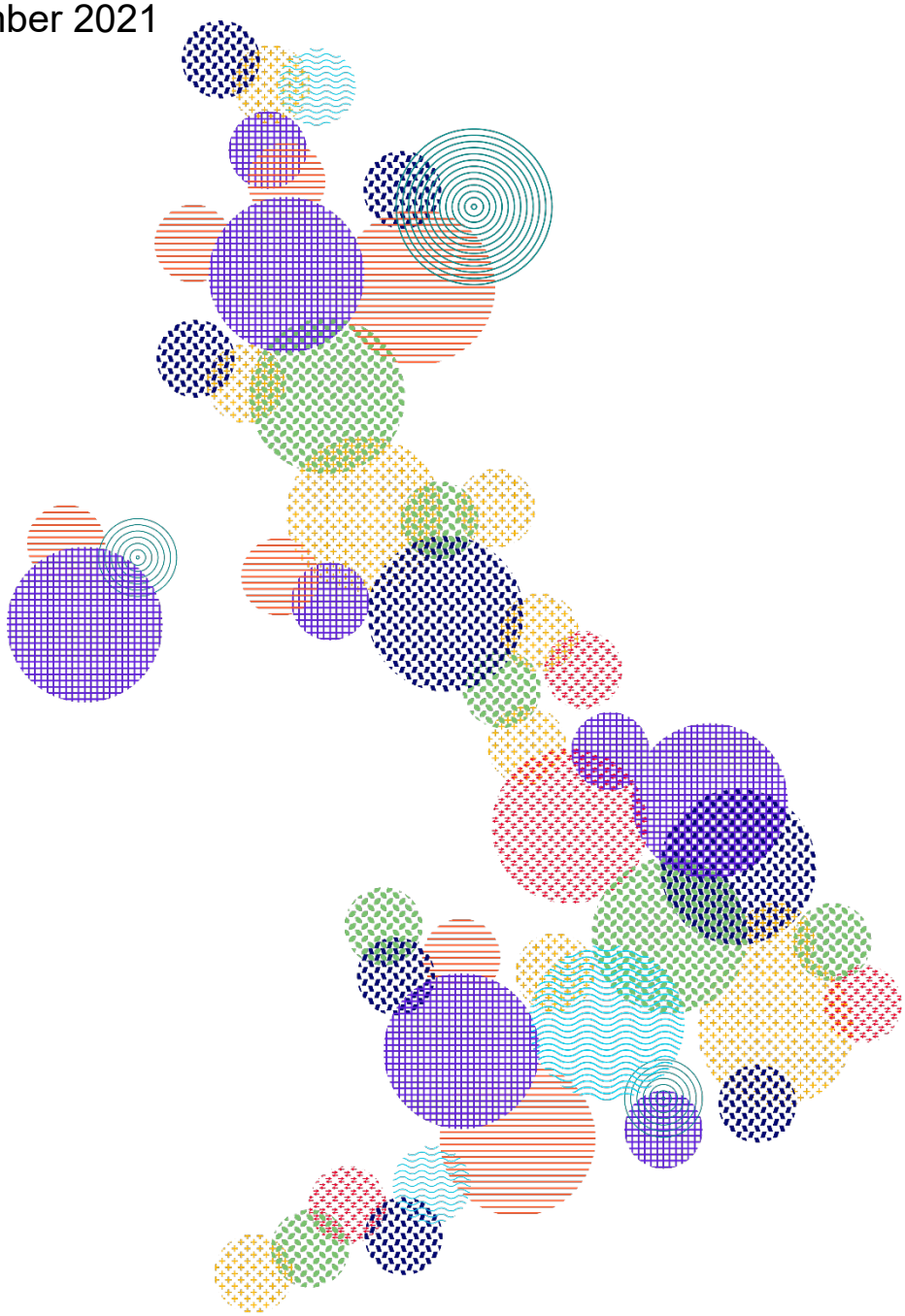
NATIONAL
DIGITAL TWIN
PROGRAMME

Digital Twins: Ethics and the Gemini Principles

December 2021



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Contents

Forewords		**3**
1.0	**Introduction**	**5**
2.0	**Research methodology**	**6**
3.0	**Key findings**	**7**
3.1.	**Summary**	**7**
3.2.	**Purpose**	**9**
	Public good	**9**
	Value creation	**9**
	Insight	**10**
3.3.	**Trust**	**11**
	Security	**11**
	Openness	**11**
	Quality	**12**
3.4.	**Function**	**13**
	Federation	**13**
	Curation	**13**
	Evolution	**14**
4.0	**Recommended next steps**	**15**
5.0	**Conclusion**	**16**
6.0	**Sopra Steria researchers**	**17**
7.0	**Acknowledgements**	**18**
	Workshop contributors	**19**

NATIONAL DIGITAL TWIN PROGRAMME

Forewords

The digital revolution is firmly established and continues to grow. One of the most exciting aspects of this is the opportunities that it presents to bring about significant benefits to society. The Internet of Things in particular, with its wealth of interconnected sensors, is helping us understand the world in radically new and important ways. Digital twin technology embraces this to provide a real time picture of events and at the same time model, predict and directly influence those events.

From improving public services to making safer roads, developing more effective land use to reducing our impact on the environment, making our borders more efficient to transforming healthcare, digital twins offer exciting possibilities for the future. Yet these benefits will only be realised if we recognise that ethics lies at the heart of technology. The benefits and risks of digital twins need to be grappled with now, at the advent of the technology. The alternative is to wait and be confronted with missed opportunities.

This report, a collaboration of Sopra Steria and the National Digital Twin Programme (NDTp), highlights a range ethical issues arising from the founding principles of a National Digital Twin. It argues that clear leadership and public engagement are central to the effective, long term development of this technology. An ecosystem of standards, guidelines and training is needed to bring out the best in digital twins for industry, government and civil society. As the report states, this is not the last word on the ethics of digital twins, but it is a significant contribution to the conversation. I hope that you read it, engage with it, and find as much value in it as I have.

