e-Research Infrastructure Development and Community Engagement

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Abstract

The UK and wider international e-Research initiatives are entering a critical phase in which they need to move from the development of the basic underlying technology, demonstrators, prototypes and early applications to wider adoption and the development of stable infrastructures. In this paper we will review existing work on studies of infrastructure and community development, requirements elicitation for existing services as well as work within the arts and humanities and the social sciences to establish e-Research in these communities. We then describe two projects recently funded by JISC to study barriers to adoption and responses to them as well as use cases and service usage models.

1. Introduction

The UK is entering a period in which significant distributed computing and data resources are being made available to researchers and higher education staff. Different disciplines have engaged with these facilities to differing extents. For example, for some communities within high-energy physics and biomedicine these services are becoming essential to everyday work while other disciplines are currently investigating how they might match their needs. The deployment of e-infrastructure, whether within institutions, nationally or internationally, has the potential to increase the pace, impact, and efficiency of research both within and across disciplines.

In order to capitalise on the leading position which UK e-Science has established internationally and the opportunities this brings for the UK research and higher education community, the process by which members of this community can adopt e-infrastructure must be first understood and then made as smooth and well supported as possible. The Joint Information System Committee (JISC) has funded two projects under the Community Engagement and Support strand of its e-Research Programme that aim to study the barriers to uptake as well as the ways in which e-infrastructure is adopted in order to develop interventions that will make e-infrastructures available to a wider group of researchers. This paper gives an overview of the thinking behind these projects, previous work done in the area and the activities we are planning in order to achieve the project aims.

2. Uptake of e-Research

As with any innovation, potential users of e-infrastructure face numerous barriers that can delay or even prevent adoption (Rogers, 1995; Molina, 1997). For e-infrastructure to be widely adopted, costs for users must be outweighed by the benefits they reap. Potential users must be aware of e-infrastructure, must understand the advantages it can bring to their own research, must be willing to invest in new skills, and must have access to the facilities and support they need for successful adoption. At the same time, e-infrastructure services must be reliable, robust and usable so that users are able to trust their mission critical work to them. Finally, users must be confident that services will continue to improve in response to their needs so that they can derive increased benefit over time.

In order to understand issues of uptake, we need to better define just who the users are and what motivates them to get involved or not. We may, for example, distinguish between 'early adopters' or 'late adopters'. These crude labels should not, however, be read as character types but as pointers to decisions people make with regard to their choices to engage or not. It is sometimes possible to identify patterns of adoption, i.e., peoples' behaviour often follows similar lines with respect to different technologies as they apply roughly the same approaches to evaluating the potential usefulness of different technologies (for their own good reasons).

For example, people may tend to follow the example of leaders in their community or may tend to wait until commercial offerings are

available. For some users, the 'network effects' e-infrastructure exhibits may be foregrounded, i.e., adoption makes sense only if there are sufficient other users. Late adopters may also be less technically skilled or more risk adverse, preferring to wait for technologies to stabilise, for entry costs to fall and to capitalise on the experiences of early adopters (Williams et al., 2005). In rare cases, adoption may occur in response to an immediately identifiable solution which e-infrastructure provides for a particular research question or scenario. Any particular person or group of people will normally consider a number of factors pertinent at the time when they make their decisions.

Understanding these patterns then gives us a handle on what interventions might increase the uptake of e-Research and lead to more sustainable use. Strategies need to be devised to address barriers, for example, by providing clear development roadmaps and migration routes. Late adopters, for example, may require direct and personalised support in the form of staff development courses (both face-to-face as well as supporting self-paced and remote learning); specific consultancy to develop new applications to utilise services in novel ways; and a single well-curated source of exemplars and information about technical components and services.

Different user communities will be at different phases of the adoption cycle at any one time and so support has to be provided for all phases simultaneously. As communities' requirements mature, their support needs may also change. e-Infrastructure users will go through cycles of evaluating requirements and assessing the appropriateness of services while providers will similarly go through cycles of improving services and developing new ones to meet developing needs. Accordingly, potential user communities – and their experiences of barriers – are likely to be highly diverse.

