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1 Overview

In this Deliverable, we summarise the findings of the state of adoption of e-Infrastructure services and e-Research practices documented in Deliverable D1.2 and outline a number of recommendations for their further development that can be acted upon by different stakeholders such as funding bodies, service providers, institutions, intermediaries and researchers themselves.

In making the recommendations presented here, we have been careful to go back to previous studies of e-Infrastructure adoption. This has served a number of purposes. It has enabled us to check where the evidence collected in the present study is corroborated by these earlier studies; it has been useful to review the recommendations (if any) that were made to address the findings; and, finally, in cases where there were recommendations intended action by UK e-Infrastructure stakeholders it has been instructive to reflect on their impact, if any.

The most significant of these studies were: the Study of Users' Priorities for e-Infrastructure for Research study (SUPER: Newhouse *et al.*, 2007); the AHRC e-Science Scoping Survey (Anderson, 2007) and the Accelerating Transition to Virtual Research Organization in Social Science study (AVROSS: Barjak *et al.*, 2007). Finally, where relevant, we have drawn on the recommendations of Century of Information Strategy report (Atkinson *et al.*, 2008) which, via the involvement of the project members, has itself been influenced by e-Uptake findings.

We recognise that the JISC does not have the remit to act on these recommendations alone. Our hope is, however, that the JISC will be able to play a major role in helping to ensure that the process of initiating discussions between the stakeholders can begin in earnest. The fact is that the challenges in realising the wider and effective exploitation of e-Infrastructure are such that we will fail to meet them unless all the stakeholders are able to work together to devise solutions.

1.1 Current State of Adoption

The present study has highlighted a broad range of applications of e-Infrastructure services and e-Research methods. As might be expected, the patterns of adoption differ between different kinds of institutions as well as between disciplines. While the type of research conducted in this study does not provide quantitative evidence of the level of uptake and the importance of issues uncovered, we can point to some repeating patterns that occur throughout our fieldwork, and which we feel are of sufficient significance to merit attention and to provide an evidence base for a number of recommendations.

1.2 Outreach, Training and Education Recommendations

Our findings relating to lack of awareness reported by our interviewees of the e-Infrastructure services available and how they might be exploited echo those of the earlier SUPER (Newhouse *et al.*, 2007) and AHRC scoping studies (Anderson, 2007). *one barrier is having not heard of these things.*

While our study follows on relatively closely after the previous two, it is nevertheless a concern that little progress seems to be being made in raising awareness.

Some progress has undoubtedly been made towards meeting the recommendations of the SUPER report (Newhouse *et al.*, 2007):

- Outreach and education about what is possible to non-traditional communities.

- Provision of self-help training materials and hands-on tutorials delivered to users throughout the UK through national and local trainers for common tools and software being used within the UK community.

The eIUS project, with its use cases and the use of short videos to communicate them, and the e-Roadshows piloted through the course of eUptake project and the Research in a Connected World brochure have made a promising start in developing new formats and dissemination mechanisms for raising awareness.

It's been interesting [...] when people start going out and about and just saying what it is possible to do just how much excitement you can generate [...] it seems to be working quite well in terms of getting engagement.

Recommendation One: What eIUS and e-Uptake have been able to achieve, however, is only scratching the surface and more investment is clearly needed here. It is equally (if not more) important (and further investment would only go some way to addressing this) to convince researchers of the value of disseminating their successes in forms which not only communicate them effectively to their own disciplines but can also serve as a more general awareness raising tool. Incentives need to be devised to recognise such work in terms of the RAE/REF. Indeed, we would endorse the Century of Information Strategy report's recommendation that *"The funding bodies should make the award of grants and the evaluation of their outputs include a significant element of contribution to education in the domain of the research."* (Atkinson et al., 2008, p.21)

Overall, on the basis of our evidence, it is hard to disagree with the Century of Information Strategy report's conclusion that *"[...] the current investment in outreach and training will not generate a sufficient increase in uptake nor be sufficiently transformative – actions are required."* (Atkinson et al., 2008, p.21)

Training needs to be clearly structured and targeted in a timely way at key audiences. At the moment, many researchers attending training courses are confronted with command-line tools that they are unlikely to adopt. Instead, the training for end users should focus on distributed computing principles and the use of application environments, portals or desktop tools.

