PERICLES - Promoting and Enhancing Reuse of Information throughout the Content Lifecycle taking account of Evolving Semantics

[Digital Preservation]

DELIVERABLE 2.3.5
Final Evaluation Report

pericles
FP7 Digital Preservation

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Glossary

Abbreviation / Acronym	Meaning
AM	Art and Media
CoP	Communities of Practice
Evaluand	The subject of an evaluation
RTD	Research and Technical Development

Executive Summary

This document is the third and final report in the PERICLES commitment to evaluating its research and development activities and results from a user perspective. It presents the applied evaluation methodology and the rationale behind the selected approach. The objective of this third evaluation campaign, which is summative as opposed to the two previous campaigns which were formative, is to elicit and report on a substantiated understanding on the value for systems-thinking of the PERICLES research results, and this from a real-world and professional practice perspective. Before presenting the results of the evaluation about the value of the PERICLES research, for both PERICLES case studies a baseline of challenges is described that were the anchor points for the RTD in the project.

The actual evaluation results, grouped per case study domain, are generated against three criteria:

1. how the PERICLES research can influence changing current practice;
2. to what extent the PERICLES research can generate momentum in emerging fields;
3. how a community can be developed and directed to a new social and professional network.

For the Art and Media case study, the most prominent evaluation results on the value of PERICLES research with respect to the criteria mentioned above are, respectively:

1. Adequate preservation of multi-component complex objects require extensive identification of key entities and dependencies, and maintaining and sharing a standardised vocabulary, to allow assess how future changes might propagate. The ontology and Linked Resource Model work prove very valuable in this regard.
2. We live in a world where digital advances are rapid, perhaps too rapid for relatively static established repositories to keep up the pace, let alone for them to advance to developing fully functioning preservation systems. PERICLES, both by its efforts in engaging communities of practice and by its technologies (such as ontologies, ecosystem description and tools), creates small changes in thought processes and manageable workflow adjustments, ultimately generating momentum into uptake and implementation of larger frameworks.
3. Although not paradigm-shifting in itself, PERICLES has potentially started the process of enticing communities of practice of expand their horizons and their roles. Collaborative and interdisciplinary interaction and knowledge sharing can bring disparate communities closer together, potentially resulting in a digital ecosystem that have a wide cross-institute applicability.

For the Space Science case study, the evaluation revealed the following points:

1. Traditionally, a major hurdle in supporting out-of-original-context usage of space science data (both experimental and observational) is underestimating its importance while at the same time fearing the extra costs in already expensive operational workflows. PERICLES creates awareness and offers education, notions and tools, nudging the scientific community in the right direction.

2. The PERICLES approach of not only involving data creators but also data acquirers is original and valuable as this more end-to-end treatment of data curation helps in fine-tuning the definition of the relevant ecosystem and in particular of what set of (meta-)data is required for future reuse that goes beyond the original treatment of experiment data into publications.
3. Often in contrast with Art and Media institutes, preservation of space science data requires extensive collaboration between numerous diverse actors with different agendas and expertise. Intelligent automated support of digital data, the main purpose of PERICLES, makes preservation both more powerful but at the same time more complex. Through its Communities of Practice, PERICLES has demonstrated that unfamiliar networked communication is possible and productive.

In addition to the use case partners providing a specialist judgment on the research, the range of underlying needs with respect to evolving digital ecosystems for preservation that formed the motivation for the PERICLES report were confronted with statements made by key members of the preservation community during the course of the PERICLES conference “Acting on Change” (held 30 Nov-1 Dec 2016 in London). The discussions during that conference are strongly supporting the validity of the needs that the PERICLES research surmised and sought to solve.

1 Introduction & Rationale

1.1 Context of this Deliverable Production

This deliverable reports on the final of three user evaluation campaigns determined in the PERICLES project's description of work (DoW). The context of the decisions made and outlined in this document, as to evaluators, evaluand and methodology, relates to the work done in the framework of the test bed scenarios and the research. It is based on a clearer understanding of what the users can effectively evaluate, taking into account the theoretical and experimental nature of the research at this stage and the fact that many results are not end-user oriented but components of systems architecture, better understood and to be assessed by IT experts. The work on the domain ontologies and the test bed scenarios are the parts in the project where the use case partners have most intensively engaged with the RTD teams and therefore the impact of the project on the user community has come from this engagement. This impact is being reflected here and the value it has for the use case partners in their role as representatives of the user communities is being assessed in this document.

1.2 What to expect from this Document

This document provides a summative evaluation on the value of the research carried out within the PERICLES project for the user communities represented by the two use case partners. It relies on the expert judgment of the two use case partners, in their double role as having (1) a better understanding of the project research outcome than the communities which they (2) represent.

1.3 Document Structure

The document is structured as follows:

Part 2 presents the methodology of the evaluation

Part 3 outlines the challenges against which the value of the research is being assessed

Part 4 assesses the value against the defined criteria

Part 5 attempts a synthesis followed by closing remarks.

2 Approach for a final evaluation

2.1 Methodological Considerations

Following the guidelines and terminology used in E. Jane Davidson's introduction[1] to evaluation, we outline in this chapter the approach chosen for this final evaluation. While the former evaluations described in deliverables D2.3.3 and D2.3.4 were formative evaluations with the "purpose of finding areas for improving an existing evaluand",[2] this present evaluation is a summative evaluation with the purpose to determine the overall quality or value of the evaluand (Davidson 2005, p. 14).

The question we needed to address first was, what is our "evaluand"? While in the first evaluation we mainly followed an approach with the individual tools being the evaluand, we already understood in the second evaluation that the innovative approach is the key purpose for the project and therefore, we evaluated key aspects of the project's overall approach during the second campaign.

For this final evaluation, we determined to evaluate the value of the research performed in PERICLES for the communities, "for whom something [...] should or might change as a result of a particular product, service [...]" ([1], p. 30).

In addition to identifying the evaluand and communities or stakeholders on which the research outcome would or could have an impact in the future, Davidson advises to describe the "needs" as assessed by the PERICLES consortium, for which the research would offer the solution.

Davidson distinguishes different aspects of needs ([1], p. 30):

1. Conscious needs versus unconscious needs
2. Met needs versus unmet needs
3. Performance needs versus instrumental needs.

We look in particular at the last category, that of *performance* and *instrumental needs*, with the former expressing the need "to do something, to be something or to be able to do something" ([1], p. 26) while the latter is a proposal for a need of a particular solution to meet the *performance need*, hence the "solution proposed".

The example she uses explains that distinction well: needing to be able to write emails on the plane is a *performance need*, while "needing" WiFi on planes would be the *instrumental need*, as would having a device on which to email (portable computer, smart phone etc.). Hence providing WiFi or a device would be the action to meet an *instrumental need* that derives from the (original) *performance need* of "having to be able to write emails on a plane".

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[1] [1] E. Jane Davidson: "Evaluation Methodology Basics: The Nuts and Bolts of Sound Evaluation" (2005). Sage Publications, Inc. Thousand Oaks, CA, USA.

[2] see Glossary entry "Formative evaluation", [1] p. 240

Let us start with what PERICLES understood the *instrumental need* to be, which is equivalent to a high-level description of the goal of the research undertaken for a *performance need* in digital preservation:

The performance need:

> Understand the impact of change in digital ecosystems, and make informed decisions on how to act with respect to the anticipated or occurred change.

To meet the performance need, PERICLES identified these **instrumental needs**:

> Managers/stewards/curators of digital resources need a proven concept of how change within digital ecosystems can be managed, as well as tools to provide them with reliable information on the impact of a change and services for automated support of acting with respect to those changes.

The solution proposed by PERICLES:

> Using ontological models to assess change impact and to act as a main driver for a suite of tools and services. These tools and services execute either automated executive workflows or provide information for human intervention to mitigate the impact of change on access and reuse of their digital assets.

What needs did the consortium assume to meet with their research?

- The lack of expertise and/or the awareness of the need to fully describe or apprehend an ecosystem and therefore understand or assess the impact of change
- The lack of resources to manage change within complex systems or objects
- The lack of technological support to replace time-consuming manual workflows in assessing planned changes and mitigating the impact of change

Meeting these needs should solve the issue of purely reactive change management, advocate informed decision-making and support automated workflow management.