3. Previous Work

In the following sections we wish to give a brief overview of existing work on uptake of e-Research and e-infrastructure development to provide a backdrop for the subsequent discussion. Due to the space available, we will limit this to a few examples. First, we wish to discuss existing work on the formation of infrastructures and communities before we look at two reports aimed specifically at informing service provision in the UK. Finally, we will discuss uptake of e-infrastructures for research in two disciplines that are not traditionally associated with use of sophisticated IT resources, social sciences and arts and humanities.

3.1 Understanding Infrastructure

A recent report investigating what we might learn for the development of e-infrastructures from earlier infrastructures (such as rail or telephone systems) has highlighted the fact that while any specific process of infrastructural development is contingent and while there is much uncertainty at any point in time, there are also "shared patterns, processes, and emergent lessons that hold widely true across the comparative history and social study of infrastructure" (Edwards *et al*. 2007).

Two related important insights from studies of infrastructure development are that "effective infrastructures are rarely 'built' in an entirely top-down, orderly, and blueprint-like way" (ibid, p.2) and that use of technologies, and in particular infrastructural ones, is often deeply embedded in a complex web of socio-material relations. A corollary, and one that computer scientists often ignore, is that there is significant continuity in the development of technologies and their use. It is important to understand just where the changes through technological development will impact on or be resisted by the ways in which research is socially organised (*ibid*. p.5).

Social organisation and technological development *mutually shape* (Williams and Edge 1996) each other, so rather than thinking in terms of 'building' or 'designing' infrastructures, we need to embrace the notion that we are making targeted interventions in a field of complex relationships and that we can never fully predict the outcome of these interventions. History suggests that the most successful attempts to create infrastructures have been undertaken by those who understood this and have consequently sought to align their technological projects with interventions in the social space. Hughes (1983) calls these people 'system builders' because they do not focus on single technological components but take a broader view of the whole network of innovation that is required for infrastructures to emerge. Thomas Edison is often named in this context but more examples can be found throughout history and also in the computing industry (Edwards *et al*. 2007).

As mentioned above, it is possible to detect patterns in the development of infrastructures. One such pattern describes how initial barriers holding back development on a wider front (or reverse salients, cf. Hughes 1983) are often

overcome by the development of solutions aimed specifically at overcoming these barriers (e.g., gateways, cf. Egyedi 2001) which often get deeply embedded in the socio-technical arrangements of use, creating *path dependencies* that constrain future development. Often, the choices made to overcome the identified obstacles are not optimal in the long-term but once established they are difficult to change, potentially creating 'lock-in' to suboptimal solutions. Of course, this course of events is not inevitable, yet it is common in technological development. One area of activity that is crucial in this context is standardisation: we need to understand how we can shape the process of standards development to ensure that we standardise the right things at the right time in order to foster flexibility and avoid lock-in.

The field of e-Research has reached the technology transfer stage which is crucial in the development of infrastructure. While a set of common underlying technologies exists and there is a certain level of convergence at the middleware level, applications are often still very much tied to the specific circumstances in which they have emerged, thus hindering their wider diffusion to, re-embedding in and uptake in other areas. These specific circumstances may relate to technical issues such as interoperability with existing IT infrastructure just as much as social ones such as having policies in place for the operation of e-Research applications and the management of e-Research data.

Furthermore, we encounter a number of areas where tensions exist between the interests of different stakeholders and where the costs and benefits of moving towards an e-Research paradigm are unevenly distributed. Perhaps the best example is the case of data curation and publication. Researchers are increasingly asked to share their research data, often created through public funding, and make it available to the wider research community. Yet for the individual researcher, this incurs extra cost in terms of necessary quality control, creation of attendant meta-data and a commitment to long-term preservation. Set against this are very intangible and uncertain benefits. In addition, there is a tension between the local, immediate use of data versus concerns about their future use by others which may require different formats, different prioritisation and selection, and so forth.

This also exemplifies the common disconnect between the drivers of a technological vision and technology developers on the one hand and the various 'users' of these technologies on the other. This disconnect has been a problem in IT for a long time where the problem of establishing a working relationship between technology design and use has led to many developments being abandoned and written off, sometimes at the same time as users take up what might be seen as inferior alternatives by the technologists. In e-Research, this tension is emphasised by the fact that the project involves multiple, largely independent stakeholders with their own separate agendas which are only partially and temporarily aligned and by the fact that the aim of the exercise is not merely the automation of an existing process but a radical socio-technical innovation of research practice. Visions of why this practice should be transformed, just how and using what means are likely to differ.