Adrian Fieldhouse
Managing Director Government Sector at Sopra Steria

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With all the excitement for digital technologies and innovations that can potentially improve our everyday lives, comes the great responsibility to ensure they are actually ethical and sustainable. This is particularly true of the National Digital Twin programme (NDTp) which is based on the premise of 'data for the public good' [National Infrastructure Commission: 2017].

From its inception, the NDTp has been guided by the Gemini Principles, a unique set of values that are effectively the conscience of the NDT. Together with our growing community, we have used the Gemini Principles to inform the research and development of standards and toolkits, guidance and demonstrators, towards enabling 'an ecosystem of connected digital twins'.

Therefore, we are delighted that the community has come together, ably led by Sopra Steria, to examine the ethics of connected digital twins, with the Gemini Principles as a reference point. This report throws much-needed light on the key ethical considerations for the community as we move towards making connected digital twins a reality.

I would like to commend this important work to you and to thank the Sopra Steria research team and our NDTp partners for their hugely valuable contributions.

Mark Enzer OBE FREng
Head of the National Digital Twin programme

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1.0 Introduction

This report summarises the findings of research undertaken by Sopra Steria and supported by a series of focus workshops with industry, government and academic experts pulled from across the National Digital Twin programme's (NDTp) wide ranging community. The research focused on capturing and understanding the ethical issues arising from the Gemini Principles, the foundational principles of the National Digital Twin. The initial research, the facilitation of the workshops and the analysis of the findings was led by Sopra Steria on a pro bono basis in collaboration with the NDTp.

The Gemini Principles report[1] was published by the Centre for Digital Built Britain in December 2018. The aim of the Gemini Principles is to align the approach to information management across the built environment through highlighting key aspects required to establish an effective digital twin ecosystem across industry, government and academia.