During a project, additional performance needs often are detected on top of the originally identified performance needs. In the case of PERICLES, these became evident in particular thanks to the communication with stakeholders in our Community of Practice[3] meetings, training events and the final conference:

1. Day-to-day challenges are a priority, giving no time for more future-oriented solutions => need for a way to reduce high demand on human resources for challenges that can be dealt

[3] Communities of Practice (CoP) were introduced as an instrument to get expert engagement as source of inspiration from other similar research fields. Our definition for PERICLES is: 'A group of selected individuals having various professional roles who are expert practitioners representative of a given industrial, cultural or academic field who are periodically gathered together to discuss a fundamental question or set of issues relevant to the preservation of digital objects.'

with automatically, and to reduce the time investment of human decision-making processes, to allow focussing on challenges that require essentially human intervention.
2. The capability gap[4] => need to bring together management, curatorial and technical expertise to better collaborate and solve digital ecosystem and resource issues.
3. Historically grown categorisations, disciplines and terminologies => need to think “out of the box” to face the new challenges of the digital era.
4. Technology distrust[5] and responsibility assured through manual workflows => need to be able to interact with the technology and feel able to intervene where necessary, learn to trust automated workflows and technical solutions.

During the course of the project, the anticipated instrumental needs in response to these additional performance needs were extended and met as follows:

- Creating a tool that would help create ecosystems (to meet 1, 2 and 4)
- Submitting ontology design pattern for general and reiterative use (to meet 1 and 2)
- Enhancing the demo and training material (to meet 2 and 3)
- Creating the Preserveware portal[6] (to meet 2 and 3)
- Writing a white paper (to meet 2 and 3)
- Introducing CoP and organising a major conference (to meet 2 and 3)

The assumed performance needs have been part of the work done on understanding the functional requirements of any given system as expressed in the challenge descriptions by the use case partners. Obviously, our use case partners were aware of many of the performance needs listed above, which is why they joined the project. However, in discussions with community members, it became apparent that while most practitioners are aware of the threat that change can mean to access and reuse of digital assets, there is as yet no clearly defined formulation of the common global need to solve this problem. There is only little awareness of “what one needs to be able to do” in order to meet this challenge. The needs listed above, such as meeting the capability gap, reducing the distrust of technology or too high expectations (technology being the magic wand), the need to mitigate the impact of change and understand non-technological change, are corroborated by the communities, but do remain in the very fabric of non-digital preservation as measures to maintain the status quo or “original”, with a reluctance to accept change as a natural element of the digital environment. The *instrumental need* of being able to face a new practice of managing continually evolving digital repositories, have not wholly reached the awareness of the community. This makes it difficult to incite their decision-makers to consider the solutions proposed by research such as that of PERICLES. Both our use case partners are representatives from the community in their understanding the challenges and discussing the value and potential feasibility, but they are exceptional in their preparedness to follow the experimental scientific explorations proposed by the PERICLES IT researchers.

[4] “Capability gap” is currently much discussed in the preservation community and designates the gap between the two knowledge bases in the community: the “problem owners” (the practitioners) and the “solution providers” (IT developers).
[5] “Vendors: we do want your services … but we don’t trust you” (Paul Wheatley, *The DPC community: growth, progress and future challenges*, PASIG 2016, Prague, March 2016).
[6] http://www.preserveware.com/

Following Davidson's guidelines, such assumptions of needs as listed above and stipulated as motivation for the research, should be substantiated by hard facts (statistics mostly). In this case, this is not feasible, not only because there are no broad statistics yet, but also because of the complexity of the dependencies involved. Though the statement below was made nearly 2 decades ago, it still is valuable for pointing out that the impact of (here merely technological) obsolescence is hard to measure.

> *Traditional (...) studies (...) are insufficient to assess the depreciation of utility property that is subject to technological obsolescence. (...), technological obsolescence is having a more profound impact on the future economic life of utility property today than it had in the past. Second, the current (...) analysis process, (...) grossly understates the true impact of technological obsolescence.*[7]

If we replaced technological obsolescence with "changes in digital ecosystem", "utility property" with "digital assets", and "economic life" with "active life", the statement would hold true for our present evaluation: at this point there are no "hard" facts or statistics to confirm what the community strongly expresses as an emerging and urgent challenge, the impact of change on the usefulness of availability of the digital information.

Most data loss analytics are still looking at theft, fire, hackers, hardware failure, etc. not at loss due to change in the digital environment. We are confident that this will become a major issue in terms of costs and draw more attention for statistical analysis in the near future. The analysis that would support our assumed needs would be one identifying how many resources are needed to recover digital objects or to react to change as a matter of urgency rather than of planned foresight. A lack of analytical figures and a lack of comparative implementations make it impossible to carry out an evaluation of "relative merit"[8] or applying ranking methods.

For these reasons, we chose for the final evaluation a participatory evaluation, with the use case partners TATE and B.USOC as evaluators of the project's "absolute merit".[9] The criteria selected in this evaluation are detailed in the following sections. They were chosen with regards to the experimental and theoretical nature with a research outcome aiming at future implementation for largely still unrecognised needs in the preservation community and by extent any organisation dealing with digital ecosystems.

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[7] Stephen L. Barreca: Technology Life-Cycles And Technological Obsolescence. 1998-2000. BRCI. http://bcri.com/Downloads/Valuation%20Paper.PDF

[8] [1] p. 246: "Relative merit. The quality or value of something in comparison with one or more other evaluands (e.g. interventions, products,...).

[9] [1] p. 237: "Absolute merit. The quality or value of something in "absolute" terms (i.e. not just in comparison with something).

2.2 Setting the objectives and criteria

The purpose of this evaluation report is to understand and comment primarily on the **value for systems-thinking of the PERICLES research results** from a real-world and professional practice perspective. Assessing the value of the PERICLES research, using our provided scenarios as context, is incredibly important. The cases put forward for the Art and Media domain as well as those for the Science case are task-specific and centred on standard questions around supporting an active life for the material over time, yet they have an intentional level of innate complexity and idiosyncrasy. Given this, it is more challenging to communicate clearly around the potential of the research and translate that value to other sectors and problem cases. The advantages of taking such granular examples for study is that it takes the research and the mind-set of the technical partners outside of the default 'box'. This default thinking consists of scenarios involving major repositories (e.g. large research data centres) with data management and preservation programmes that revolve around mainstream data collections (e.g. libraries). We have sought also to generate thinking from an individual's perspective, and around pioneering or emerging fields and other sectors where the need and value of research into preservation support is equally great but unsupported by any clearly defined and structured framework or remit or policy for data retention, preservation or management. In this context, research into supporting mechanisms within complex emerging areas of data collection is ground-breaking and can have significant impact. While the disadvantage of this is that the focus is not on high-volume assets, as these materials often retain fewer dependencies and are less complex. We are trying to remain ahead of the curve as digital material becomes more complex and emerging sector material such as 3D objects, virtual realities, and responsive objects becomes more mainstream.

The more traditional large repositories such as archives and libraries are already facing the challenges from new types of objects that increasingly populate their repositories. For example, archiving and preserving software has been vividly discussed in the recent PERICLES conference[10] as being a widely emerging challenge. This is a challenge that PERICLES dealt with through their use case partners and thus provided pioneering research that would benefit also domains and their repositories that until recently would not have been considered as dealing with complex digital data.

As the purpose of this evaluation is to address the ability of the research to ultimately benefit the communities represented by our case studies, and thus indirectly the broader digital preservation and asset management communities, our criteria for evaluation focuses on three central impacts that the research could potentially have on the communities.

1. Evaluate the impact and influence the PERICLES research can have on changing current practice
2. Evaluate whether the PERICLES research has the potential to generate momentum in an emerging field
3. Evaluate developing and directing a community to a new social and professional network.

[10] International Conference "Acting on Change: New Approaches and Future Practices in LTDP", 30 Nov - 1 Dec 2016, London (UK) see: http://pericles-project.eu/page/PERICLESconference2016

These criteria were chosen as the use case partners can evaluate the research from their perspectives, as they already have taken effect during the project lifetime. Thus the evaluation is based on experience and not on conjecture alone. It refers to the knowledge of the practitioner communities and therefore does not attempt to evaluate aspects that would require expertise from other disciplines, such as computer science, mathematical logic, computer linguistics etc.

