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| **Institution:** University of Nottingham | | |
| **Unit of Assessment:** UOA14 Geography and Environmental Studies | | |
| **Title of case study:** Projection Augmented Relief Models (PARM): New commercial services for flood risk, and changing the ways landscape is visualised, exhibited and taught in the Lake District National Park and in schools. | | |
| **Period when the underpinning research was undertaken:** 2002-present | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** Dr Gary Priestnall | **Role(s) (e.g. job title):** Associate Professor | **Period(s) employed by submitting HEI:** 09/1987-present |
| **Period when the claimed impact occurred:** 2015-2020 | | |
| **Is this case study continued from a case study submitted in 2014?** N | | |

## 1. Summary of the impact

Dr Priestnall's creation of, and subsequent research into, the Projection Augmented Relief Model (PARM) technique has changed the way geographic information is communicated and understood by commercial, public, and voluntary sector organisations. As a result, JBA consulting commissioned a PARM-based service for communicating flood risk that was subsequently adopted by the Environment Agency and used to manage public understanding of flood risk at Hebden Bridge. Lake District National Park Authority, Keswick Museum, and the National Trust at Sticklebarn have implemented PARM technology in the production of new cultural artefacts and innovative public displays. The Field Studies Council have used PARM to develop new ways to engage students with the broader landscape.

## 2. Underpinning research

For many people, interpreting maps can be challenging. The way in which information is portrayed influences whether people can gain knowledge from a display and are able to act upon it. Since 2002, Priestnall's research has explored the effectiveness of a range of digital 3D representations of landscape for helping people understand spatial patterns, using technologies such as digital mapping, immersive 3D landscape visualisation and augmented reality. A general finding was that, although screen-based landscape visualisations can offer realistic and immersive representations, they often fail to provide an overview to help convey relative positions and scale. In searching for a more effective spatial frame of reference, Priestnall created the Projection Augmented Relief Model (PARM) technique, which mapped high resolution imagery and maps onto 3D printed landscape models.

The PARM technique emerged from a desire to exploit the power of traditional physical relief models for providing natural overviews of the landscape. The rationale for developing PARM was that the natural frame of reference offered by physical models could be further enhanced by adding a richness of geographic representation through the projection of sequences of high definition maps, imagery and animations.

A prototype PARM display was developed by Priestnall in 2012 and was showcased at the Electronic Visualisation and the Arts conference (Research 1 (R1)), where Priestnall first proposed the term PARM. A research agenda was set out for developing high precision projection-enhanced solid relief displays for communicating spatial and temporal patterns across a landscape. It is the application of, and further research into, the underpinning design protocols of PARM from 2012 onwards that is the focus of this impact case study.

The development of design protocols for PARM began later in 2012 with the creation of a public display at the Wordsworth Trust in Grasmere, Cumbria (Grant 1 (G1)). The potential for geographic displays in the gallery had previously been established using a screen-based virtual tour created by Priestnall for the Trust in 2009. A series of design iterations followed the Wordsworth Trust PARM display, with the unique capabilities of the technique being reported (R2), along with explorations into adding interactivity to the surface of the model (R3). The development of the 'Grandest Views' public exhibition at Keswick Museum, curated by Priestnall in 2015, presented the opportunity to explore PARM alongside Priestnall's reconstruction of part of Mayson's Ordnance model of 1875 (G2 and R4). The further development of PARM (G4 and G5) has aimed to engage new audiences and has included studying its impact from a Human-

Computer Interaction perspective (R5). Valuable transferrable knowledge about the ability of PARM to convey spatial information in educational and outreach settings was gained through a project to visualise the nature and scale of landforms on Mars (G3 and R6).

The original contributions and main findings of this research are:

- A clear articulation of the power of physical relief models for the effective communication of spatial context. Viewers develop a strong spatial frame of reference, due to the natural representation of features rather than their portrayal in two dimensional (2D) maps. This makes it easier to judge the relative size and position of any spatial patterns, including changes through time, projected onto the physical surface model.
- A robust set of design protocols for displays combining projection-enhanced landscape models with ancillary information on a screen. This is underpinned by evaluation of several public displays in a range of contexts.
- Design of rendering techniques which use images generated from the perspective of the projector which, when projected, fit the model perfectly. This 'continuous texture mapping' technique gives a critical level of fidelity, creating a holographic effect that has greatly enhanced PARM's power and utility as a professional visualisation tool.

