

<b>Institution: University of Bristol</b>
<b>Unit of Assessment: Chemistry UoA 8</b>
<b>Title of case study:</b> <b>CH3: danceroom Spectroscopy: International Cultural Impact and Public Engagement at the frontiers of Science, Technology, and Art</b>
<b>1. Summary of the impact</b> (indicative maximum 100 words)  <p>danceroom Spectroscopy (dS) is a cutting-edge, interactive public engagement project that allows people to literally step into an interactive molecular dynamics simulation. It has its origins in fundamental research carried out to understand ultrafast chemical dynamics in liquids. On a large scale, dS impact has arisen from its deployment in premier cultural settings in the UK and internationally, eg the London 2012 Olympics, London's Barbican Arts Centre, Ars Electronica (Austria), ZKM (Germany), and the World Science Festival (New York City). Statistics indicate well over 60,000 people have so far experienced dS, with audiences spanning ages from 3 to 73, and attracting those with a variety of interests including science, technology, art and education. Within the cultural and media sectors, dS has received several awards and substantial press attention, all of which has proven beneficial to several non-academic collaborators and partner institutions. The substantial momentum and opportunities available from dS are also being commercially exploited through a spin-out company called Interactive Scientific Ltd.</p>
<b>2. Underpinning research</b> (indicative maximum 500 words)  <p>This impact emerged from a fusion of two distinct research strands at Bristol:</p> <p><b>Strand 1</b> concerns the School of Chemistry Laser Group (Professors Mike Ashfold and Andrew Orr-Ewing) who were amongst the first in the UK to use digital imaging methods to investigate gas phase reaction dynamics. They introduced two methods ('event counting' and 'centroiding') in order to improve image resolution and alleviate a range of problems that arise from using position sensitive detectors. The methodology was first demonstrated in 1996 and reported in detail in 1998 (1,2). Such developments and the science they have enabled have ensured membership in three successive EU Marie Curie Training Networks devoted to developments and applications of imaging methods in contemporary reaction dynamics (a-d) and event counting is now a standard feature in the software supplied with CCD cameras provided for imaging applications. Imaging methods are now being developed further through a Knowledge Training Partnership with Photek Ltd, and were a key tool within a recent EPSRC Programme Grant (e).</p> <p><b>Strand 2</b> is an extensive set of Molecular Dynamics (MD) simulation software programs developed by <b>Glowacki</b>, a Royal Society URF (since October 2013) who has recently been appointed to a proleptic lectureship in the School of Chemistry. From June 2009 to Sept 2013, <b>Glowacki</b> was employed as a PDRA on the aforementioned EPSRC Programme Grant (e), where he was encouraged to work with a very high degree of autonomy. <b>Glowacki's</b> software programs were developed to understand hitherto unrecognised details of the mechanisms for chemical reactions in liquids revealed by ultrafast laser experiments performed by Laser Group at the Rutherford Appleton Laboratory's ULTRA facility carried out during 2010/11. Specifically, <b>Glowacki</b> collaborated closely with <b>Orr-Ewing</b> and <b>Ashfold</b> to show that chemical reactions in liquids give rise to products with significant quantum state excitation (3,4). Through the extensive conversations that arose as a result of this collaboration, <b>Glowacki</b> became aware of the in-house experience with imaging methods, and recognised the possibility of combining real-time imaging methodology with his molecular dynamics algorithms to build a real-time interactive system. This inspired <b>Glowacki</b> to investigate combining his MD methods with 3D imaging technology. These efforts were initially funded via an EPSRC public engagement grant awarded in October 2010 (f), and EPSRC Pathways to Impact funding in 2011 (g). The most significant complication arose from the computational requirements of such a system which dramatically exceeded what could be accomplished with standard single-core processing methods. As a result, <b>Glowacki</b> began conversations with McIntosh-Smith (Senior Lecturer, UoB Department of Computer Science) with expertise in high-performance computing. This collaboration, initiated in early 2012, led to a set of GPU-accelerated algorithms for performing real-time interactive molecular dynamics (5,6) and now</p>

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forms the foundation of the dS system.