These concepts form the basis for the evaluative narrative presented in Chapter 4 on the value of the PERICLES research to our communities of interest, stakeholders and practitioners. The next paragraph first highlights the context for the evaluation and the key challenge scenarios considered.

3 The Baseline

During the progress of the project, and the evolution and refining of the research results, there was a need to concurrently define real-world scenarios that would not only provide a basal point from which the technical research could anchor its component design process but also an example of an applied task against which, ultimately, the software components or technical approaches generated within the project could validate their purpose and functionality. The evaluation presented in this report is being conducted around the challenges described in the following sections.

3.1 Art and Media: Contextual challenges as source for research and innovation

When developing challenge cases in the early stages of the project Tate had to first consider the applicability of any proposed scenario to the community that it was representing in the project and also the direct value of the scenario in supporting the development of an implementable tool to address a challenge that Tate's staff faced. Such a scenario also needed to provide a source of sufficient knowledge and depth of detail to be usefully fed into the project research.

Given these considerations, Tate presented to the project at an early stage a number of case studies, key challenges and problem scenarios from across the spectrum of collection care priorities at the organisation, concerning the conservation and preservation of objects within the Collection as well as the Library and Archive. Information about the process of defining useful scenarios and challenges for the project is outlined in previous reports D2.1, D2.3.1 and D2.3.2 but, broadly, the scenarios can be grouped or at least identified according to the type of challenge being faced, be it around exhibiting risks, around rendering and playback, obsolescence, future access and semantic interpretation or the impact on changing dependencies. Specific extracted instances from these challenges are in part used as a means to evaluate the PERICLES components in the test-bed as outlined in D6.6.

For the purpose of this evaluation report not every scenario Tate compiled during the course of the project will be discussed here to support the evaluation but rather time will be spent focussing on scenarios reflecting the key challenges and used by the technical project partners as a measure of what would be valuable providers of examples of preservation risks in the Art and Media domain. Although Tate developed a broader group of potentially useful scenarios referred to through T-#s (task numbers) in D2.3.1; T101-T108: Born-digital Archives; T201: Software-based Artwork; T301-304: Media Production; T401-T402: Digital Video Art Ingest, the main focal challenges put forward by Tate and the project partners concerned the sub-domains of digital video art and software-based art. This selection draws on Tate's experience as leaders in the field but also to validate relevance to a broader audience, chosen in consultation with our communities of practice groups as a part of PERICLES and our networks beyond the project.

Artists have been producing digital video artworks since the mid-1960s and this is now a mainstream artistic media with a number of important artworks being acquired by contemporary art museums. Increasingly, artists are producing, editing and displaying their works purely digitally and are no longer working with analogue video tape. Therefore, working practices within contemporary art museums around the conservation of video artworks need to change to reflect this move to file-based formats. The conservator will work with the artist to discuss the production history of the work and to establish what materials are provided to the museum for conservation and display. Contemporary conservation theory has developed a sophisticated strand of discourse looking at how to assess what is important to preserve. Within contemporary art conservation the artist is an important determinant of whether the original technologies used, particularly in display, are important to maintain. Detailed discussions with artists about the work, therefore, occur as part of the acquisition process and continue as the work evolves. How we represent those changes over time remains a challenge. Within PERICLES, the research scenarios start from the time a video artwork is received from an artist or a gallery for ingest into an archive system for preservation over the long-term. The baseline scenario describes a basic workflow whereby: media is received on a hard drive, metadata is both extracted and entered into Tate's collection management system manually, checksums are verified and files are monitored through a variety of software, and files are backed up on LTO tape and stored. The improved scenario refines the current workflow by: creating a clone hard-drive of the media received, automatically extracting metadata and TMS component creation, automatic error checking, an additional normalisation step, and also a workflow for moving files to a specialised high value digital asset storage system.

Software-based artworks represent one of the most recent forms of artistic practice entering museum collections and one of the least developed areas of conservation. Tate has a small but growing number of software-based works which span a number of different types of software-based art including works which are self-contained systems and those which are networked and where the functioning depends on external data. Each of these works is written in a different programming language and is made up of different configurations of hardware and proprietary and open source software. On the whole these works are delivered to the gallery with their hardware as installed systems. Developing strategies for the conservation and documentation of these works and managing them over time is new territory for the museum sector. One aspect of technical research being undertaken at Tate is on developing the knowledge around the use of emulation (or virtualisation) as a valid progressive step towards a viable strategy for the preservation of software-based artworks. Emulation creates functional independence from the operating system, thus removing the physical dependency on the original hardware and/or software. This helps to manage the risk of hardware failure. Within PERICLES, the scenarios created for the software-based artwork domain describe instances that may or may not relate directly to emulation strategy but that are compatible with it. As with the digital video artworks scenarios, we have sought to focus on workflows or use-case examples that may benefit from the support of a system or tool that has either conceptually modelled the object environment or that can generate new or specific insight about the object.

These scenarios, and the numerous versions that were developed from them, provided a context from which the technical partners were able to extract instances that could then be used as a focal point to direct and validate their research. There was necessarily a need for Tate to provide scenarios that, 1] would balance broad transferable applicability to our relevant art and media communities, with 2] the need to have a level of granularity and detail that would be useful to the technical partners in their tool design. Having criteria [2] met provided a scenario of use as a valuable real-world case such as one likely to be faced by stakeholders responsible for managing the life of similar material at the forefront of the long-term preservation challenge. This is the rationale for focussing on collections of both established material going through new challenges (video art) and an emerging field (software-based art) where new ideas and concepts need to be embedded in practice.

3.2 Space science: Unique data capture as challenge for re-use experimentation

By its specific nature as an operation centre dealing with space payloads on the International Space Station, B.USOC covers almost all aspects of science in space from physical experiments, life science and the more familiar space science and earth observations. Experiments in the pressurised modules have a lot in common with laboratory experiments as the conditions are controlled and if they can be proven to be independent from the external environment, they can be reproduced. The main specificity of pressurised experiments is microgravity which can only be achieved for long periods of time (longer than about 30 seconds) in orbit. However, the costs involved make the re-enactment of flown experiments prohibitive and thus lead to a need for comprehensively archiving the data even if the main data lie in the processed samples. Ancillary data are usually transmitted to the operation centres as well as digital science data. In the case of earth and science observations, each science data element has a unique nature. There are no elements which are not subjected to change. This is especially true for earth observations where since the beginning of the space age, human activity has been rapidly modifying atmosphere, land and ocean. The preservation of series becomes as essential as the reuse of previous data to find new phenomena which nobody envisaged when beginning with the observations.

The compilation of long term series, for example of more than thirty years as requested by climate research, needs to merge data sets representing several instrument and scientists generations. This series need to be coherent and thus use the same interpretation parameters obtained from the more recent knowledge. The older data should thus always be revisited independently from the original scientists and institutions who will be likely unavailable on the long term (above 50 years). An example are chlorofluoromethanes which were undetectable in 1967, and which now have reached a new importance as both greenhouse gases and sources of chlorine affecting the earth’s ozone shield and air quality.

The present situation for preserving or recovering historical data is not favourable, if one considers 1750 (the IPCC reference date for climate evolution) as the start date. The systematic collection of worldwide data in World Data Centres only began in 1957-1958 with the International Geophysical

Year (IGY)[11]. Data from before this date are dispersed in diverse memory institutions (observatories, libraries…), and as the standard procedures of the IGY were not defined before 1954, the data might be operator or institution dependent. Between the IGY and the space-digital ages (beginning around 1980), the data were stored mainly in final form on printed records published after peer review of the observation procedure and data retrieval processes. Intermediate steps such as calibrations or use of external data for determination of the final procedures were not systematically preserved. If these data are to be reused, a search for these old metadata would need to be performed in the originator's archives if they have not been irremediably lost.

