-based audio installations, Audio Nomad for pedestrian use presents several additional challenges. Practicalities of developing a mobile system for multiple individual users limit the bulk and expense of all hardware components, with concomitant limitations to their performance specifications. Predominant limitations are due to limited positioning accuracy and limited data storage capacity and computation processing power. These ultimately limit the extent to which an implementation achieves the project goals to provide a highly convincing augmented audio reality, and provide the end user experience envisioned by the artist.

## LOCATION-BASED SPATIAL AUDIO PERCEPTION

Audio Nomad spatial audio quality depends on many factors of a particular implementation system. Ideally, location-based spatial audio would seem perfectly realistic, indistinguishable to the user from a situation where sounds were actually emanating from the objects chosen by the artist or other creative content producer. In any practical system, however, the perceptual quality afforded by the implementation is limited by factors such as positioning and orientation accuracy, total system latency before this data affects the sound output, and computing power available to render convincing spatial audio. Subjective experiments being carried out by Mariette [5] intend to evaluate perceptual quality of spatial audio for mobile pedestrian users of audio augmented reality systems like Campus Navigator, with respect to various implementation and human factors. Ultimately, the complete characterization of perceptual quality according to various implementation factors will enable a system design that optimizes the match between artist intentions and end-user perceptual experience for given technology performance specifications. Perceptual experiment outcomes will also feed back into the authoring tool workflow and user interface.

## ALTERNATIVE POSITIONING TECHNOLOGIES

Audio Nomad authoring software and deployment systems have been designed with the potential to use any positioning technology. GPS has been the first choice because it is economical, readily available, and convenient, particularly for outdoors positioning and the maritime Audio Nomad projects. However, GPS is not suitable for some more likely pedestrian Audio Nomad environments, for example "urban canyons" and foliage-covered areas outdoors, or for any indoors applications, such as a gallery or museum tour guide. Ultimately, a pedestrian Audio Nomad application should support seamless service transition between outdoors and indoors use as depicted in Figure 8. Indoors, purpose built systems such as Active Badge, cricket, The Bat, and others, are available [6], although in many cases it is possible and cost effective to attain adequate positioning performance using existing infrastructure such as Wireless LAN. For high accuracy performance both indoors or outdoors, pseudolite technologies such as Locata provide a solution. RFID technology is also being tested for simpler location-based audio applications such as gallery guides.

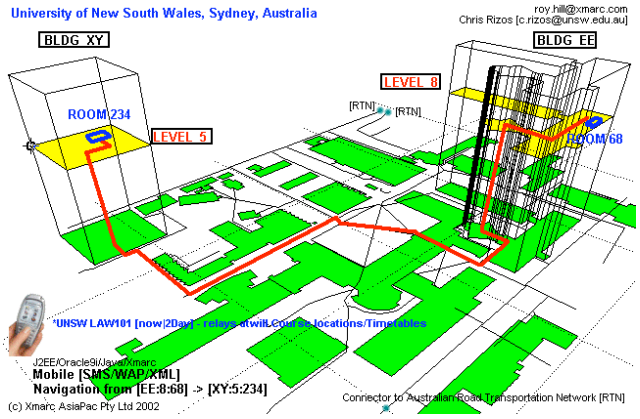


**Figure 8 – Building to building navigation**

Researchers at University of New South Wales (UNSW) [7], and elsewhere, have developed innovative implementations of indoors mobile user position estimation using signal strength of Wireless LAN (WLAN). WLAN is a technology that provides local wireless access to fixed network architectures and has seen rapid market growth, making consumer hardware cheap and readily available. While WLAN is not designed for positioning, signal strength measurements are easily made and display high spatial variance, enabling metre-level accuracy for the best techniques. Increasingly, WLAN positioning systems are seen as convenient for indoor environments, urban areas, or wherever WLAN is deployed. Additionally, applications such as Virtual Wall may use a WLAN network to update or stream content data to the user device on demand.

While GPS is a popular and mature technology, it is heavily dependent on a relatively unobstructed sky-view and good satellite geometry. In "challenging" environments where satellite occlusion is common, such as urban environments, satellite-based technologies produce disappointing performance. A solution developed by the company *Locata* [8] is to deploy a network of terrestrially based transceivers (*LocataLites,* Figure 9) that transmit ranging signals.

These transceivers form a positioning network called a *LocataNet* (Figure 10) that can operate in combination with GPS when available (as in urban environments) or entirely independent of GPS (for indoor applications). A special property of the *LocataNet* is that it is time-synchronous, potentially allowing single point positioning with cm-level accuracy.

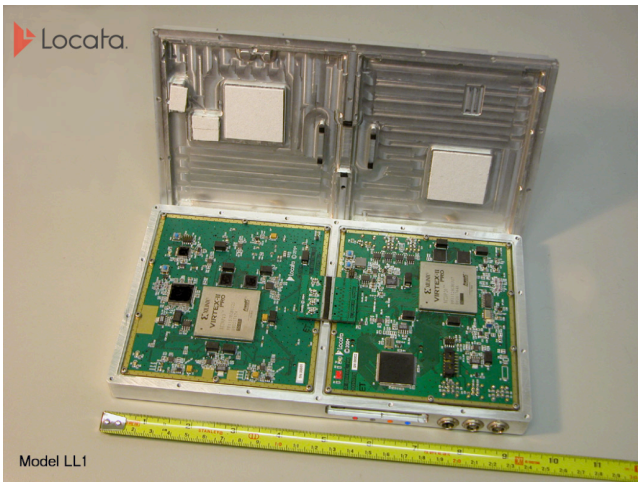


**Figure 9 – Prototype LocataLite**

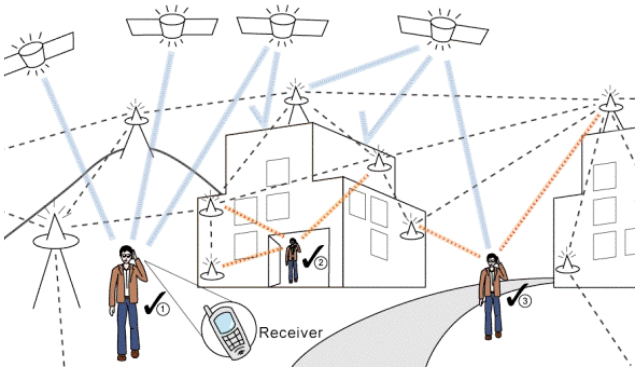


**Figure 10 – Locata can be used indoors and in urban or other environments where GPS cannot**

## SUMMARY

Audio Nomad projects are developing the creative and technical possibilities of location-based playback of spatialized audio content, using GPS and digital compasses to provide user position information. As GPS technology becomes more ubiquitous, Audio Nomad is well placed to take advantage of new platforms such as mobile phones. The developed technology considers multi-platform deployments, with playback architectures such as streaming audio and reduced sound spatialization implementations to enable content scaling to fit devices from ship-based systems to pedestrian handheld devices. Research has also focused on the design of efficient authoring tools, and workflows for the creation of content for multiple deployments. This unique multidisciplinary collaboration has driven the design of tools with great creative potential to provide new alternative location-based services poised to engage and appeal to the imagination of future GNSS users.

## ACKNOWLEDGMENTS

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