**3. References to the research (R)**


1. **Priestnall, G.,** Gardiner, J., Durrant, J., and Goulding, J. (2012) 'Projection Augmented Relief Models (PARM): Tangible Displays for Geographic Information', *Proceedings from Electronic Visualisation and the Arts (EVA) London* doi.org/10.14236/ewic/EVA2012.28
2. **Priestnall, G.,** Goulding. J, Smith, A. and Arss, N. (2017) 'Exploring the Capabilities of Projection Augmented Relief Models (PARM)', *Proceedings of the Geographical Information Science Research UK (GISRUK) Conference*, Manchester, April 2017. https://huckg.is/gisruk2017/GISRUK_2017_paper_113.pdf
3. Arss, N., Smith, A., and **Priestnall. G**. (2017) 'Interactions with Projection Augmented Relief Models (PARM)', *Proceedings of the Tenth International Conference on Advances in Computer-Human Interactions (ACHI 2017)* March 19-23, 2017, Nice, France https://www.thinkmind.org/download.php?articleid=achi_2017_5_40_20209
4. **Priestnall, G.** (2019) 'Rediscovering the Power of Physical Relief Models: Mayson's Ordnance Model of the Lake District', *Cartographica*, 54(4), 261-277. doi.org/10.3138/cart.54.4.2018-0003 Refereed Journal Paper
5. **Priestnall, G.,** & Cheverst, K. (2019) 'Understanding visitor interaction with a projection augmented relief model display: insights from an in-the-wild study in the English Lake District', *Personal and Ubiquitous Computing*, 1-15. doi.org/10.1007/s00779-019-01320-2 Refereed Journal Paper
6. Sprinks, J., Dowthwaite, L., **Priestnall, G.,** and Wardlaw, J. (2020) 'MarsCAPE: Mars Communicated through an Augmented, Physical Environment', *IEEE Computer Graphics and Applications*, 40(2), 43-56. doi.org/10.1109/MCG.2020.2967319


**Grants (G)**

1. Spatial Knowledge Acquisition: Exploring the Potential of the Projected Augmented Relief Model (PARM) technique. EPSRC Research Development Fund, RDF/0312 Pump Priming section. GBP8,662, Gary Priestnall, January–March 2012.
2. Reviving Mayson's Ordnance Model of 1875 AHRC Creative Economy Knowledge Exchange, GBP10,724, Gary Priestnall, May–November 2013.
3. Revealing the Martian Landscapes through Linked Physical and Virtual Models, UK Space Agency, GBP6,000, Jessica Wardlaw (Nottingham Geospatial Institute) PI and Gary Priestnall Co-I, March 2016–April 2017.
4. PARM for Public Understanding of Flood Risk, Impact Leaders Programme, GBP5,000, Gary Priestnall with External Collaborator JBA Trust, October 2017–May 2018.
5. Projection Augmented Relief Models (PARM) for Spatial Decision Support and Education, ESRC Impact Accelerator Award, GBP9,000, Gary Priestnall, February–November 2017.

**Awards**

- Research R1, which included a demonstration of PARM, won the best demo award at the 2012 Electronic Visualisation and the Arts conference.

- The paper exploring interactions with PARM (R3) was awarded a best paper award by the International Academy, Research, and Industry Association.
- A PARM display designed to communicate flood risk was 'Highly Commended' in the British Cartographic Society's 'Garsdale Design Award for 3D Mapping' in 2018.

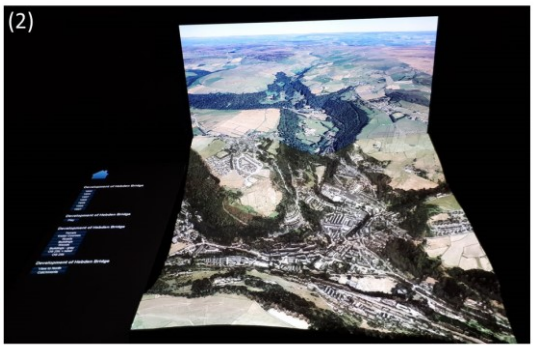
**4. Details of the impact**

Dr Priestnall's creation of the PARM technique and the development and application of innovative design protocols has successfully demonstrated substantial reach. It has attracted a broad range of partners from the charitable and education sectors as well as public and private sectors. Priestnall's impact has been in three main areas:

***New commercial services for communicating flood risk***

Priestnall's research has led to the creation of new commercial services offered by Jeremy Benn Associates (JBA), an environmental engineering consultancy company with over 700 employees, to better visualise flood risk as part of community consultation. JBA provide hydrological modelling for the Environment Agency (EA) and other clients who would typically communicate flood risk using conventional maps. JBA identified the additional capabilities of PARM (R1, R2, R3) for conveying the temporal as well as spatial extent of flood model outputs in a way that is highly suited to community engagement. Priestnall gave a joint demonstration with JBA at the Flood Risk Management conference (September 2017), which led to a collaboration between Priestnall and JBA Consulting. Priestnall created a permanent PARM display at the JBA Head Office which showcases and animates JBA Consulting's flood data (Image 1) and has changed the way the company communicates flood risk, exemplified by a demonstration to over 60 EA staff (October 2017). As a result of keen interest from the EA, JBA Consulting allocated research and development funds to develop expertise in automating the creation of animated flood sequences from their own computational models in a form suitable for use on PARM and began to offer PARM-based services in 2018 (Impact a (Ia)), building capacity to communicate environmental risk. Writing in his testimonial the Executive Chair of JBA Consulting commended *"PARMs [role] as a valuable new capability enabling us to deliver a more engaging form of display that enhances the benefits of our flood risk modelling activities. We expect future PARM commissions to be profitable, but more importantly the true benefits of the PARM are in helping our clients to deliver reductions in flood risk with community buy-in"* (Ib).

The first PARM to be commissioned from JBA by the EA was for Hebden Bridge (Image 2), and was well received in October 2019, with Emma Howard Boyd, Chair of the EA, publicly recognising it as *"a useful way to illustrate flood risk"* (Ic). Work began on three further potential commissions in Spring 2020 (please see the 100 word Covid-19 statement). A quote for a new display is currently being considered by Natural Resources Wales (November 2020).


***Changing the way museums and visitor centres visualise landscape***

Priestnall's research (R1, R2, R4) has changed the way that Keswick Museum engages the public with their collections. Priestnall led the curation of an exhibition in 2015, 'The Grandest Views' (Id), based on his exploration of the power of physical relief models both past and present. The exhibition was visited by approximately 5,000 people and showcased a PARM-based reconstruction of a Victorian landscape model (Image 3). The exhibition was featured on BBC TV's Countryfile (18 January 2015, viewed by over 7,100,000 people) which brought PARM

to a national and international audience. It has significantly impacted and shaped the museum's artistic direction in the way that it curates exhibitions and delivers its educational strategies by developing a more explicit focus on landscape. This was exemplified by the design of the 'Wainwright' (2015) and 'Dive into Derwentwater' (2019) exhibitions and the redesign of the exhibition space in 2019. The Keswick Museum Manager stresses the importance of Priestnall's involvement: "*The work carried out with Gary on PARM and Dive into Derwentwater directly fed into the development of our new Landscape Zone, forming part of the vision for our exhibition spaces…This work would not have been possible without the expertise we were able to access through Gary's involvement"* (Ie).

In addition, the research has significantly enhanced the museum's reputation, supported successful bids to Arts Council England and helped the organisation to deepen the quality of its audience engagement and education (If). The collaboration received high acclaim from the Curator at Keswick Museum: "*This [co-production] was fundamental to the development of the organisation's new manifesto which has at its heart 'helping people to share their love of Keswick and the Lake District' …and our successful nominations in 2015 for 'Museum of the Year' at the Cumbria Life Culture Awards and the Best Small Visitor Attraction at the Cumbria Tourism Awards… Following the success of the exhibitions, we have now developed a greater depth and quality of engagement with our audiences and also encouraging closer collaboration between visitors, local groups, museum volunteers and researchers… Landscape context is now a fundamental part of our core educational offer with the learning and activities coordinator using a permanent new floor map…"* (If).


(3)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(5)

Public interest and engagement in the research has been stimulated through the exhibition, evidenced for example by the creation of a 'Map Mondays' feature by lifestyle blogger Cassie in response to her visit to, and review of, the exhibition, prompted by the BBC Countryfile feature which she referred to as *"one of those stop-talking-and-stare-intently-at-the-TV moments"* (Ig).