Actual raw data corresponds to the signal received at a ground receiving station. This signal mixes several instruments data streams in data packages, and it contains data that is transmitted in real-time from the satellite, as well as data that is first recorded and stored on the satellite and only at a later point played back or even data that is forwarded to relay satellites first and then played back from those. The first task of the operation chain is to parse this set and produce a time-tagged stream corresponding to the science channel of an instrument, representing individual experiments. This set of data is called Level 0 and is what the scientists usually understand by raw data. Level 0 data usually includes also noise, internal calibration packets as well as orbit and attitude information. Level 1 is a more advanced set where the calibration parameters are used to convert the data to physical units. In the case of, SOLAR, level 0 data are delivered to the scientists which produce level 1 after having checked the inflight calibrations and finally produce level 2 data using their own scientific tools. Level 2 are the data which are always preserved as they represent the final quantity which was the objective of the instrument mission. Even more downstream, level 3 are interpolated and extrapolated data usually produced now by an assimilation process. Level 0 is stored by space agencies according to their data policy, for the new ESA SENTINEL programme, the access duration is 25 years after data acquisition. For HRE (Human and Robotic Exploration) it is still ten years. The same applies to level 1 which meets the needs of most users. Higher levels are more complex as their preservation depend on the policy of the scientists and institutions that produced them, they can be expected as it is the case for SOLAR to be consigned to a memory institutions.

The more recent digital-space age presents a slightly better case for data management than has historically been the case. The funding governments drew the space agencies' attention to the cost of acquiring data and therefore took steps for maximal use and preservation using the paradigms[12] of the original data use. The continuous use of the original paradigm, however, lead to insufficient preservation of newly acquired data regardless of the opportunity to gather additional data with the improvement of space or network instruments, for example, the data from the ground-based ozone measuring spectrometers present only tables of ozone data to the Toronto World Data Centre despite the fact that the instruments of the network have improved and shown later a capability to measure other gases and atmospheric aerosols. Again, this effort was limited by storage technology and only an already processed level of data has been stored, usually "Level 1" raw data (geo-localised

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[11] IGY was "...an international scientific project that lasted from July 1, 1957, to December 31, 1958", see https://en.wikipedia.org/wiki/International_Geophysical_Year. The IGY rekindled cooperation between the Soviet Union and the United States which had common interests in both the arctic and Antarctic.

[12] The term paradigm is used in this text as "model or approach of thinking".

and time-tagged data in physical units) together with various sets of “Level 2” data (values of the parameter to be determined).

True preservation of earth and space science raw or low level data together with the relevant metadata ensures the possibility not only to produce new versions of the original products constituting coherent time series, it allows also to produce new parameters which were not envisaged in the begin of the observations and which correspond to a new need. These new versions are generated by specialised teams of the space agencies which also are in charge of curating the archives and their distribution. They depend thus on a chain of knowledge much wider than the preserved data.

No formal data policy ensures presently the maintenance of this extensive chain beyond budgetary cycles especially if the responsible agencies disappear or reorient their activities. One example for this is the termination of the activities of some USOCs (User Support and Operation Centre) - ERASMUS USOC (NL) and MARS USOC (I) in 2014.

Reusing these data will however be necessary in the future in order to homogenise continuing series of new observations with the previous data. The success of these reinterpretations will depend on the amount of ancillary and metadata stored with the original series.

In the PERICLES space science scenario, different successive and parallel data flows compose a scenario. In the first instance, a scientific team introduces a project in response to a call by a space agency which in the European case can be ESA, the European Union or a national space agency. This proposal is already a set of digital objects including descriptions, simulations, evaluations, instrument mathematical models and a data management plan. The second step constitutes also a chain: first, acceptance by the agency, then phase A: detailed feasibility involving industrial partners, phase B: detailed design and phase C/D: design and development. Each of these pre-flight phases generate documents, calibration and characterisation data as well as reviews and studies. Phase D is the operation phase when finally, the sensor operates in space and both science data and engineering data are transmitted to the earth under a sequence managed by the operation centres managing the spacecraft and payload. These raw data are then processed by a software and calibration database developed by the scientist's, using the data collected before and during flight. These are finally sent as raw data, time tagged and geo-localised, to the scientific groups who interpret these to produce high level products which are published after peer review and even are communicated to the public. If the final high level products have an operational use, then this entire chain goes to the same qualification chain as the hardware (Phase A, B , C, D) plus a formal quality control procedure. A phase E is also defined for the entire project and includes the data and hardware disposition when the space segment is deactivated. The picture can even be more complex if part of the data is not digital, for example, a sample, either produced in space or brought back from a space target. Then, the context of the sample as well as the digital data generated by the analysis of the returned sample become part of the workflow.

In the space science case and generally in science cases, the workflow goes even further, the preserved data are distributed to users. Users compare them with other data, models or derive new products from them, this constitutes effectively a new start and a seed for a reuse of the original data in a new paradigm. This change in objective is addressed through the PERICLES model-driven approach to preserving data. Thus, a data set managed within the structure proposed in PERICLES would give an ideal solution for data reuse by an independent community, already present and not necessarily expected by the data provider. This process could be repeated in the distant future, the objectives of the new user communities being unknown to us.

User communities in observation sciences have a huge interest in the variations of the geophysical or astronomical parameters as they may be able to point to common behaviour and thus would lead to understanding the observed targets as parts of a system. The absence of any synchronism or correlation is also an important information as it is a mark of independence. For example, recent astrophysics have proved the role of dark matter and dark energy in the universe as a dominant part. Only long series of observations from both ground-based and space observatories will establish the relation between these new elements and the previously known universe. The important parameters may also differ from the ones which are studied now and thus the entire series should be susceptible to be reused in order to search for the new parameters wished for by the scientists of the future.

Another major challenge in space science data is the dispersion of the locations for the space scientific experiments. It is one of the main risks for data losses. Pre-flight data are kept usually at the prime contractor location. The contract of the industrial supplier usually ends at the end of the commissioning phase, a few weeks after launch of the satellites. The hardware is then formally delivered to the space agency which funded the project together with spare parts and documentation, there are usually no plans for preserving anything else than the formal documentation. An operation centre as B.USOC has responsibility as soon as ESA designates it as Facility Responsible Centre and detains pre-flight data necessary for flight operations. Flight operation data are stored at the space agency operation centre. Finally, the science data is stored with its processing software at the science users home base. Finally, the science data is stored and distributed at a specialised centre.

The chosen space science case studies.

The deliverable D2.3.2 (Data Surveys and Domain Ontologies)[13] provides a detailed inventory of the SOLAR case including a survey of the detailed aspects of data to be preserved. This inventory provided an important source for an array of scenarios. For the purpose of testing the validity of the components in the testbed, we decided on very simple cases[14] to demonstrate the concepts advanced by PERICLES. In particular, science scenarios corresponding to a change in data policy or a

[13] http://pericles-project.eu/uploads/files/PERICLES_WP2_D2_3_2_Data_Surveys_and_Domain_Ontologies.pdf)
[14] SOLAR could unfortunately not be used for the PERICLES demonstration cases as HRE (Human and Robotics Exploration) ESA data policy limits the manipulation of data beyond the secure zone of the operational part of B.USOC where only B.USOC Belgian civil service and SpaceApps personnel have access in the frame of the B.USOC ESA contract. Data slices were authorised by ESA and these slices were used within B.USOC for the studies of the PERICLES anomaly detector. The space segment of SOLAR stopped operations on February 15, 2017 and this end of the operational phase might have consequences on data availability but this date is too late for new PERICLES developments.

change of scientific objective can easily be adapted to realistic cases[15]. SOLAR presents the unique case where an entire data set can be considered by a single institution. This is because ESA gave the mandate to B.USOC to be the SOLAR Facility Responsible Centre which means that B.USOC is mandated among other tasks to maintain a complete repository of SOLAR generated data for ten years after acquisition. All the cases proposed to the PERICLES partners correspond to real needs for data preservation of the geoscience community. Several proposals for more extended data sets were made: first, the SOLAR data already processed by the scientists and made public after peer review, these are now directly available from ESAC (European Space Astronomy Centre) for the period 2008-2017; second: ESA ENVISAT data from 2002 to 2012 from the SCIAMACHY atmospheric sounder and third: data from the SEVIRI (Spinning Enhanced Visible and InfraRed Imager) instrument on the METEOSAT operational satellite available from EUMETSAT. This SEVIRI case was finally chosen because of easy data access by the PERICLES partners. The product selected by the University of Edinburgh partner was the Cloud Optical Thickness (COT) from METEOSAT second generation which provides operational data used for weather forecasts.