Finally, we need to consider ownership and investment models, or what Edwards *et al*. (2007) call the political economy of infrastructure. At the highest level there are questions about the role of public funds, central steering versus decentralised development and decision making as well as (trans-) national cooperation and coordination. At the project level, issues of confidentiality, intellectual property, commercial exploitation of results and etiquettes in collaboration are of importance.

In order to achieve wider uptake of e-Research and sustainable use of e-infrastructures, it will be crucial to drive developments *within* research communities rather than just offering services *to* them from an outside position. Ultimately, the vision behind e-Research will only be accepted, taken up and further developed by researchers if it becomes their own project and is shaped by their own concerns. What is needed, therefore, is a certain amount of 'activation energy' that will help overcome the hurdle of establishing a programme of discussion and development within research communities that can help to develop ways in which they engage with, take up and shape e-infrastructures.

The engagement with research communities needs to target both individual researchers and existing social structures such as professional societies which often have a role in establishing formulations of 'good practice' in their subject areas, are involved in building sustainable (technical) support structures, training programmes, and so forth. However, as e-Research is often multidisciplinary, we need to encourage work across the boundaries of traditional discipline-based structures to support the formation of communities organised around

particular research questions (Borda *et al.* 2006) rather than disciplinary boundaries.

3.2 Informing Service Provision in the UK

In the past few years, several initiatives have focused on the identification of requirements for the development and support of e-infrastructure for the UK research community. The Office of Science and Innovation (OSI) within the DTI is responsible for UK Science Policy and for funding basic research allocated via the Research Councils. In 2004, in response to the *Science and Innovation Investment Framework 2004-2014* published by the Treasury, the DTI, and the DfES in 2004, it commissioned a Working Group (and sub-groups) made up of senior representatives from the Research Councils, JISC, RIN, and the British Library, to explore the current provision of the UK's e-infrastructure and help define its future development.

The final report, published in 2007, summarises the findings of the working groups and outlines the steps required to ensure that the UK has the e-infrastructure required to support data-led research and new forms of scholarly publication. Whilst each of the sub-groups made a series of recommendations relating to data creation and curation, search and navigation, virtual research communities, and networking and computational capabilities, a number of recurrent themes were also identified. These included: engagement with UK industry, interoperability and global integration, policies to encourage culture change, coordination at all levels, quality assured e-infrastructure, and the provision of training.

Other initiatives with similar aims but including an additional remit to identify short-term requirements addressable within existing funded initiatives include the EPSRC and JISC funded Study of User Priorities for e-Infrastructure for e-Research (SUPER) and the JISC funded Intute Research Support Theme. SUPER, as well as identifying longer term requirements (3-5 years), outlines a set of short-term (6-18 months) priorities for existing national e-infrastructure providers: OMII-UK, NGS, and DCC (amongst others), being the specific audiences in mind. Following feedback by the e-Research community in early 2007, the final report was published in April 2007. The Research Information Network (RIN) published the results of a study into researchers' requirements for discovery services (Nov 2006), the conclusions of which were similar to those reached by the Intute Research Support Theme. The Intute study, however, addressed resource discovery requirements with a specific aim to improve the Intute service (at the core of which is a database of web resources for education and research)

3.3 SUPER

The SUPER report (Newhouse *et al.* 2007) identifies five recurring common issues and gives recommendations in three broad areas: software, policy, and support. These findings are based, primarily, on a qualitative analysis following a series of unstructured interviews in late 2006 with representatives from approximately 30 UK e-Research related projects. Those interviewed were classified as end-users (current or potential end-users of e-infrastructure), technologists (those building or adapting existing technology for a specific set of end-users), and generic tool developers (those building technology for the 'mass market' for use in multiple disciplines). A draft of the report was endorsed at a meeting of the UK e-Science Centre Directors' Forum in January 2007, and its findings further supplemented through a workshop in February 2007, and an online survey.

The findings presented in the report are pitched at a relatively high level and generally avoid citing concrete examples of the actual use of e-infrastructure by discipline communities. There was, however, an indication of a movement away from the use of home-grown solutions towards the adoption of third-party offerings, although this movement was, according to the report, being hampered by a 'notable lack of information about what is truly available'.