One theme that has not surfaced in previous studies but which comes out strongly from our study is the importance of integrating outreach, education and training activities, an issue also emphasised by the CIR Strategy: *"Addressing this communication and training deficit is an urgent and essential part of the change management necessary to transform a significant proportion of UK research. If it does not reach those already engaged in their research careers they will be unable to contribute to the new research and are liable to feel disenfranchised and undervalued."* (Atkinson et al., 2008, p. 33).

e-Research practices need to be embedded in the education of future generations of researchers to achieve the scalability of training efforts and thereby wider uptake and more routine usage. The CIR strategy makes the same point:

"[...] the goal should be that every graduate will have the opportunity to appreciate the emerging digital information age, including the opportunities provided by ICT-enabled collaboration, data collection, computational modelling and analysis. It is envisaged that HEIs will provide foundation courses for all students and more advanced courses for many disciplines, such as medicine, life sciences, earth sciences, physical sciences and engineering. The majority of doctoral and masters programmes should

one of the biggest challenges that faces us is translating all of this stuff into the next generation of suitably equipped PhD students and young researchers [...] we need a much more structured approach to postgraduate training than we have at the moment.

have relevant elements developing the ability to exploit e-Science. A substantial proportion should prepare their graduates to engage in the creation of new e-Science-enabled methods.” (Atkinson *et al.*, 2008, p. 34).

The CIR recommendations are echoed by the AVROSS report which also stresses the importance of graduate education (Barjak *et al.*, 2007, p. VIII):

“Funding and training are key issues in building the capacities for e-research and making e-Infrastructure sustainable. Graduate education provides the basis for a professional research career and teaches the standards of research in a field.”

The Century of Information Strategy report goes on to make a series of interlocking recommendations for outreach, training and education which we believe provide a useful starting point for developing a more coordinated and hence far-reaching response (Atkinson *et al.*, 2008, p. 32-33):

1. Establish several levels and forms of training and agree the curricula.
2. Develop and share training materials, and deploy suitable delivery methods, including access to self-paced learning, as many researchers wish to acquire a skill when their research generates the requirement.
3. Liaise with professional bodies and skills accreditation bodies to embed the training in standard practice to raise quality and recognition.
4. Work with research leaders to ensure that researchers are given the opportunities to develop their skills through training. The research councils and the Committee of Vice Chancellors and Principals should establish expectations that encourage relevant training.
5. The research councils, the Higher Education Funding Councils and JISC should organise a programme of communication and awareness raising that will alert researchers to the new methods and facilities, and encourage the uptake of training. This should include a requirement in all research grants to contribute effectively to outreach about the value of the research and its dependence on the nationally supported e-Infrastructure.
6. Work with industry and the Technology Strategy Board to agree training attainment targets and to establish a two-way flow of knowledge on the development, deployment and use of new research methods and technology.
7. Establish flagship examples through funder-university-industry consortia to showcase the opportunities and benefits and work with media organisations, museums and schools to disseminate their value.
8. Persuade high-profile research leaders to expound the achievements that have been made possible through computationally enabled research – e.g., as a British Association for Science Christmas Lectures presentation.

perhaps there's a general need for more training that's aimed at the domain experts rather than e-Science experts.

Recommendation Two: Action should be taken to implement the recommendations of the Century of Information Strategy report. Plans should not only cover graduate training, targeting key audiences such as the newly established Doctoral Training Centres and Digital Economy Hubs, but must also recognise the vital importance of bringing e-Research to future generations of researchers through schools.

An important pre-condition for the wider availability of training is the provision of a training infrastructure that is available when courses are run and that is indistinguishable from the production infrastructure for all practical purposes.

Recommendation Three: Action needs to be taken now to provide this training infrastructure. This infrastructure does not need to be permanently installed but can be provided on demand through virtualisation and cloud computing mechanisms.

However, while the hardware resources can be provided on demand, there is a need for a continuous provision of human resources to keep training material and the training environment up-to-date and to provide an important outreach and liaison function.

The case of expanding on outreach, training and education programmes is unanswerable. It is important, however, that current programmes are reviewed in order to identify whether their impact is in keeping with expectations and that be problems properly diagnosed if this is not the case.