**3. References to the research** (indicative maximum of six references)**Publications:**

- (1) The photodissociation of iodine monochloride at 235 nm. L. J. Rogers, M. N. R. Ashfold, Y. Matsumi, M. Kawasaki and B. J. Whitaker, *Chem. Phys. Lett.*, 1996, **258**, 159-63. DOI: 10.1016/0009-2614(96)00617-3
- (2) Ion imaging studies of the Cl ( $^2P_{1/2}$ ) and Br ( $^2P_{1/2}$ ) atomic products resulting from BrCl photodissociation in the wavelength range 235–540 nm. M. J. Cooper, P. J. Jackson, L. J. Rogers, A. J. Orr-Ewing, M. N. R. Ashfold and B. J. Whitaker, *J. Chem. Phys.* 1998, **109**, 4367-77. DOI: <http://dx.doi.org/10.1063/1.477039>.
- (3) Ultrafast energy flow in the wake of solution-phase bimolecular reactions. D. R. Glowacki, R. A. Rose, S.J. Greaves, A. J. Orr-Ewing, and J. N. Harvey, *Nature Chemistry*, 2011, **3**, 850-855. doi:10.1038/nchem.1154.\*
- (4) Vibrationally Quantum-State-Specific Reaction Dynamics of H Atom Abstraction by CN Radical in Solution. S. J. Greaves, R. A. Rose, T. A. A. Oliver, D. R. Glowacki, M. N. R. Ashfold, J. N. Harvey, I. P. Clark, G. M. Greetham, A. W. Parker, M. Towrie, and A. J. Orr-Ewing, *Science*, 2011, **331**, 1423-1426. DOI:10.1126/science.1197796 \*
- (5) Danceroom Spectroscopy: Interactive Quantum Molecular Dynamics Accelerated on GPU Architectures using OpenCL. D. R. Glowacki, P. Tew, T. Mitchell, J. Hyde, J. Price, and S. McIntosh-Smith, URL: [UK Many Core Development Conference 2012 \(UKMAC '12\)](#).
- (6) Sculpting Molecular Dynamics in Real-Time using Human Energy Fields. D. R. Glowacki, P. Tew, T. Mitchell, L. Kriefman, J. Hyde, L. J. Malcolm, J. Price, and S. McIntosh-Smith, in [Molecular Aesthetics](#) ISBN: 9780262018784 (MIT Press). Can be supplied by the UoB to the REF Panel on request \*

**Grants:**

- (a) Ashfold (Bristol component), *Imaging Network for the Direct Visualisation of Chemical Dynamics: IMAGINE*, EU (ERBEMRXCT970110), 1998-2001, €184,730.
- (b) Ashfold (Bristol component), *Product Imaging and Correlation: Non-Adiabatic Interactions in Chemistry; PICNIC*, EU (HPRN-CT-2002-00183), 2002-5, €163,573.
- (c) Ashfold, Orr-Ewing (Bristol component), *Marie Curie Initial Training Network: Imaging and Control in Chemistry: ICONIC*, EU, 2009-13, €613,545.
- (d) Orr-Ewing, Ashfold, *et al.*, *Portfolio Partnership LASER*, EPSRC GR/S71750/01, 2003-8, £3,060,014.
- (e) Orr-Ewing, Ashfold, *et al.*, *New Horizons in Chemical and Photochemical Dynamics*, EPSRC [EP/G00224X/1](#), 2008-13, £5,934,426.
- (f) Glowacki, Ashfold, *et al.*, *danceroom Spectroscopy: Collectively Generating Music from Movement*, EPSRC, [EP/I017623/1](#) £20,000.
- (g) Glowacki, EPSRC Pathways to Impact Funding, University of Bristol, £37,000.

**4. Details of the impact** (indicative maximum 750 words)**Introduction**

The algorithms driving dS are taken from software and methods developed by **Glowacki** in order to understand the fundamentals of chemical reaction dynamics and energy transfer in liquids. This research occurred as part of the EPSRC Programme Grant employing **Glowacki**, through collaborations with **Orr-Ewing** and **Ashfold**. The exceptional performance of the dS software benefits from a suite of GPU-accelerated algorithms, developed by **Glowacki** in collaboration with McIntosh-Smith and Tew, a resident at the Pervasive Media Studio in Bristol.