This report explores:

- High-level ethical considerations for each of the Gemini Principles
- Ethical interdependencies between the Gemini Principles
- The context-specific nature of ethical considerations regarding digital twins
- The value of stakeholder engagement in the development and deployment of digital twins
- A need for clear leadership and ethics in the ongoing development and use of digital twins

[1] https://www.cdbb.cam.ac.uk/system/files/documents/TheGeminiPrinciples.pdf

2.0 Research methodology

Sopra Steria has undertaken extensive academic and industry research into the ethics surrounding digital twins. This research provided the foundations for three stakeholder workshops exploring the ethical considerations behind digital twins and the National Digital Twin. Stakeholders were invited due to their expertise and experience with ethics, data and digital twins. There was an array of perspectives from organisations spanning government, academia, and industry and this collaboration sparked invaluable insight throughout the workshops.

These workshops were focused specifically on understanding the Gemini Principles from an ethical perspective. Sopra Steria's seven categories of digital ethics[2], drawn from academic and industry standards, were adopted as a framework with which to approach the Gemini Principles. The workshops then explored the relationships between the framework values and the Gemini Principles. Combining the initial research with the analysis from the workshops has provided insight and clarity on the ethical aspects of the National Digital Twin for the NDTp and users of the Gemini Principles. This is essential for the operationalisation of the Gemini Principles, turning them from aspiration to reality.

[2] https://soprasteria.turtl.co/story/digital-ethics/page/4?sfvrsn=544f38dc_2

3.0 Key findings

3.1. Summary

The opportunity to revolutionise industries sits with a multitude of new and innovative technologies that are emerging. Digital twins are a stand-out player in this space. Digital twins bring with them ethical risks and opportunities. These can create value for industry and society. However, ignoring either the risks or the benefits will mean that potential problems cannot be mitigated, and potential benefits may be missed. In either case, digital twins will not fulfil their potential and may induce adverse public reaction. It is therefore essential that a nuanced ethical understanding of digital twins is developed in line with industry, academia, government and civil society thinking.

Digital twins are growing rapidly in scope, application and interconnectedness. A comprehensive review of ethical issues arising from new technologies is impossible to achieve, as new developments can lead to novel ethical concerns. Rather than attempt to review the state of the art in digital twins, this report looks at the founding principles of the National Digital Twin, the Gemini Principles. Given the widespread international adoption of these principles, the ethical considerations arising from the Gemini Principles will permeate the global landscape of digital twins.

The Gemini Principles were created to guide the development of the National Digital Twin and the Information Management Framework[3] that will enable it. They are organised under three overarching groups: Purpose, Trust and Function.

The Gemini Principles are inherently connected and interdependent. All nine need to be respected to create an effective National Digital Twin, and if one is not upheld it will adversely impact the ability to execute the remaining eight. There are shared characteristics between all the Gemini Principles in each of the three groups, but all nine are mutually dependent. This holds for the ethical considerations of each principle as well. This report explores key ethical considerations arising from each of the principles, demonstrating that there is an array of ethical issues for each. In these, common themes emerge, such as the need for an appreciation of context, stakeholder engagement and governance.

The context in which a digital twin, or an ecosystem of connected digital twins, is deployed will dictate certain ethical considerations. While these considerations span industries and uses, such as the ethical use of data and the need for transparency, the context will dictate which ethical considerations have a particular bearing on certain digital twins. Different sources of data will be needed for different digital twins[4]; some may rely on historic data, some on sensors, some on personal data, each with shared and unique ethical considerations. A digital twin created to make fossil fuel extraction more efficient, for example, will have an assortment of unique ethical considerations that will not all apply in equal measure to a digital twin used in the development of smart highways. Both, however, have ethical implications that if ignored are at society's cost.

The complexity of digital twins, coupled with their potential impact on society, means that stakeholder engagement is key to their success. When stakeholders are not engaged in technology development and deployment, ethical considerations may be overlooked (such as unfair distributions of risk), public trust is diminished, and there is a risk of public rejection to not only individual digital twins, but also the creation of an ecosystem of digital twins as a whole. This would be to the detriment of all. Taken alongside the context-dependency of digital twins, this suggests that an ethics-by-design approach would benefit the field. This would help to ensure that ethics are a continuing consideration throughout the design, development and deployment of technology.

