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Studying long-term storage as material visions of the future

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ABSTRACT

Long-term storage is a phenomenon that has not been theoretically defined and systematically studied. We argue that long-term storage can be construed as an object of investigation that covers a range of instantiations which can be empirically examined. Study of long-term storage with perspectives based in science and technology studies (STS) can provide new knowledge about visions of the future prevalent in contemporary Western societies. To outline this research object, we deploy four concepts: infrastructure, anticipation, transmissibility and social commitment. Investigation of this topic will reveal explicit and implicit visions of the future; illuminate material manifestation of societies' hopes and fears about the future and enable critical scrutiny of how long-term storage also shapes the future through material and cultural obduracy. This approach, anchored in STS, makes it possible to move beyond the study of representations of the future and look also at material structures.

1. A new object of investigation

Long-term storage, i.e. deliberate retention of objects for an undefined potentially indefinite period of time, is a little studied phenomenon and, as far as we are aware, it has not been theoretically addressed. We argue that long-term storage can be construed as an object of investigation that covers a range of instantiations which can be empirically examined. Study of long-term storage with perspectives based in science and technology studies (STS) can provide new knowledge about visions of the future prevalent in contemporary Western societies. In-depth analysis of long-term storage illuminates material manifestations of societies' hopes and fears about the future.

A significant amount of resources are going into the creation of long term storage, for a variety of objects of concern, i.e. entities considered worth to preserve for the future or in need of containment to reduce risks. More facilities for long-term storage are currently being built due to the accumulation of such entities. Public policies as well as commercial considerations are driving the long-term storage of new objects of concern (e.g. scientific data). Investigation of this topic also enables critical scrutiny of how the future is also shaped through material obduracy (Blok, 2022). To outline this research object we deploy four concepts: infrastructure, anticipation, transmissibility and social commitment.

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2. Infrastructure

Infrastructure has been elaborated as an analytical notion capturing the interplay of social and technical elements in the ordering of society by STS scholars since the 1990s. Star and Ruhleder (1996) extended the notion from referring only to systems of technical artefacts enabling a society to function, to including a more complex interplay of social and technical elements. In addition to viewing digital technologies used in scientific knowledge production as infrastructure they emphasised the role of human action required to make the technology work smoothly. This laid the ground for STS understanding infrastructure as socio-technical assemblages with continuous interplay of social practices and physical and/or digital elements (see among others Edwards et al. 2009 or more recently Pickren, 2018). Star (1999) notes that infrastructure is invisible when it is working as intended but causes serious disruption of social order when it is not. Infrastructure is also critical for standardisation as Bowker and Star (2000) discussed in a much-cited book. The STS notion of infrastructure has proved useful in analyses of anything from the Panama Canal (Carse, 2012), to gender imbalance on Wikipedia (Ford & Wajcman, 2017), to the shaping of economic ideas (Pinzur, 2021). We suggest that long-term storage provides infrastructure for rendering objects of concern as immobile as possible in space and time (DeSilvey, 2017). To remove such objects from their contexts of origin and use requires both dedicated technical artefacts and expert knowledge and if any component of the system breaks down rendering it defunct the purpose of storage is defeated.

Recently the notion of infrastructure has been developed as a verb, infrastructuring, which draws attention to the fact that infrastructures are never fully completed and fixed. Vonderau (2019: 701) rephrases Niewöhner's (2015) definition of infrastructuring as "a continuous process of ordering, of relating and mediating between places, technical structures, moral values, organisational resources and communities of actors". This approach encourages consideration of infrastructures as assemblages where cultural, economic, political and material dimensions are continuously renegotiated. In relation to long-term storage this points to the need of maintenance and updating. Neither physical structures or expert knowledge can continue to function without maintenance which also always involves adjustment and change, both social and material.

3. Anticipation

Long-term storage infrastructures come into being when societies allocate resources, space and regulation for a purpose invoking the future. To understand this driver we deploy the notion of anticipation as widely used in academic discussion, including in this journal. We follow Granjou et al. (2017: 10), who explains that "anticipation is explicitly a taking care of (preparing for) ahead of time". In addition, we draw on Grove's (2017: 30) notion of how organised systems "incorporate projected future states into its present functioning". We conceive of long-term storage as constituted in anticipation. Societal actors anticipate future threats and/or opportunities which motivates an allocation of resources to the construction of facilities intended to preserve objects of concern.

Infrastructure and anticipation are foundational concepts in our construction of long-term storage as a researchable topic. They characterise the phenomenon as socio-material, insisting that both social and physical features must be present to drive the design and construction of long-term storage. In addition, the notions of transmissibility and societal commitment capture durability as a planned feature.