In terms of software provision, work was recommended in the areas of data management, virtual organisations (VOs), simplified authentication, and the integration of e-infrastructure with existing user environments. Data management, in this context, referred more to the management of data found in files, rather than data held in databases. However, the question whether issues with the use of databases were underreported was raised at the SUPER workshop . The report also highlighted the lack of agreed definition of a VO much beyond a mechanism giving groups of individuals across different organisations, coordinated access to various services such as data storage and computing capacity. In the area of user environments, it was recommended that work be carried out to provide a consistent (for example, PBS-like) scheduling system and command line across multiple Grids.

The policy and support recommendations outlined in the report complemented the proposed software recommendations to help encourage a wider take-up of e-infrastructure by the UK research community. They focused on providing a number of materials and consultancy for end-users, developers, and those deploying e-infrastructure, for example, by producing 'best practice' documents and schemes, providing consultancy and training, self-help materials and tutorials, and outreach and education for late adopters.

3.4 RIN and Intute Resource Discovery Studies

The RIN commissioned report, "Researchers and discovery services Behaviour, perceptions and needs" (RIN, 2006) aimed to investigate the perception and use of resource discovery services by the academic community. The work was undertaken primarily through the interview of 450 members of the research community (including librarians). The findings are wide ranging, which is perhaps not surprising given the multidisciplinary nature of the community. Key findings included: frustration at not being able to access resources discovered; researchers use a large variety of services within different disciplines and at different points in the process; networks of peers are very important for support; there is an underlying fear of missing anything important (so email alerting and similar services are popular).

The Intute Research Support theme report "Supporting the Research Community - A requirements report" (Wilson and Fraser 2006) addresses the specific objective that the Theme "undertake and publish an analysis of the needs of the research community with respect to online resource discovery in general and Intute in particular". The bulk of the findings were generated through an online survey carried out between March and April 2006. The survey attracted responses from 355 researchers from over 100 different institutions. The design of the survey and ideas for additional Intute services were informed through a number of informal interviews with practising academic researchers and those working on developing requirements for Virtual Research Environments (VREs).

The report uses the findings from the survey as the basis for recommendations on how Intute should develop its service further to meet researchers' evolving needs. These recommendations include both short-term usability improvements to its existing core services but also suggestions for the development of a series of value-added services such as community feedback mechanisms, allowing for user submissions, corrections, ratings, and reviews; databases for funding opportunities, events, researchers, training resources, and academic mailing lists and forums. For many of these, it was recommended that feasibility studies be set up to assess the applicability of building relationships (both technical and organisational) with existing services.

3.5 Disciplinary Perspectives

The Arts and Humanities Data Service (AHDS) has completed an e-Science Scoping Survey which identified opportunities that e-Science offers Arts and Humanities, as well as strategic reasons that Arts and Humanities researchers are not yet engaged with e-infrastructure. Experience to date, further reinforced by the outcomes of the recent AHRC e-Science Research workshops, and EPSRC e-Science demonstrators, suggests that an effective e-infrastructure is critical if the adoption of e-Research in the arts and humanities is to be realised (cf. Anderson 2004). This underlines the premise that, for arts and humanities disciplines, an infrastructure that makes it possible to identify components of complex data, compute resources, and human expertise and then connects within and between them, is critical. These activities showed that there are specific needs that have to be addressed to make e-Research work within these disciplines. The data relevant to humanist research is particularly fuzzy and inconsistent as it is not automatically produced, but is the result of (often dispersed) human effort. Data in arts and humanities is discursive and not just empirical collection of factual data. It is fragile and its presentation often difficult: for example, data in performing arts that only exists as an event. Any e-infrastructure for arts and humanities research will need to take account of this if it is to be useful, or even usable, for the researchers involved.

In 2003, the Economic and Social Research Council undertook a series of scoping studies of e-Science (Cole et al. 2003, Fielding 2003, Anderson 2003, Woolgar 2003,). These studies focused equally on applications of e-Science in social science research and on how the social sciences might contribute to the achievement of the goals of the UK e-Science Programme for the wide take-up of e-Science. Following the commissioning of a number of Pilot Demonstrator Projects, small scale explorations of the use of e-Research infrastructure and methods, the National Centre for e-Social Science was launched in 2004. Its research

programme is divided into two strands. The applications strand is aimed at stimulating the uptake and use by social scientists of e-infrastructure in order to achieve advances in both quantitative and qualitative economic and social research. The social shaping strand is defined very broadly to include all social and economic aspects of the genesis, implementation, use, usability, immediate effects and longer-term impacts of e-infrastructure.