[15] An example workflow within PERICLES is documented in section 7.5.2 of deliverable D5.3, found at http://pericles-project.eu/uploads/files/PERICLES_WP5_D5.3-Complete_Tool_Suite_for_Ecosystem_Management_and_Appraisal_Processes-V1.4.pdf

4 On the value of the research

4.1 Art and Media: Digital Video and Software-Based Art

To assess the value of the PERICLES research for the Art and Media domain, we focus on the impact the research, and resulting approach and software components, can have for our community and on whether this promises a contribution to driving forward the long-term digital preservation field. Rather than an analysis of interviews and surveys, the approach provides an assessment that is representative of questions or sentiments from stakeholders, extracted from conversations, social media posts, community of practice focus groups, conference workshops and our final project event.

Each evaluation criteria is considered separately and the narrative feeds on a number of sources for support. These sources represent direct feedback from the communities of practice on software-based art conservation challenges as well as from public project events such as the thematic session on day 1 of the final conference titled, 'Capability gap - Preservation isn't just throwing tools at the problem'. Additionally we have garnered insights from the material now displayed on the website in videos and other articles. These inputs are combined with the direct reports from our media conservators at Tate and institutional decision makers, as well as sections from the information presented within project deliverables including but not limited to D2.3.2, D5.3 and D6.6 covering aspects of ontology creation, tools development and test bed results.

4.1.1 Criterion 1: Impact and influence on changing practice

Under this criterion, and perhaps also under the others, the most significant impact that has been felt by our community, centres on the newly embedded knowledge that has been generated through project research. The issues and problems brought forward by our key challenge scenarios can in theory be resolved or at least sufficiently addressed by having full knowledge of the object and of course then a model or system in which to manage that knowledge .

There is no one who will argue that the few software-based artworks in national collections globally are not complex. As experienced and knowledgeable as the person responsible for ensuring their preservation may be, increasingly without the help of tools to understand not only the inner workings of an artwork component but also to gain insights on its history, the preservation risks for that object increase. The process of investigation, and new levels of required object description have brought forward a new field of conservation in terms of identifying key entities and dependencies and have highlighted the need to share in a standardised vocabulary.

The work on ontology descriptions and their relationship to the Linked Resource Model has proved particularly valuable in forcing the need to understand the interrelationships that exist for complex multi-component objects and to thus consider how any given future change to one aspect may or may not impact another dependent aspect. This concept is not new to media conservators but the discussions and focus on understanding dependencies and intention has brought the field forward.

This new mind-set or perspective on how to view a work moves beyond the granular description process and has influenced fundamental workflows, at least at Tate. It should be noted that much of the research components from PERICLES may not directly be incorporated into Tate workflows. They are proof of concept components and there is still a long way to go before these results are taken up by communities and/or commercial entities and developed into something with a higher technology readiness level. However, the conceptual thinking behind the proof of concept is very powerful and aspects of the PERICLES results can and have influenced thinking around workflows that moves towards a greater degree of automation and standardisation of our approaches to workflows when acquiring an object, particularly on aspects of metadata collection and significant properties.

In D6.6, the final implementation of the test-beds, two particular instances from these scenarios are drawn out. These instances, with the use of the Technical Appraisal tool along with an associated user interface and other PERICLES ecosystem models, act as inputs to assess and then later manage the preservation risks for an art object entering a collection. The instances in this case focus on risks concerning consistent video playback with respect to video encoding formats and wrappers but also consistent display more broadly. The test-case presented provides a useful example of how the components created in the project can link together and thus how the Technical Appraisal tool works in tandem with MICE and the ERMR and indeed with open source tools such as MediaInfo and MediaConch. The advantage of the tools lies in that risks can clearly be assessed prior to anticipated or modelled change. The disadvantage of the tools is that their collective value is reliant on being supported by accurate ontologies for modelled objects and collections and while ontology building tools are available it is unclear as to how much external support is required to take an ontology concept or initial design and integrate it into a model and then into a working system or current workflow.

4.1.2 Criterion 2: Generating momentum in an emerging field

It was clear at the start of the project, and throughout our research that to expect the development of a silver bullet or fully functioning preservation system was at odds with what was a realistic ambition. Even in 2016 towards the end of the project, after almost two decades of grant funded research into the sector, during our final conference in the Wellcome Centre the question was raised by a panel member as to why it was taking so long, why have we not got our perfect answer yet? This generated quite a response with the majority forming a consensus around the idea of constantly shifting goalposts. Living in a digital age means that the inter-connectivity between hardware and software is constantly expanding the scope for innovation. Those with a responsibility to manage and safeguard digital material for future access and use thus need to take on an evermore complex set of vocabularies and integrate and communicate with a wider network of specialists than ever before. The advantages of this networking are outlined in the evaluation of Criterion 3. The flipside is that it seems that even with ground-breaking research results it is a case of two steps forward and one step back i.e. we take time to collaborate and gain new knowledge but by the time we do objectives or goals or technologies have changed. Recognizing the power of networking and better inter-domain communication, those partners in the project representing user communities were better placed to understand and appreciate that the tools being developed within PERICLES were not only of value as 'enhancers' to established mainstream practice but that for domains such as software-based art, where the field itself is emerging, then these tools and the PERICLES approach had the potential to have more significant influence over future practice and at a faster rate than perhaps likely in more static established repositories.

Certainly then for the case of software-based art and digital video art conservation practice the tools developed by PERICLES stand to move these emerging practices forward at Tate and by proxy, as a looked-toward leader in the field, momentum can be generated in the community as is already taking place through our engagement in communities of practice directly engaged in the project and externally.

Again the benefit of working with the notion of ontologies, with the ecosystem description and with tools such as PET for software-based artworks running in a live environment, is the recalibration of how a community needs to define and understand their objects and the deep knowledge that is needed to take advantage of the potential of the tool which can then deepen further the knowledge gained. This cycle of deepening knowledge and object monitoring for risk, is recognised as very powerful for collection management and preservation yet our emerging fields are at the start of this journey. These small changes in thought-process and manageable workflow adjustments to incorporate components such as the PET or the Technical Appraisal tool, generate the momentum required to sow the seed for up-take or development and implementation of the larger frameworks envisaged by the ecosystem model and fully functioning linked resource model. As domains such as software-based artwork collection management grow and strengthen, then the PERICLES approach is well placed to offer solutions to real-world challenges. The constraint on this is both experience and institutional reform. By this we mean organisations need to recognise the increased responsibilities placed on-, remit of- and knowledge to be covered by-, in this case, time-based media conservators. Organisations need to support the development of their staff and support the need for training, infrastructure development, and the need for collaboration with specialist consultancies and service providers.

4.1.3 Criterion 3: Developing and directing a community to a new social and professional network

Given the nature of this evaluation as an overview of the potential effect of our results in the community there is some overlap between criteria, and a sense of culminating in the evaluation of Criterion 3. This criterion looks at how the community, be it as a whole or through clusters, will have to expand the horizons of what their role entails. PERICLES has not brought about a paradigm-shifting event, as yet, but the concepts delivered through PERICLES to communities, such as practitioners in the software-based and digital video art domains, has potentially started this process or can at least provide a nucleus for its growth. The next step faced by these audiences is in visualizing the implementation or rather the potential of the PERICLES tools in an integrated system. To achieve this level of visualisation demands, of our audience, investment in training and development of systems to meet exact needs. This is not an easy task and cannot be labelled as simply an advantage or a disadvantage of the PERICLES legacy. What can be said is that through engaging in a collaborative and interdisciplinary way with professional colleagues from disparate sectors to work for mutual benefit we can learn and share new vocabularies. This will aid communication and develop tailored approaches that will move us towards a level of knowledge useful for the transfer of our objects or collections into a digital ecosystem that can have commonalities with other institutes doing similar things and thus in turn bring our own community closer together.