The above considerations strongly advocate for clear, accountable leadership in the development and use of digital twins. Defining key terms, setting standards, and training future generations so that the technology develops in a genuinely beneficial way requires clear and agreed leadership which brings together stakeholders from industry, academia, the government and civil society.

[3] https://digitaltwinhub.co.uk/projects/imf/what-is-the-imf/
[4] https://digital-twins.kumu.io/describing-digital-twins

3.2. Purpose

Public good

The first Principle states that digital twins must be used to deliver genuine public benefit in perpetuity. Reference to the public good renders this an inherently ethical stance. However, clarity is needed as to what is defined as the good, who defines it, and how it is distributed throughout society? Without this clarity, there is a risk of developing or perpetuating power imbalances and unequal distributions of risk and benefit in society. To counter this risk, stakeholder engagement in the development and deployment of digital twins is essential to recognise potential ethical blind spots. Stakeholders should include, at the very least, civil society bodies affected by a particular digital twin, those whose jobs will be impacted (given that digital twins will both create and displace jobs) and silent stakeholders such as the environment and future generations, who can be represented through stakeholder 'champions'. A fair representation of stakeholder groups, across demographics and levels of expertise, will require accessibility to those groups. In effect, this means that participating individuals should be reimbursed for their time; otherwise, those in privileged positions could be the only ones with the capacity to participate.

Clarity is also needed in reference to the term, 'in perpetuity'. This is an immeasurable term and may be seen as aspirational only. An agreed, common decision-making framework could provide a solid foundation for clarifying what is meant here, using established tools such as taxonomies of harms and benefits. Including the requirement of delivering Public Good into established processes such as tenders and bids is another avenue to explore. Again, this raises the question as to how delivery of the Public Good would be measured and validated within these processes.

A further challenge with the consideration of perpetuity is the potential for changing societal values over time (see the Evolution Principle). While changing values cannot always be anticipated, efforts should be made to clearly record and justify why particular decisions were taken, ensuring that thinking and intentions are recorded for posterity.

Value creation

As with the Public Good, Value Creation is by its nature an ethical position. There are, though, both ethical values (e.g. fair) and prudential values (e.g. efficient) and so clarity of terms is again important. Different actors in the digital twin ecosystem are likely to have different expectations of value, such that a corporate organisation's concept of value (potentially focusing on profit) may differ from that of government or local communities (potentially focusing on social benefit). A lack of clarity here risks engendering confusion and frustration. As with the Public Good, clarity is needed regarding an understanding and agreement of terminology and how to achieve a fair distribution of value. Once more, stakeholder engagement and representation in the development and deployment process can aid in this.

Even when value is agreed upon, trade-offs in competing values will at times be required. Environmental sustainability, for example, is a key area that digital twins can add value. Through using digital twins, assets and infrastructure can become more efficient, and sensors can monitor environmental trends. However, the use and industrial context of the digital twin may involve power requirements for computing resources that could erode any environmental benefits, such that net value to the environment is reduced.

Insight

To enable meaningful insights from NDT, a strong and adaptive culture must sit across the eco-system to allow for flexibility and openness to innovation. A critical element of this is that insights should be used to create iterative feedback loops on the decisions made using digital twins. These need to be coupled with defining metrics to accurately measure the value of a digital twin.

A need for flexibility implies that an appreciation of learning is essential in the supportive culture of digital twins. This should ensure that feedback and insights provide real progress. It should also demonstrate that a digital twin is creating value and lessons are being learned. To support this, decision making processes based on insights will need to be transparent, with clear audit trails.

In keeping with earlier comments regarding stakeholder representation and engagement, insights need to be shared with and explained to a broad set of stakeholders. These insights need to be provided in meaningful ways using accessible media. This can be addressed from both ends of the spectrum: consultation from experts and improving levels of digital literacy and understanding across society. This should be carefully balanced as experts are often needed to interpret data, but if these interpretations become too simplistic then the agency of others risks being diminished. Accessibility also needs to be implemented delicately, given that some organisations may unnecessarily fear the accountability that can come with sharing insights. Legislation can help navigate this. Building upon this foundation, organisations could shoulder the responsibility of ensuring that ethics sit at the core of this principle. However, this will require that appropriate processes, such as whistleblowing policies or empowering ethics boards in decision-making, be in place. Beyond providing accountability, a clear opportunity exists for organisations to use insights as a tool to improve equality in society, and to determine whether a technology has disproportionate impacts on certain demographics.