Data has been one of the key drivers for NCeSS from its inception. The social sciences face a challenge to increase the value to research of the 'data deluge' – the profusion of multi-media digital data being generated that is relevant to understanding socio-economic processes. Some of this data is the result of ESRC data infrastructure investments in accordance with its National Data Strategy and some is 'naturally' occurring through the proliferation of mobile digital devices and online services. e-Infrastructure has been identified as the means to provide researchers with better tools for locating and accessing this data, cleaning it, maintaining its security and confidentiality, combining different datasets, and facilitating secondary analysis.

4. The Enabling Uptake Project

The Enabling Uptake of e-Infrastructure Services project involves the National Centre for e-Social Science (NCeSS), the National e-Science Centre (NeSC), and the Arts & Humanities e-Science Support Centre (AHeSSC). It develops strategies to deepen and widen uptake of e-infrastructure and significantly increase the user-base of JISC-funded services. Involvement of actual or potential users of e-infrastructure services is a key element in this: what we aim to achieve is a change in culture, in the way that researchers see their practice and the role that advanced information technologies play in their work. At the same time, we wish to provide service providers and technology developers with a sound grasp of problems as perceived by users. In addition to the tangible outcomes of the work, we envisage that this culture change will help to achieve wider impact and sustainability. Both of these elements will feed into and benefit from other (JISC-funded) activities such as the e-Framework and VRE programmes, and Call III of the e-infrastructure programme (Use Cases and Service Usage Models).

The project will be structured around three main activities: desk-based research and systematic synthesis of current work being undertaken by the three partners on barriers to adoption within their respective communities; a series of case studies to understand these barriers in detail; development of a coordinated set of responses to these barriers – such as outreach, training and exemplars – with active participation of the user communities to develop them.

The user requirements case studies will be conducted through surveys of research communities, interviews with key stakeholders, including: researchers and working e-Scientists, e-infrastructure builders, members of e-infrastructure support initiatives, resource providers and funding agencies. Where appropriate, interviews will be conducted using Access Grid or by telephone. The study design will incorporate several key dimensions: discipline (physical sciences, systems biology, medicine, social sciences, arts and humanities), e-infrastructure components (e.g., middleware, security, service registries) and services (e.g., NGS, OMII, DCC, Access Grid Support Centre, NaCTeM, EDINA, MIMAS, UKERNA, Viznet).

We will complement surveys and interviews by taking advantage of our existing activities that supporting adoption through training. These activities can occur at multiple points in the adoption cycle. For instance, there are frequent requests from communities at the stage of assessing whether or how they should engage with e-infrastructure. Making use of these activities has the advantages of:

1. providing an existing group from communities, in all domains, who are willing to engage,
2. bringing together representatives from multiple groups to interact with a focussed manner,
3. providing access to users who interacting with the e-infrastructure to do real tasks
4. enabling production of training materials that are collations of tasks common to different user groups

Through the case studies, the project will map the adoption of e-infrastructure across different research fields, and investigate similarities and differences between them. It will then use these findings to identify the main barriers to the wider adoption of e-infrastructure and how they manifest themselves within different user communities. Following from this, we will identify appropriate technical and non-technical responses to these barriers. The key deliverables will have a direct value in helping to inform service providers in their future development of

services for these communities. They will also cultivate and influence the provision of training to address the identified barriers and influence the development of specific support services and self paced support materials to provide long term help for these communities. Further to this, funders will be able to tune their future calls in response to project findings.

The project will build on related activities already being undertaken by the partners in conjunction with members of their respective communities, thereby offering the opportunity for a quick start on this project and an increase in its scope and impact. For example, work will feed into the training, outreach and education activities already undertaken by the project partners. For example, through NeSC's Training, Outreach and Education team, we will feed into training activities in the wider contexts of EGEE, EGEE II, NextGRID, OMII-Europe and ICEAGE. An important vehicle will be the development and running of summer schools for researchers from various disciplines, the social sciences and arts & humanities in particular.