4.2 Earth and Space Science data

Despite being fundamentally different with respect to preservation objectives, requirements and existing or non-existing practices, it is found that the complexity of the data, their uniqueness (art or SOLAR observation) and the importance of the creator of the data (artist or scientist) lends itself to surprising similarities with regards to the challenge of keeping these types of data accessible and reusable. The difference lies in the communities and their awareness and knowledge of LTDP. Therefore the criteria proposed for the evaluation take different angles when looked at from the science community perspective. While for example change in practice with the Media and Art refers to a “preservation practice”, in the science community, a change in practice would entail an introduction of a preservation practice. In the same way, an emerging field in Art & Media represents innovative preservation means, while in Science long-term preservation is in itself the emerging field. And as for the networking, in the field of stewardship of cultural heritage which belongs to the humanistic disciplines, a discourse and reflection on one’s own practice has a long tradition and as such exchanging experiences in networked groups to express challenges is as a principle more common to this community, than in the science community where the sharing is more focused on the results and the correct methodology to acquire them.

4.2.1 Criterion 1: Impact and influence on changing practice

Success criteria have always been a point of discussion in space science, frequently, the only success criteria for space agencies, in the case of a pure science mission, consists in one correct operation of the entire space segment. In the case of an operational mission, the success criterion is the delivery of the final product to the users for the nominal duration of the mission.

With the increased understanding of the usefulness of data in new contexts and for other purposes than the originally contracted objective, the need for long-term preservation as a means to being able to reuse data is increasingly being discussed in different stakeholder groups.

ESA (European Space Agency) for example has put Long Term Data Preservation (LTDP) in its main objectives in two successive ministerial conferences but has failed to fund it and organise it at the date of January 2017. However, ESA, as most European and American funding agencies, require now a data management plan at proposal level which includes the final disposition of data. Preservation aspects are thus now relevant for most new scientific proposals.

Science data users demand preservation of the data stream and its reuse, which requires the recording of all the data in a repository, transforming it into a reusable archive. The users in the case of observations have essentially two main strategic objectives. The first is exploration - discovery of phenomena that have never been observed. The second objective is to obtain reference series in order to determine variations and trends. This second objective is especially important for earth observations as changes can have important societal aspects.

PERICLES, by focussing on change as a major risk with regards to reuse of data, provides an approach and relevant tools for archiving and reusing science data which can be divided in two categories, experimental data and observational data:

Experimental data are the main paradigm of science, a scientist determines all the relevant conditions and measures the starting and final parameters of the experiment. A complete description of the relevant conditions would make the data fully reusable. The PERICLES approach advocating sheer curation constitutes a promising aspect to provide the necessary metadata and contexts for data reuse. Implementing tools that would help gather the necessary metadata, such as the PET tool, would prove invaluable, and as sheer curation avoids adding the preservation burden to the scientist's or operator's workload, it is a promising component to foster a change in practice when creating or processing data.

During the final conference, one key concern surfaced in every discussion:[16] creating an awareness with scientists to lead them to understanding the importance of delivering data in a way that is reusable for other scientists. Overcoming the constraints that impede this additional task for scientists, was seen as a major task. The current endeavours tend towards “education” of the scientist, e.g. to use stable formats rather than custom-made software. In discussions with stakeholders, in particular the CoP, sheer curation and the PET’s focus on gathering significant environment information seemed to them to point into the right direction for future practice of producing scientific research data.

The call for change in the science community is getting more urgent, and PERICLES offers notions and insights that meet these requirements. Perhaps in memory institutions, where the creation and gathering of significant information was, as part of the expertise of the curator of the repository, the shift to including the significant information from “alien disciplines” such as IT technology. This would have other implications than in science communities for whom communicating the context of experimental data in the first place is unusual, but support from technology might be easier accepted if automation reduces this part of the workload.

Observational data differ in the sense that the scientist has no control over the context and measures the evolution of parameters depending on external influences. Nobody could pretend on a complete knowledge of all the environmental factors, this is the case for all earth science and space science data, it is also true for space physical and biological data obtained in space conditions. This context, expressed either in metadata or ancillary support data is essential for data reuse. These contextual data must be present in the database used for data reuse, which they often aren’t. In this

[16] e.g.https://hydra.hull.ac.uk/resources/hull:11243: Filling the digital preservation gap : A JISC Data Spring project

respect, working with domain-specific ontologies helps establish the awareness of “context” needed for rendering data useful over time and for different use purposes.

Ancillary data. First, pre-flight data and in particular the calibration plan outputs and tests results are stored by the contracting industries and national space agencies separately from the flight data. Usually, no plans exist for the disposition of the data when the mandate of the contractor ends. In the case of flight data, instrument health parameters are not stored with the science raw data which is to be transmitted to the scientists, these parameters are obtained in space and could contain the influence of unknown space factors which would become in the future indications on important scientific phenomena. As an example, in the first half of the 19th century, perturbations on telegraphic lines correlated with solar activity while scientists of the time, most notably Airy, the Astronomer Royal, negated all connections between solar activity and electricity. As a consequence, these records were not systematically preserved.

Here, the work on ontology descriptions and their relationship to the Linked Resource Model has proved particularly valuable in demonstrating to the space science data provider the need to understand the interrelationships that exist for the multiple components of the data and to thus consider how any given future change to one aspect of the chain may or may not impact another dependent aspect.

Ecosystem monitoring. Instrument conditions in flight are constantly monitored, usually this monitoring gets attention only if one of the parameters is outside pre-set limits, in this case, it triggers troubleshooting. In normal conditions, retention of these nominal parameters can have three roles. First, they might influence the science data as for example a detector temperature. Second, in case of failure, their trends and value play a role in the forensic investigation. A third aspect is as these data are obtained in space, they can contain traces of an external influence from a phenomenon different from the main science investigation. Here creating ecosystem models would be a valuable support in creating a history of change to be analysed for phenomena not originally paid attention to.

Entire missions. For a case such as SOLAR, the key preservation challenge is to be able to “replay” the entire mission with a new objective and generating new scientific products which were not thought of when the mission was designed. The challenge is even more complex as long term series ideally necessitate to merge successive experiments in order to obtain series covering several decades. The preservation risks increase with complexity as some data which are only secondary for the first determination of the science products could become important context for the new ones. Again, the notion of modelling the data, to ensure that the complexity involved is being captured and taken on board when storing the data, is a compelling contribution to the current practice.

The adoption of LTDP in B.USOC will be a decision of the new Belgian Interfederal Space Agency which is due to be installed after July 2017 and will allow initiatives independent of the ESA contract binding now B.USOC for the support of ISS payload. The experience gained in PERICLES and especially the reflection on SOLAR data will then be a way to consider a proactive action for data preservation.

In conclusion, PERICLES addresses the need of reusing the entire original space science data sets not only to produce updated versions of the existing products but also to produce new products corresponding to the needs of a community which is, by definition, unknown: the scientists of the future. The tests show the feasibility of this distant objective but the real demonstration would be to develop an entirely new product from a preserved data set without any interaction with the original teams. This is still a challenge for the future.

4.2.2 Criterion 2: Generating momentum in an emerging field

The emerging field in the science case is "preservation" itself. A practice which the former criterion touched upon already. Therefore, we will take another angle here: the attempts at a coordinated preservation on the organisational level, with data policies and data management plans. The value of the research in this respect will look at how to take on practices from the preservation community which is largely dealing with cultural objects and data, and at the same time take into consideration challenges that they themselves are still struggling with, such as increased automated workflows and technological support.

There is undoubtedly movement in the science sector in terms of increased awareness for LTDP, even though these efforts would not necessarily be termed "preservation", but considered as part of RDM (research data management) and as a precondition for "sharing data"[17]. This is not only a question of the lack of a shared vocabulary in the science field, but also a token of the fact that preservation has not yet received the attention it has in memory institution communities (perhaps because the urgency of it is not yet felt).

> *The Preservation Interest Group is focussed on the preservation (some use the word curation) of digitally encoded information.* [18]

The recent history of the emerging discussions and reflections on "preservation" as part of research data management, shows that the focus is on "first things first", which explains the widespread advocacy of metadata[19] creation, schemes, and standards.