**Impact: Public Audiences**

**Glowacki** recognised that combining his fast MD algorithms with 3D-depth sensors could facilitate an immersive, interactive molecular dynamics experience. This led him to develop an integrated software/hardware system that functions as an installation piece for cultural institutions. dS's sonic and graphic tools may be used by a range of non-specialists, including artists, educators, and hobbyists. This has facilitated the development of 'Hidden Fields' (HF) the world's first dance show based on molecular dynamics (1), which **Glowacki** developed along with an interdisciplinary team

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including Tew, choreographer Laura Kriefman, musician Joseph Hyde (Professor, Bath Spa University), music technologist Thomas Mitchell (Senior Lecturer, UWE), a team of five professional dancers, and film-makers Nathan Hughes and Jacob Parish. To date, over 20,000 people have attended dS and HF events (2). Web statistics show well over 40,000 hits for related content (3), and 'Googling' 'dancerroom spectroscopy' gives more than 200 pages of hits. Notable live events include (2):

- Shambala Arts Festival: Aug 2011, 2000 participants, mostly a young, arts-oriented audience (2).
- Bristol's Arnolfini: July 2012, 2000 participants, a wide cross-section of the public, spanning all ages with a range of interests (2).
- London 2012 Cultural Olympiad: Aug 2012, 2000 participants, spanning all ages with a range of interests.
- London's Barbican Arts Centre: Nov 2012, 2000 participants with interests in art and technology (4).
- London's Big Bang science/engineering fair: Mar 2012, 6000 participants, children and families interested in science (5).
- New York City's World Science Festival: June 2013, 1000 participants, children and families interested in science (2).
- The Bristol Old Vic theatre, in collaboration with violinist Nicola Benedetti as part of the Bristol Proms: Aug 2013, classical music audience (2).

Following the tremendous audience response dS and HF received at the London 2012 Olympics and the Barbican Arts Centre, NVIDIA and Arts Council England have provided nearly £70k in funding to support algorithm development and an international tour of dS and HF in 2013/14 (6). The momentum associated with this tour has led to a further £75k of funding from The Royal Society of Chemistry, EPSRC, University of the West of England, and the Watershed Arts Trust to support a dancerroom Spectroscopy festival, (7) with events aimed at year-9 school children, university students, artists, and the general public. Upcoming performances of dS in 2014 will include the ZKM Centre for Art & Media (Karlsruhe), and London's Barbican.

dS is profoundly cross-disciplinary, combining physics, chemistry, computer science, human-computer interaction, art, and music. It thus offers a brilliant "way in" to complex chemistry and physics for people who are often hard to reach, eg teenagers, clubbers, festival-goers, and those interested in art. The majority of dS participants indicate that they come from arts backgrounds, with little exposure to science. Written feedback obtained over 21-22 July 2012 at the Arnolfini suggests that dS sparks interest in science and the way that scientists think. Example quotes of respondent's impressions having seen dS/HF include:

- *"[dS made me think about] how we interact with all the matter constantly surrounding us."*
- *"Science has never been so spellbinding."*
- *"[dS/HF] can teach science in an innovative and creative way."*
- *"Whether dance or science dS is totally absorbing and utterly wonderful."*
- *"[dS/HF] makes me think about how I might be influencing everything around me."*
- *"an amazing fusion of science and art, something I have never seen before."*
- *"just because we cannot see [things] does not mean they are not there. There is more to the universe than meets the eye."*

#### **Impact: Cultural, Artistic, and Media Sectors**

dS and HF have resulted in a number of awards and award nominations including (8):

- 'Best Digital Innovation 2012' from the UK Royal Television Society.
- Honorable mention for the Prix Ars Electronica (amongst the most prestigious global awards in digital art).
- University of Bristol 2013 Public Engagement Award.
- Nominee for 2013 UK Media Innovation Awards

There have been many opportunities for exposure to dS via media outlets. For example, dS was highlighted by the newly appointed chair of Arts Council England, Sir Peter Bazalgette, during his