Further opportunities for cross-fertilisation exist with the partners' other activities around research on uptake and sustainability of e-Research such as the e-Science Institute Research Theme on 'Adoption of e-Research Technologies', the EU funded project on 'Accelerating Transition to Virtual Research Organisation in Social Science' (AVROSS) and the Arts & Humanities e-Science Support Centre.

5. eIUS: Use Cases and Service Usage Models

The eIUS Project is led by Oxford University's Research Technologies Service and e-Research Centre in partnership with NCeSS. Its aim is to gather and document evidence of how e-infrastructure is currently being, or planning to be, used to facilitate the research process. (across all major disciplinary areas). This is not simply a requirements-related project but rather is intended to broaden participation in the use and future development of e-infrastructure services. In this respect the project builds on the work done by early adopters in order to appeal to 'mainstream' and 'late' adopters. eIUS is not confining itself to national e-infrastructure but will also investigate UK researchers' interaction with institutional and international e-infrastructure.

The Project will gather evidence through interviews, 'talk aloud' observational studies, and focus groups. Participants will be drawn from across the subject communities, identified from the user communities of existing e-infrastructure service providers and projects. From the raw evidence (the 'experience reports'), we will construct use cases that will describe a range of scenarios of technology usage (in the sense of idealised 'stories' describing 'a day in the life of' typical users in a typical context). The use cases will articulate the roles, stakeholders, goals and steps taken to reach the scientific aims and will demonstrate the ways in which e-infrastructure plays a role in these endeavours.

Each use case, which will be linked back to a series of experience reports, will be developed incrementally through a process of frequent review and validation by members of the discipline communities, to provide an element of quality assurance. We will also attempt to incorporate other types of media, where appropriate, to offer the consumer a more meaningful interaction with the use case and avoid a simple docucentric approach to the development of use cases.

In a further step of abstraction and bringing in a perspective on particular services or service genres, we will define Service Usage Models (SUMs) linked back to the evidence base found in the use cases. These will bring together the research processes with the behaviours and choreographies related to the usage of services and service genres. SUMs are a core component and concept of the e-Framework Initiative, funded by JISC and the Australian Government Department of Education, Science and Training. Their purpose is to further the adoption of service-oriented e-infrastructure by providing information on how particular research activities can be supported through the combination of existing services. Publishing such 'beaten paths' can help reduce the effort involved in developing service-oriented domain applications. Finally, SUMs can be used as a way of better directing the effort of technology developers, service providers and funders, ensuring their offerings address real needs.

The project intends to develop a self-sustaining community of e-infrastructure users and providers, supported by a community portal hosted at NCeSS. The portal will enable the deposit, peer-review, and enhancing of the experience reports, use cases, and service usage models. This, together with other dissemination activities, we hope will encourage the establishment of a network of technology developers, e-infrastructure providers and users, helping to develop a sustainable support model for the future. eIUS differs from previous

projects in that it sets out to collect concrete information about use of e-infrastructures for research and to make it available in an easily accessible form.

6. Conclusions

e-Research involves complex changes in the way that research projects are done and these are likely to be more complex and difficult to achieve than the technological changes. It is, therefore, premature to assess the achievements of the initiatives like the UK e-Science Programme at this point as a number of crucial developments have not taken place yet. In many areas of research, there are still no established practices that effectively *embed* new working practices and technological support in the normal practices of research communities. What is needed, very often, is to build *communities* of research practitioners that drive forward these developments.

The vision of e-Research involves a transformation of the 'what' as much as the 'how', that is, it sets out to change the targets and objectives that researchers set themselves as well as the means to achieve them. This is inherently a challenging task and we see some evidence that there is an interesting tension between the 'grand vision' and what might perhaps more modest but achievable aims. Perhaps we need to better understand how the activities involved in research and start supporting them before we can move on to the next level of innovation and start transforming the 'what'. What seems certain is that we need to better understand the processes that shape emerging e-infrastructures and the possible interventions we can make in this space. This kind of knowledge can only be attained through a combination of research and practical experience which will involve people from different backgrounds, in different roles and with different interests.

The two projects we have outlined here, together with the other activities within which they are embedded, are specifically designed to achieve this. It is an important aspect of these projects that they are not designed to be one-way roads but seek to provide opportunities for dialogue through various forms of *community engagement, mutual learning and shaping*.

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