Strong stimulation for the discussion came first from the data curation initiatives such as DCC with their SCARP project[20] during which the term "sheer curation"[21] was coined which is being also strongly advocated by PERICLES. Amongst the many preservation and data curation

[17] e.g. https://www.rd-alliance.org/ The Research Data Alliance (RDA) was launched as a community-driven organisation in 2013 by the European Commission, the United States Government's National Science Foundation and National Institute of Standards and Technology, and the Australian Government's Department of Innovation with the goal of building the social and technical infrastructure to enable open sharing of data.

[18] Charter of RDA IG Preservation: https://www.rd-alliance.org/groups/preservation-e-infrastructure-ig.html

[19] To name one of many examples: Ria Groenewald, Amelia Breytenbach, (2011) "The use of metadata and preservation methods for continuous access to digital data", The Electronic Library, Vol. 29 Issue 2, pp.236-248, http://www.emeraldinsight.com/doi/pdfplus/10.1108/02640471111125195

[20] 2007-2009: http://www.dcc.ac.uk/projects/scarp

[21] by Alistair Miles, 2007: https://alimanfoo.wordpress.com/category/sheer-curation/

projects between 2007 and 2013, the SCIDIP-ES (Science Data Infrastructure for Preservation) – Earth Science project [22] put a strong emphasis on science data.

The science community became more aware of data curation, which largely involved metadata but started fostering the understanding of long-term preservation practices.

> *Preservation is about ensuring that what is handed over to a repository or publisher remains fit for secondary use in the longer term (e.g. 10 years post-project). Curation connects first use to secondary use. It is about ensuring that project results are fit to archive, and that valued research assets remain fit for reuse.* [23]

Undoubtedly metadata are the backbone of data curation and preservation. Complete sets of metadata demand the coordination of the different actors of the data flow, this should be specified in advance in an extensive data management plan. A data management plan is usually requested from the scientific team proposing the experiment and due to the fact that its main concern is the final data, it limits itself to the downstream part of the data flow and the final distribution and disposition of data. Capturing complete sets is more complex than describing them because some elements are not preserved even for a short time as they are perceived as internal notes. The understanding of capturing the ecosystem, and with it all entities relevant or significant for the data curation and ultimately reuse, fostered by PERICLES, has driven discussions of B.USOC with other members in their community that data management plans need to specify the preservation requirement for all members of data flow chain. This should not be considered a responsibility of the scientific teams only. In contrast to previous space data preservation programmes similar to SOLID,[24] PERICLES involved not only scientists but also the operators that are actually performing the data acquisition. This approach is very original and gives a new direction to the proactive data preservation programmes of the space agencies of the future.

The more the importance of reusability and the requirements of data curation have been accepted in the science community, the more the discussion turned towards the responsibilities of organisations to implement policies.

> *There has been a decisive shift towards greater oversight of the research process motivated by the driving principle of data as a public good. This shift is seen in the concerns of policy-makers, and in changes in legislation and its implementation. (...)* [25]

And lately, "preservation" as a natural part of data management for long-term availability of the data has gained momentum in the discussion. For example, in the Research Data Alliance community, a second IG group on preservation is being proposed.[26]

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[22] 2011-2013: http://www.scidip-es.eu/home/scidip-es-in-brief/

[23] Whyte, A., Tedds, J. (2011). 'Making the Case for Research Data Management'. DCC Briefing Papers. Edinburgh: Digital Curation Centre. p.2
http://www.dcc.ac.uk/sites/default/files/documents/publications/Making%20the%20case.pdf

[24] http://cordis.europa.eu/project/rcn/106571_en.html , http://projects.pmodwrc.ch/solid/,

[25] Whyte, A., Tedds, J. (2011). p.2

At the beginning of the project, the IPCC effort corresponding to the redaction of IPCC report 5 (2015) led to put all possible effort on quality control of data series relating to climate. In particular SOLAR physics research, as solar energy is an important factor of natural climate forcing, has moved from a research interesting for the physics community alone to an important societal value activity. In this respect, SOLAR scientists participated in the Space FP7 SOLID programme. This scientist-led programme was devoted to final data and especially to the elimination of horizontal gaps (times where no data were available) and vertical gaps (instances where two series supposed to represent the same parameter differ). The PERICLES SOLAR case, considering the extensive data flows processed by B.USOC as an operation centre, has more potential for data reuse than the reprocessing of the final data presented in the SOLID programme. The reflections initiated by both these complementary programmes led to contributions to the IPCC WG1 report 5.

Moreover, without the reflection initiated in programmes like PERICLES, the science data series would still be considered as collections of final values quality controlled by peer review. This definition gives extremely limited possibilities of going back to the raw data in its full detail for a complete reinterpretation. In the specific case of SOLAR, if data policy dictates keeping the current B.USOC repository for more than 10 years after data acquisition, PERICLES will have provided the understanding to grasp the unique opportunity to analyse and reuse an entire project.

The use of ontology and model editors allow the different elements constituting the data of a science experiment to be structured. Ontologies were built for the SOLAR case, the PET has been tested with a ground based solar UV data network (http://uvindex.aeronomie.be/) and allowed to analyse all the processes involved in an operation. The PET scenario and its outcome was already described in the first evaluation report (D2.3.3). The anomaly detector was tested in the operational environment (using historical data in order to comply with ESA data policy) and could provide a failure forecast allowing corrective action in time.

The PET tool tests, despite the fact that they were not tested in the operational environment, have shown their value in capturing the environmental information (soft- and hardware) and the process related information. From our tests on the IASB-BIRA ground based UV network (http://uvindex.aeronomie.be/), they prove that they could be helpful for automating the production of standard reports and the collection of relevant metadata.

The discussions in the Community of Practice focussed quickly around appraisal and data policy as main elements influencing long-term data preservation versus the current data preservation mechanisms.

Preparatory work[27] and the discussions in the community of practice lead to some conclusions, the first is that the volume of data requires a selection using the appraisal tool. Moreover, the appraisal tool could have operational applications in selecting the data at the source in order to reduce the amount of data transferred from the sensor to the ground based operation centre, the building of this capability in instruments would allow to operate as frequently as possible in conditions of

[26] https://www.rd-alliance.org/groups/preservation-tools-techniques-and-policies, for the first IG see footnote 18

[27] PERICLES WP2 deliverable D2.3.2 Data survey and domain ontologies for case studies

degraded transmission (distant planets and even earth polar regions). This would be a major application of the PERICLES project as data selection and preservation would begin at acquisition level.

As an example, inspired by the B.USOC and PERICLES, ESA was interested by the PERICLES effort and proposed an intermediate solution for the preservation of the final science data, under the form of archiving the heliophysics database. All data obtained by space means should reach the World Data Centres but these, initiated 60 years ago had archaic procedures and since 2009, ICSU (International Council of Scientific Union) redesigned this network as World Data System (http://www.icsu-wds.org/). Currently, WDS operates procedures which are state of the art of the digital age.

4.2.3 Criterion 3: Developing and directing a community to a new social and professional network

One important difference to be considered in the present situation of the science community and the memory or cultural heritage institutions is that the former do not commonly have staff solely dedicated to the task of data curation and preservation. This implies that the responsibility for these tasks is being distributed over diverse actors. And this in turn calls for collaboration and sharing of experience and knowledge, leading to new forums and networked communication, and community-led platforms such as RDA, or social network services such as ResearchGate[28]. Institutions as DANS[29] or STFC[30] foster networking and training with the aim to assure widespread awareness and implementation of reuse-oriented data management from the time data is captured or created.

The important contribution of PERICLES research is to add a new angle to a discussion about research data reuse and archiving, which is still lacking a long-term preservation focus. The preservation can no longer be considered a specialist remit, but needs to be dealt with as integral part of keeping data accessible and reusable. The purpose of PERICLES is intelligent automated support of digital data, the effect is that preservation through change becomes a complex challenge. From the previous points which were examined in several test cases, the project could be considered as a feasibility study, a phase A in terms of space project vocabulary. The science community for science data preservation diverges from the art and media community as it is more difficult to start new initiatives. Space data acquisition and management requires large teams distributed on several institutions and even space agencies. A community unanimity on a new preservation paradigm would be of no effect if it is not followed by space agencies. In this sense, PERICLES in the SOLAR case has already been a success as it induced ESA to consider data preservation for ISS results.