Recommendation Four: The present study, through **Deliverable 2.1.1 (Training Requirements Report)** and **D2.1.3 (Support Gap Analysis)** makes a useful start in this respect but we believe that more will need to be done in the future to monitor the requirements for, and provision of, training, outreach and education activities.

We return to general issue of putting in place the capacity to track the adoption of e-Research and e-Infrastructure in the concluding section.

1.3 Discovery, Access and Use of Digital Resources

e-Infrastructures for Research often provide relatively advanced functionality but it is important to recognise also that relatively simple services that are broadly applicable could have a similar impact. Issues of data management have been flagged up in previous studies (e.g.,

Newhouse *et al.*, 2007) and feature strongly in the responses we gathered (cf. D1.2 sections and xxx). e-Uptake Respondents raised a range of concerns about digital

in terms of dealing with relatively complex data and relatively complex analytical techniques, at least complex to the perspective of social scientists, there is this basic tension between describing things clearly and from an introductory level and having enough space to go into the more details, detailed output.

resources, most commonly in relation to research data. The problems encountered range from a lack of storage capacity to performance issues and problems with a lack of skills in curating and managing large and complex datasets. Many researchers use flat files where database management systems would offer a clear benefit. Many researchers share data by email where a secure data sharing facility would offer much more control and be easier to use.

The curation of digital resources is becoming an issue with which researchers are increasingly expected to grapple. For example, if new (or derived) datasets are to be discoverable, researchers must prepare them for deposit according to accepted standards. However, curation of

some researchers are a little concerned that putting either research papers or data in an institutional repository [...] they're worried that that will increase their workload [...] that will slow them down and take them away from actually [...] conducting research which is what they see their role as.

existing data is not an activity that researchers would generally define as part of their normal role. Our findings indicate that there is currently a greater awareness of issues of data curation amongst intermediaries than researchers.

Recommendation Five: The SUPER report made a number of recommendations for data management and curation. The findings from this present study would suggest that more effort needs to be made to ensure that they are acted upon (Newhouse *et al.*, 2007):

- Mechanisms to support controlled and convenient sharing of files between groups.
- Automatic data annotation and provenance tools to support domain specific schema.

- Development of common annotation schemes for individual communities to enable consistent meta-data labelling within these communities.
- Development of a best practice document to support research groups in developing their own data curation policy.

The findings of the UK Research Data Services Feasibility Study are that research data remains “*a substantially untapped resource beyond the originators in many disciplines*” (UKRDS, 2009) and it recognises that the scale of this problem can only grow as more and more research data is ‘born digital’. Working closely with centres of expertise such as the Digital Curation Centre, research funding bodies need urgently to develop data curation frameworks and ‘best practice’ guidelines for the discipline areas they support; data curation frameworks and guidelines already exist for some disciplines, but requirements may be such that their value as templates for newly adopting disciplines may be limited. At the same time, research funding bodies need to examine the case for policies requiring detailed data curation plans as a condition of research funding and for ensuring that data curation work is properly budgeted for.

Not all the problems researchers experience concerning data, however, are associated with curation and long-term archiving, what we may think of as the ‘end point’ of the data lifecycle. Researchers face difficulties in managing their data day-to-day as they collect, clean, share and analyse it.

We have spent endless hours, essentially one person full time on a big collaborative project negotiating [licensing] issues, and it’s just about got away through, but the fact that there is no national policy has cost us [...]

Recommendation Six: In addition to their current efforts directed at the long-term curation and preservation of research data, the JISC, service providers and HEIs must consider the day-to-day data storage, access and management needs of researchers, including issues such as licensing arrangements (which are often still in their formative stages) and security where datasets contain sensitive information. In the light of this, the recently announced JISC Data Management Infrastructure call is very timely. It must ensure, however, that the development of the ‘human infrastructure’ of data management services provision receives equal priority with the creation of the technical infrastructure.

The e-Research vision assumes transparent access to (multiple) distributed resources. The SUPER report found that this was still some way from being achieved and recommended that there should be:

- Reliable documented software base to enable virtual organisations built around individuals to gain access to services and resources, and collaborative mechanisms to facilitate research between these individuals.
- License management software, across a site and across a VO.
- Simplified authentication tools – better user interfaces and focus on ease of use and local (client) deployment.
- The definition of a set of recognised roles, actions and relationships to support the construction of virtual organisations.