3.3. Trust

Security

The scope of the Security Principle is not limited to the digital environment but includes the protection of people and assets. This is of particular concern when considering digital twins of national infrastructure or public transport networks and could require trade-offs with other principles (such as Openness) and values (such as Privacy). Lessons can be learned from other fields, including cybersecurity, open banking and medical communities, on how to balance security, openness and privacy (including location privacy). For example, security is key to providing a trusted system, especially when that system deals with location or other personal data. The risk of re-identification of anonymised datasets through the use of digital twins, must therefore be taken seriously, adding levels of complexity to the safe and secure use of data.

From the perspective of malicious actors, digital twins present the risk of data/identity theft through their accessing insufficiently protected datasets and infrastructures, such as surveillance systems. Sensors can be the starting point for malicious attacks, and if they are not tested appropriately, or sufficiently protected, they may pose major threats to the entire system. At the same time, there is also the potential for function creep for those overseeing a digital twin, as access to large quantities of data relating to society can present opportunities for control. This may be exacerbated in cases where there is a lack of oversight or accountability of the overseeing body.

Openness

In light of the Principle of Security, Openness clearly cannot imply complete transparency of data. The context will always be influential in determining degrees of openness and trust. Even then, openness will not guarantee that people trust digital twins. Trust in the institutions deploying digital twins will also be significant, as will trust in governance mechanisms. The issue of trust in governance raises the importance of the gatekeeper to the NDT, overseeing the governance and regulatory aspects guaranteeing openness.

With this understanding, and while still adhering to data protection principles, such as data minimisation, open data should, where possible, be the default setting for digital twins. But with this will come questions around data stewardship and ownership (see the Curation Principle), while also ensuring effective governance of downstream uses of data requiring the necessary security measures if applicable.

Open data does not equate to openness. Data must be interpreted in a way that genuine knowledge is shared across and accessible to appropriate stakeholders to derive the true value of openness. Educating stakeholders on the value of sharing data in the context of a digital twin will help to achieve openness and establish a common language around the use of digital twins, making them more accessible. Technical approaches can also be used in

achieving openness of data, such as the sharing of meta or synthetic data, or the implementation of multi-party computation tools that amplify the benefits of a federated system.

It should also be recognised that unequivocal trust in technology is not to be desired in a democracy. A degree of scepticism is healthy. Rather, a supportive ethical framework for digital twins can help improve levels of trust while not seeking blind faith. Such an approach could include engaging community representatives, a balanced representation of all stakeholders, and learning from other industries, such as the medical field with the use of trusted/accredited operators.

Quality

Establishing the ethical foundations around Quality will support and strengthen the other Gemini Principles. However, what is meant by Quality (in terms of the value, accuracy, transparency and appropriateness of data, as well as the use) will vary depending on context. This means that further agreement will be required on how the Gemini Principles should be applied in different scenarios. Furthermore, the measurements used to define and assess Quality are a critical aspect of this Principle.

Although the data that are used as the foundation for digital twins should be ‘quality’ (i.e. accurate), preparation will typically be required to improve that quality, such as normalisation, filtering, missing value imputation, outlier detection, and/or harmonisation. Data preparation is a critical process for ensuring quality, without which there is a risk that results will not be well informed, leading to potential safety issues. However, decisions made regarding data preparation will impact the outcome of the digital twin in ways that may have ethical implications (see Curation).

Essential to Quality is an understanding of how the data have been generated, as there are numerous sources of imprecision and bias related to data capture. Bias in data collection, which can present itself as an underrepresentation of specific groups or an overrepresentation of groups in the dataset, risks creating issues of fairness and discrimination with a digital twin. Selected data should therefore be properly representative, relevant, accurate, and used to form generalisable datasets. Likewise, the limits to the parameters of algorithms used in a digital twin should be acknowledged and explored for potential biases.