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[28] ResearchGate https://www.researchgate.net/

[29] Data Archiving and Network Services (DANS)- an institute of The Royal Netherlands Academy of Arts and Sciences and of De Nederlandse Organisatie voor Wetenschappelijk Onderzoek (the Dutch organisation for scientific research) - encourages researchers to make their digital research data and related outputs Findable, Accessible, Interoperable and Reusable.

[30] The Science and Technology Facilities Council (STFC) is a UK government body that carries out civil research in science and engineering, and funds UK research in areas including particle physics, nuclear physics, space science and astronomy (courtesy wikipedia).

Better collaboration and communication between the partners is the key to more efficient distribution and preservation of the data. In the ESA case, the separation between space science, earth observation and manned exploration lead to sub-optimal collaboration as essential objectives for one community are ignored by the other ones. This bad situation is of course worse when the communities' managements are completely separated, for example, the climate community is mainly represented by the IPCC (Intergovernmental Programme on Climate Change) managed by the World Meteorological Organisation while the weather community is centred around the European EUMETSAT and the U.S. NOAA.

Through its Community of Practice activities, PERICLES has been effective in demonstrating networked communication not widely common in the science community. The fact that much of the research in PERICLES originates from disciplines outside mainstream disciplines usually involved preservation research, has helped find commonalities in a peer to peer exchange with the science communities. For example, computer linguistics, logical mathematics, quantum theory were all employed in the investigation of the PERICLES approach, topics that resonated well with the science community and fostered the creation of the CoP on the Reuse of Science data and on Semantic Shift.

PERICLES' specific research has shown the importance of the links relating all the components of a data set including in space science, the numerous elements present in the data flow from the instrument in space to the final user. The downstream evolution of data as they are manipulated by successive users extends even further this process, growing in all directions like a spider web. PERICLES guides to consider the preservation as a living process which continues to develop long after data acquisition. In this respect PERICLES advocates new networks and awareness for the dependencies between different actors and their performance and importance along the chain.

5 Synthesis

When considering a feasible way to provide a user evaluation of the final outcome of the PERICLES project, we had to deal with following situation: from the inside point of view of the project and its description of work, the objective has been achieved and the planned results have been provided, hence the project results are considered to be final and complete. However, from an outside point of view of an end user, the results are intermediary results, a first step into translating an innovative approach into a future practice.

This had an influence on choosing the “evaluand” and the evaluators. The evaluand could have been:

a) the sum of all individual results;
b) the overall result;
c) or a specific performance.

As only few of the individual results are directly involving an end-user and have a maturity that is considered ready for use, it would not have made sense to choose option a) as technical expertise rather than practitioner (our user) expertise would have been required to assess the progress of the components, tools and models in their current state. With option b) a final evaluation is difficult as proof of concept it has no implementation value for the user yet, and therefore any evaluation by the user would have been purely by conjecture on a potential value, anticipated and projected for a future use. Therefore the option c) was chosen, the value of the research performed during the project and evaluating areas where it had an actual impact for the users.

As the objectives of the project requires an introduction to them (which we had done in training workshops as preparation for the second evaluation campaign, the purpose of which had been a formative evaluation assessing the progress of the overall objective and the potential benefit for end-users), we decided to have this final evaluation based on what Davidson describes as “specialist judgment”.[31] As end-users, the two use case partners were both representatives of the end-user communities and had specialist knowledge of the project results. And both having different theoretical perspectives complies with the specialist judgment evaluation type. However, we also should get evidence from other sources. If the directly experienced impact of our research is the basis of the evaluation, then it is difficult to find proper “evidence” of this with external sources. What, however, external sources can provide are statements that underpin the need, in the sense of performance and instrumental needs as explained in section 2 of this document, to which the research could provide an added value or positive impact as described by the project use case partners.

We went through the recordings of the PERICLES conference “Acting on change”[32] with the three criteria in our minds:

[31] [1] p. 111
[32] http://www.pericles-project.eu/videos/post/ActingOnChange

1. changing current practice
2. generate momentum in an emerging field
3. develop and direct a community to a new social and professional network.

Kara van Malssen from AV Preserve in her keynote speech on day 1 of the conference on the topic "Seeing the Forest for the Trees" explained how her company, an information management consultant, has recently been approached by different clients for a service they hadn't advertised, and what on their client's behalf they have started doing, calling that work "organisational alignment projects"[33]. So from auditing individual collections or repositories for ISO 16363, they have come to do "lite assessments" of how well preservation and management of different collections and content of value throughout the organisation is aligned. There is a strong awareness in complex organisations with distributed collections and content that not only does it involve a lot of redundant human effort but that there must be all kinds of gaps and risks. So the question is how can we operationalise digital preservation? Taking a broader ecosystem view can be considered a change of awareness that initiates a change in current practice. It is no big leap to seeing how the PERICLES approach of modelling digital ecosystems in order to align workflows, policies and processes would be a valuable means of supporting the organisational alignment and operationalisation of digital preservation across complex organisations.

Another interesting statement in this keynote related to AV Preserve's use of only short and medium term evaluation categories, acknowledging that after 2 or 3 year period, "you need to take a new look"[34]. Again, using the PERICLES modelling approach would help with establishing a history of change that would support an evaluation. ISO 16363 audits are an increasing practice, yet evaluating the evolution of digital ecosystems in the iterative practice of "revisiting" or taking a new look could surely benefit this emerging change in practice.

Matthew Addis in his keynote "Preservation through the Power of Many" on day 2 of the conference advocates the "need for change and where digital preservation can be applied to solve new problems in new communities with a much wider benefit and how that might feed through to benefit us within our digital preservation community."[35] This would seem to tie in with what we said about criterion 2 for the science communities, but the examples Matthew Addis uses include other domains where preservation could be considered an emerging field, such as medicines, pharmaceutical industries or the financial sectors such as the stock market. Addis makes a case for moving "digital preservation upstream into the world of content creators", which in the domains he presented is happening in the very organisations that also need (often legally) steward the created data. PERICLES has used "Preservation by design" and "sheer curation" to point towards the need to change the behaviour or practice within the lifecycle of the digital objects. Providing tools such as the PET or the EcoBuilder would belong in this new emerging field of technology fostering "preservation" as part of the creation phase.

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[33] see also her slides 8 and 9 on http://www.slideshare.net/kvanmalssen/seeing-the-forest-for-the-trees-a-look-outside-the-oais-reference-model
[34] https://youtu.be/kEaw4TtBQU4, at 20:20 min
[35] https://youtu.be/VDOk0Fci5no at 8:32 min

However, the strongest correlation was felt with criterion 3. Even though it does not seem a key objective of PERICLES, at its core the approach is fuelled by the interdisciplinary approach and by introducing a level of abstraction that has been proposed as a seminal way to keep data re-usable on the long term.[36] Throughout the whole conference, the need for collaborations with stakeholders outside the box, be it IT developers and archivists, or data preservation curators and business organisations, was repeatedly stressed. But also the diversity of knowledge needed, and the fact that there are too many "silos", be it data type silos or community silos, which are not good practice in the face of the digital preservation challenge. This certainly resonates with what the use case partners felt to be a positive impact of the interdisciplinary research for the preservation and data curation communities.

[36] https://youtu.be/4r9S8MAitOI at 55:00 min proposed by Jean-Yves Vion-Dury (XEROX) and supported by an audience comment afterwards.

6 Closing remarks

Although from a user perspective "change" appears suddenly, disruptive and in rapid sequences, the way leading to a change and the path leading to durable changes in behaviour and practice are slow and tedious. PERICLES proposes a change in practice supported by technology, which is perhaps not as slow as policy or societal changes, but certainly slower than change in software development. Introducing a change in practice requires many phases of review, verification, validation and adaptation by a range of different stakeholder groups. And whatever the original key objective for a change, it will undergo major transformations until becoming an established and community-sanctioned practice. PERICLES made step 1 in proving a concept and demonstrating the functional side of the approach in test bed scenarios. Having worked with user community representatives in a collaborative co-designed fashion has had an impact in the way described by the evaluators that is another vital step in fuelling the change proposed by the project: opening the minds towards the notions introduced through the research, inspiring the discourse on emerging solutions, and stimulating knowledge exchange and sharing through new forms of cooperation, as championed by the preservation community.

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