Recommendation Seven: The findings of the present study suggest that there is still much progress to be made in meeting the SUPER report recommendations. While, for example, Shibboleth and the UK Access Management Federation offer a potential solution for many authentication scenarios, they are not without their problems. Practices for issuing certificates differ from one registration authority to another, with institutions adding to the complexity of the

at the moment, there is this huge XML file that has to be passed round which is here’s everybody that the UK Access Federation knows about.

process. Action needs to be taken to develop common policies and procedures for issuing certificates and to ensure that the SUPER report recommendations are finally met.

1.4 Human Infrastructure

It is increasingly recognised that the technical infrastructure needs to be embedded within a 'human infrastructure' (Lee, Dourish and Mark, 2006) consisting of social and organisational arrangements that enable the technologies to be effectively utilised. Our current capacity to deploy raw technical resources outstrips our capacity to use them effectively and to develop e-Research practices that tackle research challenges by bringing together research expertise into collaborative working arrangements over a sufficiently long period of time for the work to bear fruit.

there is a need for more people to sit down with scientists and work with them on their specific applications [...] people that understand both, people that can understand the applications and also understand how to grid-enable them.

Compared to the investments in the development of underlying technologies and the development of technical services, the investment into this 'human infrastructure' has been almost negligible.

This issue of human infrastructure features again and again within our own findings. One way deficiencies in the current provision of human infrastructure manifests itself is in the lack of understanding of user requirements. The AVROSS Report recommended involving users *"at all stages: conceptualization, design and development, diffusion [...] funding agencies should insist that users be involved at all stages of the development of the infrastructure, Funders should also reward projects that are user-centred and collaborative design, encourage the porting of existing tools to maximize adoption, as well as encourage projects that work within the users' current work environments."* (Barjak et al., 2007, p. VIII)

Recommendation Seven: The present study's findings emphasise the importance of local research support services adopting new ways of engaging with their users, for example, building deeper and more long-term relationships through the development of 'hybrids', intermediaries who combine technical and domain-specific skills.

One of the most frequently recurring themes relating to user support has to do with the lack of support structures that span the local provision of IT and support for research, the institutional provisions that provide economies of scale and the national provision that helps to align arrangements throughout the HE sector. As the SUPER report recommended, there is a need for:

"Better technical consultancy to end-users who wish to move their applications to use e-infrastructure services, developers who wish to use best practice to build e-infrastructure services, and deployers who need to configure e-infrastructure services for maximum performance and reliability – in general, better information with a human behind it. This needs to be a funded, coordinated service with experts behind it, simple lists are worse than nothing as they are always dated and often misleading." (Newhouse et al., 2007)

Integration generally is a common theme within our findings. As e-Research thrives on researchers' ability to combine resources creatively to tackle new research challenges, it does not suffice to provide partial solutions that exists as silos. To paraphrase one of our respondents, the key challenge is to keep the balls in the air at the same time, to foster the technical as well as human infrastructure, to develop new research methods as well as to create sustainable funding arrangements and organisational structures that enable trust to be built in these new practices.

Recommendation Eight: Funding bodies must seek to avoid fragmentation of effort by supporting coordinating structures such as discipline-specific programmes driven from within the application areas themselves. Taking into account the interdisciplinary character of e-Research, this support should contain an element of encouragement for new kinds of collaborations around thematic areas.

Problems have been caused by an undue emphasis on technological achievements at the cost of understanding the real circumstances of use and the impact of arrangements on the research process. To a degree, this is rooted in the fact that many technology providers are computer science researchers, who are evaluated by their production of papers and grant income rather than the production of technologies that are fit for general usage. Another element is the general problem that the emphasis in computer science education is on the technology and that computer scientists often do not have the conceptual vocabulary and research methods that would enable them to engage with their stakeholder communities.

it's one of the things that's sort of continually frustrating in the field is the assumed terminology if you know what I mean? That there's a lot of terminology that's come over from computing science which is never designed for the rest of us who actually do the science [...]

Recommendation Nine: There is a need for more practical knowledge about methods for studying working practices to be embedded in the education of technologists entering the field of e-Research. The combination of technological skills and an ability to conduct workplace studies and engage with application researchers is a key enabler for the development of hybrid skills that enable effective boundary spanning.