Following the success of the exhibition, the Lake District National Park Authority (LDNPA) invited Priestnall to install a PARM display at the visitor centre in Brockhole near Ambleside to visualise new cycle routes, drawing upon his research linking projection-enhanced displays with ancillary information (R2). The General Manager of the Brockhole visitor centre, LDNPA, emphasised the "*benefit of the 3D model projection system over a traditional static 2D display",* and in particular PARM's *"ability to combine images of the new cycle routes and the surrounding landscape with an accurate representation of the route's topography"* (Ih). The display ran at the centre between 12 May and 7 November 2016, during which time 155,283 people visited. The popularity and success of the display was noted by the LDNPA who *"ran out of the extensive stock of free leaflets that accompanied the model"* (Ih).

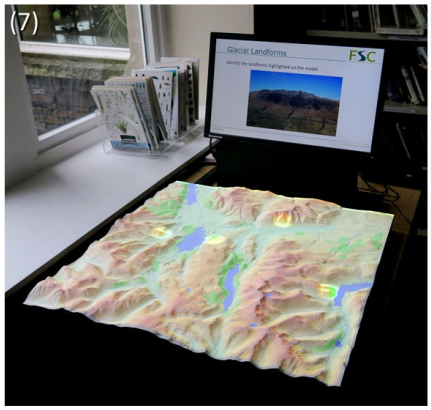
A PARM display at the National Trust's (NT) Sticklebarn visitor site in Langdale, Cumbria in 2017 (Image 4), promoting exploration of the local landscape, proved to be very popular and engaging (R5) and has led to a model being on permanent public display at that site. In July 2017, UNESCO World Heritage Status was awarded to the Lake District, with the NT and LDNPA as major partners. The NT and LDNPA jointly developed a PARM display to be hosted at Brockhole, representing the first collaboration between World Heritage partners and a first step towards co-authoring an interpretation strategy. The Manager of Brockhole Visitor Centre, LDNPA, stressed that *"UNESCO expects its WHS stories to be communicated to wider audiences, to build awareness, grow knowledge, and foster interaction. I expect PARM to*

*continue to play an important role within this responsibility"* (Ih). A display co-created by the NT, LDNPA and Priestnall, was successfully trialled in Spring 2019 to explore public reaction to the proposed content and form of display (Image 5). A permanent display was due to be installed in Spring 2020 but has been postponed until Spring 2021 due to Covid-19.

***Creating new educational technology interactions***

The PARM technique has changed the way geographic information is visualised to students at the Field Studies Council (FSC) field centre at Blencathra, Cumbria. The Senior Tutor of the FSC made clear that "*having the 3D model enabled students to interpret the landscape more easily"* (Ii). In 2018, Priestnall developed a teaching-oriented PARM working with over 200 students at Keswick school (Image 6). The experiences from the Keswick school were presented at the Geographical Association conference in Sheffield (April 2018) and led to PARM enhancing student learning on environmental landscapes at four other schools and the National Space Centre in Leicester (R6). The findings underpinned the adoption of PARM by the FSC at Blencathra where senior tutors developed their own display (Image 7). The Senior Tutor makes clear that the *"biggest gains are visible in younger GCSE students from more urban settings"* and "*those students who don't perform well in that traditional school setting"* (Ii). In parallel to these activities, JBA Trust (the outreach arm of JBA Consulting) delivered 11 educational sessions to over 700 students, using their own version of PARM (Ij), including a summer school for less advantaged students from inner city London. The Executive Chair of JBA Consulting described PARM as *"an exciting new addition to the outreach capabilities of the JBA Trust"* (Ib).

(6)




(7)

**5. Sources to corroborate the impact (I)**

a. Website of JBA Consulting describing capability of PARM
b. Letter from the Executive Chair, JBA Consulting
c. Tweet from the Chair of the Environment Agency
d. 'Grandest Views' exhibition guide
e. Letter from the Manager of Keswick Museum
f. Letter from the Curator of Keswick Museum
g. 'Map Mondays' blog feature
h. Letter from General Manager, Brockhole Visitor Centre, Lake District National Park Authority
i. Letter from the Senior Tutor, Field Studies Council
j. Website of JBA Trust describing PARM