4. Transmissibility and societal commitment

In acoustics transmissibility refers to the ability of sound to travel over distance before the signal is lost and no longer can be heard. At stake is the quality of the signal. To retain the quality of the signal over longer distances requires amplification. We find this idea of reach after initial input evocative when transposed to time. Long-term storage infrastructures must be constructed in a way that secure transmissibility of the objects of concern. Transmissibility requires that the physical integrity of both storage facilities and stored objects can be maintained over time. In addition to physical integrity, long-term storage requires that future generations remain committed to maintenance and governance. This is guaranteed through societal commitment that ensures the continuity of effort across generations. The maintenance of long-term storage requires continuous funding and education of experts who know how to handle the objects and facilities. Funding for the maintenance can come from private or public sources and education requires an institutional framework.

5. Fleshing out the new object of investigation

The conceptual framework devised above can be explicated by a comparison of two examples: seed banks and nuclear waste repositories.

The anticipation of biodiversity loss, that includes concerns about agricultural productivity and climate change is a motivating force for both scientists and governments to promote the preservation of seeds. This anticipation underpins the construction of facilities in which seeds of both wild and cultivated plants can be kept in stasis for an unspecified possibly indefinite length of time. Such facilities comprise dedicated infrastructures involving scientific knowledge and research, technical experts and expertise as well as material flows of energy and water. In existence since the 1960s seed banks have demonstrated transmissibility through generations of expert staff, scientists and societal decision makers (Curry, 2022; Peres, 2016). Taxonomy, coding and freezing are discernible as key elements for ensuring transmissibility of the knowledge needed to maintain the value of stored seeds into the future, knowledge about species, location of origin and more (see Chacko, 2019; Curry, 2019; Harrison, 2017; Laboissière, 2019; Peres, 2019, among others).

In contrast to seed banks, nuclear waste repositories are driven by anticipation of the risks to humans and the environment posed by this extremely toxic material. Faced with the risk of irreversible damage societies have committed to geological disposal as the safest way to isolate high-level, long-lived radioactive wastes from the surroundings for thousands of years. Scientists and governments have pursued this long-term storage option since the 1970s (Ialenti, 2020). However, although a few facilities are currently being constructed, this solution has not yet been implemented in full scale, hence, infrastructure is not yet actual (Landström & Bergmans, 2015). In this case transmissibility pertains to the idea of long-term storage in the form of geological disposal that has survived changes in governments, scientific projects and technical expert organisations (Parotte et al. 2024).

Using the four key concepts, anticipation, societal commitment, infrastructure and transmissibility in a comparison of seed banks and nuclear waste disposal we find that both originate in the anticipation of nuclear annihilation present during the cold war (Curry, 2022; Harrington, 2023). Later this has changed with the growing awareness of environmental degradation in the 1960s, followed by new legislation and international agreements for environmental protection, such as the three Rio Conventions in 1992 addressing biodiversity, desertification and climate change (UNCBD, 1992; UNFCCC, 1992). Seed banks became a backup solution for humanity to withstand climate change and biodiversity loss (Pellegrini & Bulatti 2016). In contrast the anticipation of radioactive damage did not evolve, instead it has turned into a practical problem of accumulation. Interim storage facilities of spent nuclear waste are filling up and long-term storage is badly needed, however, geological disposal has proved politically extremely contentious, with local protests halting many attempts to site facilities (Blowers, 2016).

Bringing these two very different types of long-term storage into the same analytical framework reveals both commonalities and diversity. Although contemporaries, the divergent realisations of long-term storage tie them to different visions of the future in the present. Historical investigation of their evolution would reveal much more than what this very brief outline does.

Another example that our conceptual framework includes is data centres. These did not begin as facilities intended for long-term storage but to enable space for and speed of access to digital data (Nost & Goldstein, 2022). Scientific data, as well as data collected by commercial actors and public authorities required centralised storage for reliability and access. As more information collected and processed by governments and public authorities that must be kept for long periods, such as public archives, become digital the need for long-term storage arises (Fredriksson et al., 2017; Svärd & Borglund, 2022). Recently tech companies have begun to offer cloud data storage services tailored for governments on all levels, e.g. “Google for Government” (https://cloud.google.com/gov). In this case, an infrastructure is emerging that is turning into long-term storage due to the objects of concern placed in it. Today anticipation for the future of data centres identifies risks that must be managed, for example power outages and cyber security. Transmissibility also presents challenges for data centres not initially planned to provide long-term storage across generations, as technology becomes obsolete and the experts developing and managing the first facilities approach retirement. Still, the societal commitment to data centres can be said to be extremely high since we all, institutions, organisations, business and individuals depend on them for work, entertainment, communication and many other aspects of contemporary life.