1.5 Sustainability

The initial cost of implementing e-Infrastructure services has often been covered by time-limited research grants. The level of completeness, usability and quality of what can be achieved given these arrangements is often limited. While initial development can often produce applications that are mature enough to be adopted by researchers, the initial use often gives rise to further requirements and to a need for ongoing maintenance that is not sustainable under these funding models.

So when you finally deliver something it's going to be a prototype it's never going to be a finished product. But they then start depending on it and then the problem arises because you don't have the funding or even the capacity to maintain [it ...]

Uncertainty about the long-term sustainability of e-Infrastructure services was a common concern for both researchers and intermediaries. As the AVROSS report notes, this is likely only to be resolved by the introduction of radical changes in how services are resourced:

"Funding agencies should ensure that the integration of applications into the work routines of [...] researchers is accompanied by sufficient support measures. These are costly, and it would be a false conclusion to expect that e-Infrastructure resulting from public research can be provided without any costs when the development has been terminated. An ingredient to success seems to be that new services are accompanied by minimal costs for the users." (Barjak et al., 2007, p. VIII)

Recommendation Ten: There is an urgent need to begin the process of negotiation among research community stakeholders that will lead to the development of business models that are capable, where appropriate, of monetising services in ways in which both research funding bodies and researchers find acceptable and affordable. Stakeholders should also strive to apply business models as uniformly as possible so that researchers are not faced with a complex landscape of different business models and service options.

I think the [AG] node here, there was an attempt to try and make it pay for itself or make it generate money, and people stopped using it and therefore the service was very sketchy but we were still quite reliant on it.

It is clear that the emergence of a pervasive set of new practices across disciplines will take some time. The fostering of a sustainable human infrastructure and, in particular, the emergence of sufficient numbers of boundary spanners who can act as facilitators will depend on the emergence of clear career paths for individuals interested in pursuing this career.

Recommendation Eleven: Assuming the role of an 'intermediary' or 'hybrid' is fraught with career risks. Funding bodies as well as HEIs must signal their commitment to supporting the emergence of such individuals by encouraging the development of clearer career progression routes and by acting to raise the profile of their research support services. Finally, as recommended by the CIR Strategy report, steps should be taken to ensure that such hybrid skills are recognised by professional bodies, such as the Engineering Council, the British Computer Society and the Institute of Engineering and Technology.

2 Concluding Remarks

e-Infrastructure promises those who adopt it access to an almost limitless range of resources for research. Its value as a facilitator of larger-scale and more multi-disciplinary collaborations, as an enabler of new kinds of research and for reducing 'time to discovery' is unquestionable. e-Infrastructure is, however, as the e-Uptake project has revealed, often seen by its users (both current and potential) as complex and challenging. From our findings, it is clear that current users often experience frustrations, while potential users may be unaware of its benefits and of how to take the first steps towards exploiting them.

It is clear that there is a continuing need to promote innovations in the technologies that underpin e-Research. Equally, those issues which we have categorised as social issues provide clear evidence of the need to improve the 'human infrastructures' which ensure that the research community has the capacity to exploit these technical innovations. As the AVROSS report also observed, the adoption of e-infrastructures is as often hindered by human and organizational issues as it is by technical ones.

There is clearly a need to continue to develop the technologies which constitute the technical of e-Infrastructure in order to create a more satisfying 'user experience': there is still much that needs to be done to deliver the vision of inter-operable services and resources, and to improve ease of discovery, access and use. It is on the human e-Infrastructure, however, that we believe that attention must be focused if wider adoption is to be achievable. Just as the technical infrastructure often fails to shield the user from the complexities of accessing distributed, heterogeneous resources, so too it seems that the human infrastructure often fails to provide the user with access to the right information and advice as and when they need it.

The overarching conclusion we draw from the social issues uncovered in the present study is the need to establish support structures for e-Research practices that span the local provision of IT and local support for research, the institutional provisions that provide economies of scale and the national provision that helps to align

arrangements throughout the HE sector. It is necessary to foster a human infrastructure that integrates across organisational boundaries and, hence, is better tuned to the technical capabilities of e-Infrastructure. Just as at the technical level, the e-Infrastructure community seeks to create an environment where location ceases to be a barrier to access to resources and to collaboration, it must also strive at the social level to create support arrangements that are coordinated nationally but grounded in a local presence that makes them pervasive and accessible.