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inaugural lecture in March 2013, **Glowacki** has conducted radio interviews for both BBC Radio Bristol and Monocle-24 (a London-based radio station), dS has been written up in the press at least 35 times, including a range of popular science outlets including *Physics World* (Institute of Physics), *Chemistry World* (Royal Society of Chemistry), *New Scientist*, and *The Guardian* (8,9).

dS's impact on the UK's cultural, artistic, and media sectors has been strengthened considerably through connections to Bristol's Pervasive Media Studio (Watershed) (10) and Arnolfini Art Gallery, who together provided over £35k of in-kind support for dS development during 2010 to 2012. For example, dS's recent London premier at the Barbican has provided excellent exposure for both these institutions within the UK creative technology sector. The Watershed have recently used dS as a "Talent Development Case Study" detailing successful examples of cross-fertilization between media organizations and the academic sector and in collaboration with the Institute of Physics, dS's inspired the Pervasive Media Studio to initiate a public communication of science residency.

**Impact: Non-Academics**

dS and HF have had substantial impact on **Glowacki's** non-academic collaborators. Following dS/HF success:

- Kriefman has enjoyed significant exposure, with invitations to conduct workshops in collaboration with premier UK dance institutions including the Royal Academy of Dance (London) and Northern Ballet.
- Tew has boosted his international reputation as a generative digital artist. He was awarded a Pervasive Media Studio residency, which led to his participation in a MADE commission to work on a multi-site European digital art project entitled "Me and My Shadow".
- Hughes and Parish have produced a series of high-impact legacy film documents detailing the groundbreaking collaboration that has resulted in dS/HF. For example, a dS mini-doc was recently shortlisted for a \$100k "Forward Focus" prize sponsored by GE (11).
- The professional dancers who performed in HF have gained valuable experience at the collaborative frontiers of art and science, and learnt strategies for incorporating technology into arts practice. They have improved their ability to engage public audiences in bringing hybrid forms of art to nontraditional audiences.

**Impact: Commercial**

dS has momentum for expansion into commercial sectors, with an initial focus on education. It has resulted in the first ever real-time 360°, 3d depth-capture system and yielded a state-of-the-art, GPU accelerated framework for carrying out quantum molecular dynamics. To exploit these opportunities, **Glowacki** formed a spin-out company, Interactive Scientific Ltd. (12) with a projected turnover of approximately £150k expected during 2013/14.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

- (1) Hidden Fields video trailer: <http://vimeo.com/48764930>
- (2) List of all past dS events: <http://dancerroom-spec.com/events/>
- (3) dS project website: <http://dancerroom-spec.com/>
- (4) Emma Ridgeway, Barbican art director: [emma.ridgeway@barbican.org.uk](mailto:emma.ridgeway@barbican.org.uk)
- (5) Big Bang Video doc: <http://www.chm.bris.ac.uk/~chdrg/educationTrailer.mov>
- (6) Arts Council Funding: [www.lottery.culture.gov.uk/GrantDetails.aspx?ID=22473758&DBID=AE](http://www.lottery.culture.gov.uk/GrantDetails.aspx?ID=22473758&DBID=AE)
- (7) [www.watershed.co.uk/news/first-dancerroom-spectroscopy-festival-announced/](http://www.watershed.co.uk/news/first-dancerroom-spectroscopy-festival-announced/); [www.theguardian.com/science/small-world/2013/oct/25/dancerroom-spectroscopy-invisible-world-visible](http://www.theguardian.com/science/small-world/2013/oct/25/dancerroom-spectroscopy-invisible-world-visible)
- (8) RTS award: <http://www.bristol.ac.uk/news/2013/9200.html>, Prix Ars Electronica: <http://prix2013.aec.at/prixwinner/11898/>, University of Bristol public engagement award: <http://www.bristol.ac.uk/news/2013/9429.html>.
- (9) List of over 35 dS press stories: <http://dancerroom-spec.com/press/>.
- (10) Dick Penny, director of Watershed Media Centre: [dick@watershed.co.uk](mailto:dick@watershed.co.uk), Clare Reddington, director of Pervasive Media Studio: [clare.reddington@watershed.co.uk](mailto:clare.reddington@watershed.co.uk).
- (11) Forward focus semifinalist video: <http://vimeo.com/51890018>.
- (12) Interactive Scientific website: <http://www.interactivescientific.com/>.