Our final example for demonstrating the potential of studying long-term storage is museum reserves. These facilities were created in response to both accumulation and anticipation of future use. Museum collections are perpetually growing and the exhibition spaces cannot accommodate all of the objects (Brusius & Singh, 2017; Morgan & Macdonald, 2020). When the private collections of European royalty and nobility in the 17th century became the responsibilities of museums in the 19th century, the number of objects rapidly outran the spaces available for public display. Still, the value assigned to the collections prevented disposal and encouraged storage. The objects considered worth placing in museums are also regarded as important for future generations, they must be preserved and protected against internal and external threats. As ever-expanding infrastructures museum reserves provide an example of transmissibility of storage across generations. Generations of experts have been committed to the conservation of objects that circulate between the reserves and the exhibitions (Kreplak & Beltrame, 2024). The connection of museum reserves to the exhibitions resembles that of seed banks to botanical gardens and it is likely that in both cases the link supports the transmissibility of the long-term storage infrastructure. While museum reserves are often housed in facilities off-site, they are becoming less secluded today when some open up parts to public visits (Kreplak & Mairesse, 2021; Rubio, 2020). This could be one response to diminishing societal commitment and therefore shrinking budgets.

6. Researching long-term storage

The above outline of four examples of long-term storage in the preliminary framework provided by our key concepts - anticipation, infrastructure, transmissibility and societal commitment points towards new questions to investigate.

More in-depth examination of anticipation regarding specific objects of concern can provide insights about the complexity of assessment of future value or their status as threats. For example, both seed banks and museum reserves store objects that are viewed as valuable and should be preserved for the future but for very different reasons. How are these valuations done in different societies, by different collectives, at different times? Are there conflicts over selecting which seeds or artefacts to store? While both seed banks and museum reserves store objects of concern that are threatened by internal decay and require continuous maintenance (Rubio, 2020), their position in relation to external threats like climate change or social collapse differ, depending on access to expert knowledge and actual location. How are these threats managed in the present and which strategies are created to address them in the longer term?

Further questions arising in relation to the infrastructures of long-term storage concern the material immobilisation of the objects stored. The examples of nuclear waste repositories and data centres both involve sophisticated technical solutions to keep the objects stored in a fixed place and firmly contained. How is the immobilisation maintained in relation to very different objects of concern and what does it mean? Nuclear waste is to be immobilised in the sense of not removed from the geological repository and it must be contained with technologies that prevent leakage of the toxic material. Digital data is immobilised in storage media that must render it accessible to legitimate users while being contained in a way that protects it from intruders. What do these differences mean for the location of the long-term storage infrastructures and perceptions of remoteness? These examples point to the challenges the accumulation of objects of concern cause, such as physical extension of storage or internal reorganisation. Which possibilities do different long-term storage infrastructures have for adding stored content?

Transmissibility indicates questions about knowledge, expertise and technical know-how as well as governance. The examples of nuclear waste and museum reserves point to very different processes, the former premised on advanced scientific research, technical experimentation and international regulatory frameworks but still not operational after more than 50-years of anticipation-driven planning. The latter emerged from the practices of collecting and displaying culturally valuable items, prompting fields of knowledge and demonstrating transmissibility across different governance systems. What roles do the knowledge about the material and immaterial features of the storage facilities and objects of concern play in the hand-over to the next generation? Which governance systems could be adaptable to new generations of custodians?

Societal commitment points to the importance of long-term storage being able to entice wide support for the ongoing investments required and sustain the political will to maintain the infrastructures over generations. In this context museum reserves present the only example of actual long-term societal commitment. The example of nuclear waste points to the opposite - it is an issue that divides societies, which could explain the lack of actual infrastructure despite scientific, technical and political ambitions. Today some seed banks and museums experience challenges to funding and expertise that could compromise their longevity. Which strategies are devised to maintain or reignite societal commitment? Who takes on the responsibility for developing such strategies? Data centres are in comparison very recent but they could suffer from the dependence on private corporations which locates them outside of the public domain. This raises questions about the relationship between private and public interests regarding long-term storage, and societal commitment. What happens if a privately owned and operated long-term storage facility ceases operation?

7. Conclusion

In this comment we have argued for the value of considering long-term storage defined as deliberate retention of objects for an undefined possibly indefinite period of time, an object of academic study. The novelty of this suggestion is the construction of long-term storage as an analytical category cutting across a variety of empirical instantiations. Previous studies have focused on one type of storage such as museums or nuclear waste. By looking at the creation of facilities for long term storage in this sense, we can learn about societies' visions of the future.

We exemplified the analytical construct of long-term storage through four categories of facilities, seed banks, nuclear waste repositories, museums reserves and data centres. The list might be extended, we believe, to other categories as well, like carbon capture and storage or environmental specimen banks. We propose that investigation of this topic will reveal explicit and implicit visions of the future; illuminate material manifestation of societies' hopes and fears about the future and enable critical scrutiny of how the future is also shaped through material and cultural obduracy. This approach, anchored in STS, makes it possible to move beyond the study of representations of the future and look also at material structures.

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CRediT authorship contribution statement

Catharina Landström: Writing – original draft, Conceptualization. **Valerie November:** Writing – original draft, Investigation, Conceptualization.

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