Recommendation Twelve: Action is required to create a greater degree of integration and inter-working between service providers who operate at the national level and the support available to researchers at the local, institutional level to ensure that the former are integrated effectively in the latter. One of the goals must be to work to ensure that users experience a uniform service and support interface wherever they (or the service) may happen to be located. This is particularly important for services such as the Access Grid whose usefulness depends on them offering the same quality of service everywhere. We note the plans under National Grid Service 3 (NGS-3) to develop its services through the pursuit of partnerships with HEIs. We suggest that this might form a template which other national e-Infrastructure services could adapt in order to achieve a greater level of integration and cohesion with local support provision.

Recommendation Thirteen: In a similar vein, action is required by HEIs to foster closer collaboration between local support services and their users so that the former have a better understanding of the latter's requirements and the latter have a better grasp of the opportunities available to innovate their research methods and practices. Influencing the practices of local support services will be difficult. However, one way forward might be for the JISC to review and strengthen its requirements for user involvement in future calls for e-Infrastructure services development projects. In the meantime, we would also recommend the JISC build on the end of Community Engagement programme events held in June 2009 by convening a series of meetings where HEI local service support staff could share user engagement best practice and discuss issues in its implementation.

It is all too likely that any plans to meet the demand for more effective support structures will be compromised by lack of resources, both in the sense of expertise and funding. We suggest that there are solutions to this problem if we recognise the potential for leveraging the e-Research community's capacity to support itself and we believe that too little has been done so far to investigate what might be possible.

Recommendation Fourteen: Action is required by national service providers and local support services to devise new ways to leverage research community contributions to support infrastructure, for example, by exploiting emergent social networking tools. Within some research communities, these tools are already demonstrating significant impact as a means to facilitate ad-hoc, informal sharing of expertise (Waldrop, 2008): we believe that such approaches have the potential to expand into areas of relevance to research support service agendas. As with our recommendations for increasing community contributions to raising awareness and data curation, we recognise that the participation in such activities may need to be incentivised through appropriate reward structures at both the local and the community level.

We believe that activities such as the Community Engagement strand are essential to the continued success of the whole while e-Research endeavour. The importance of community engagement is being increasingly recognised internationally. For example, the NSF is funding a programme of work under its Virtual Organizations as

Sociotechnical Systems (VOSS) call¹. Likewise, the European Commission will be including a strand on Virtual Research Communities in its latest call under the FP7 programme. The outline of this strand contains a number of elements that are consonant with the aims of the e-Uptake project.

JISC has been pro-active in recognising the importance of the human and organisational elements of e-Infrastructures and has funded projects that have raised the bar for community engagement activities. We believe that while the current funded activities provide value to the community and will have a significant impact, research must continue in order to capture the continuing evolution of e-Infrastructures and e-Research methods, measure and reflect on adoption patterns, successes and failures, provide capacity for the early detection of new barriers and expertise to devise responses to deal with them.

Limited time and resources have constrained the scope and depth of our analysis: we hope that the data we have collected will continue to be of use to the community and we have made provisions through the Connexions platform to make this possible. Nevertheless, there is a danger that the evidence gathered by the projects ages and becomes less and less useful or even misleading as it no longer describes contemporary realities: the adoption of e-Infrastructure and e-Research is fast changing and dynamic as new user communities engage and new technological solutions come into play. As the AVROSS report stressed:

“The character and impact of barriers to adoption are highly likely to change as this process continues and a one-off evaluation activity cannot capture this. A research program that has the capacity to continually monitor adoption patterns, processes and challenges faced as e-Infrastructure diffuses into new [...] user communities will be central to maximizing the value of the investment. Such a program could provide feedback into the strategic planning and execution of e-Infrastructure programmes and projects. Monitoring could be instituted at three different levels: individual users and developers, research fields and research organisations.” (Barjak et al., 2007, p. IX)

Recommendation Fifteen: Arrangements currently in place for sustaining the outputs of the JISC Community Engagement strand will ensure that future activities will not have to start from scratch but have a solid foundation to build on. It is vital, however, that planning for these future activities begins now if we are to ensure continuity and avoid loss of momentum. Therefore, we would recommend to funding bodies that they consider including similar calls for community engagement activities in their future e-Infrastructure development programmes.

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