3.4. Function

Federation

A Federated ecosystem promotes collaboration over competition. For a National Digital Twin to operate, short of being centrally managed, it will need to be a Federated system requiring clear standards and guidelines for interoperability. This open and Federated ecosystem model has proved effective in improving collective safety and quality, as demonstrated with the development of open source code online.

There may be concerns with a Federated system, similar to the Principle of Openness, regarding the security of data, both personal data and intellectual property. As with other areas, trusted approaches can be explored from disciplines facing similar challenges, such as blockchain. Others may fear the quality and robustness of data or approaches shared in a Federated model are below par and therefore could damage the overall ecosystem. Once more, clear leadership, standards and guidelines are essential for this to succeed.

A Federated ecosystem can improve safety for society through improving accessibility to infrastructure for numerous stakeholders, including SMEs and civil society organisations. However, as data sharing is crucial for the success of federation, key issues such as data protection and privacy must be considered. Recognising the significant role preferences and context can have on consensual data sharing is crucial.

Curation

The Curation of data and management of technology underlies the inherently ethical nature of a digital twin. Choices must be made as to which data to collect and which to ignore, which parameters to use and which to exclude, and where to introduce threshold considerations. Each of these choices carries with it an ethical implication, and hence there are numerous considerations in relation to this Principle. This, collectively, and taken with other Gemini Principles such as Federation, highlight the need for an agreed approach to governance and the need for (a degree of) regulation around digital twins.

Numerous possibilities, including the application of sector-based regulation and the deployment of data guardians (similar to Caldicott Guardians in the UK medical field), should be examined as possibilities across industries. Leadership should span traditional boundaries, with the inclusion of academic, industry and government institutions, with civil society representation, in the governance of digital twins. This approach should be layered and accessible to all. Active learning and iterative improvements should also be intrinsic to Curation to encourage generation of the greatest value for society.

Evolution

There is a critical loop in the Evolution of digital twins for an ethical National Digital Twin. Technology needs to keep pace with changes in society and our collective understanding of ethics, while our understanding of ethics needs to keep pace with the development of technology. There are numerous cases of one of these falling short of the other, whether in the context of COVID-19 and changing perspectives on the value of privacy, or extensive examples of discriminatory algorithms which struggle to reflect ethics in technology. As a collective, opinions and perspectives on ethics evolve and legislation needs to balance efficacy with the flexibility to facilitate this.

There are emerging topics pertinent to digital twins that sit across the spectrum of data ethics. Protecting group privacy, for example, is increasingly being explored, which could result in more stringent data protocols. For example, General Data Protection Regulation (GDPR) is generally perceived to be insufficient compared to the newer California Consumer Privacy Act (CCPA) on the protection of individuals for ‘inferences drawn’. Conversely, the National AI Strategy in the UK has raised the possibility of collecting more data on equality, diversity and inclusion in the future to provide insights that facilitate more equitable decision making. Legislation needs to consider these and other issues around digital twins, including autonomy, responsibility and the potential for skill dilution.

Depending on the particular digital twin and data set used, some cases, such as those used to query and predict social behaviour, for example in public policy development, may necessarily rely on historical data. However, those data risk failing to reflect changes in social behaviour, law, and institutions or governments, which can radically alter the model. As a result, digital twins of this nature could be limited to representing the future based primarily on historical data. The result of this is a risk that the future presented by such a digital twin will be little more than a repeat of the past.

While balancing these nuances, legislation is needed to establish a baseline on value to determine the true impact of digital twins. Unless a clear and proactive approach is taken to establish a starting point, in a federated system with constant data sharing and an evolving ecosystem, it will become extremely difficult to articulate the true value and impact of the technology.

4.0 Recommended next steps

Through exploring the ethical considerations behind the Gemini Principles, the research team at Sopra Steria recommend the following steps to ensure ethics remains at the heart of the National Digital Twin.

1. Agree and develop clear, long-term leadership for the National Digital Twin in a manner that brings together industry, academia, government and civil society with the aim of agreeing terms, setting standards and creating guidelines regarding ethics.
2. Develop processes for stakeholder and civil society engagement with the development of the national digital twin and use of digital twins.
3. Create an ethics board for the National Digital Twin, with representation from across industries, academia, government and civil society. Initially, this ethics board should address the issues discussed in this report, and it should be a compulsory and prominent presence in the decision-making process.

5.0 Conclusion

This report has introduced ethical considerations arising from the Gemini Principles, the founding principles of the National Digital Twin. Owing to the widespread adoption of the Gemini Principles in the UK and beyond, these ethical issues permeate the industrial, academic and governmental use of digital twins.

Throughout the report, several key, overarching themes emerge. One is the need for widespread stakeholder engagement in the design and development of digital twins. This will help to avoid ethical blind spots while increasing public trust in digital twins. A second is a need for clear guidance and leadership on key issues in the digital twin space, such as defining terms (public benefit, perpetuity, etc.), setting standards (for federation, curation, etc.) and overseeing fairness in benefit distribution throughout society. Finally, the inherently contextual nature of digital twins must be acknowledged: the almost endless applications of digital twins lead to a range of ethical considerations which will differ in weight and bearing depending on the context of use. Taken alongside the complexity of ethical considerations raised in this report, an ethics-by-design approach would benefit the field. This will help to ensure that ethics are a continuing consideration throughout the design, development and deployment of technology.

The report has also identified ethical issues arising with each of the nine principles. Given the interdependencies between the Gemini Principles, it is not surprising that the ethical issues arising are similarly inter-related. As such, in seeking to develop and deploy an ethical digital twin, these issues should not be considered in isolation. Just as there is a relationship between, for example, Federation and Curation, so is there a relationship between Security, Privacy and Openness. These interdependencies lead to a requirement for complex ethical trade-offs to be made. Once more, these trade-offs are best made with clear and accountable leadership and through engaging stakeholders, including the general public, while recognising contextual dependencies of each individual digital twin.

Lastly, it is important to recognise that the issues raised here do not form a comprehensive list. This would be premature given the ongoing and rapid development of digital twins. Instead, these issues highlight the key considerations that should form the starting point of any ethical investigation into a digital twin or an ecosystem of interconnected digital twins. It is hoped that with time a more comprehensive picture of the ethics of digital twins will emerge. In the meantime, this report aims to start a conversation as to how that picture should appear.

6.0 Sopra Steria researchers

The initial research was conducted by Nick Wild, Digital Ethics consultant in Sopra Steria's Digital Ethics and Tech for Good Team, and Haleh Asgarinia, PhD candidate at the University of Twente, overseen by Dr Kevin Macnish, Digital Ethics Consulting Manager at Sopra Steria.

Kevin has 12 years' experience as an academic and consultant in digital ethics and was a lead contributor to the EU SHERPA project on the ethics and human rights implications of AI. He has published over 40 academic articles, chapters and books in this sphere.

Nick works as a Digital Ethics consultant in Sopra Steria's Digital Ethics and Tech for Good Team. He has extensive experience helping organisations understand the digital ethics considerations within different technologies and contexts. Recently he has been working in projects to define ethics in digital twins across industries. He brings his previous experience as a consultant in the public sector and training in user research to his current work in digital ethics.

Haleh's project is part of the Marie Skłodowska-Curie Innovative Training Network 'PROTECT - Protecting Personal Data Amidst Big Data Innovation', funded by the European Commission's Horizon 2020 programme. She was working with Sopra Steria on a three-month internship as a part of that programme.

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In collaboration with the NDTp, this report has been produced by Sopra Steria who have provided their time and expertise on a pro bono basis.

About Sopra Steria

Sopra Steria, a European leader in consulting, digital services and software development, helps its clients drive their digital transformation to obtain tangible and sustainable benefits. The company's trailblazing Digital Ethics practice is shaping the standards and driving the innovation behind the responsible technology movement. With 46,000 employees in 30 countries, the Group places people at the heart of everything it does to build a positive future.

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