THE DIGITAL OIL PLATFORM.

Institution of MECHANICAL ENGINEERS

Examination of Issues Raised at the IMechE Seminar

Improving the world through engineering

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EXECUTIVE SUMMARY

The concept of digitisation is currently being widely promoted as the answer to many problems in the engineering sector. Fusing the data streams provided by comprehensive instrumentation systems, with powerful, real-time system simulations (or "digital twins"), is believed to offer benefits that include the rapid identification and remediation of production faults and material flaws, and the ability to forecast future performance growth and limitations.

The oil & gas industry is notoriously conservative. The potential financial penalties from adopting new technology that fails to deliver are so great, that most operators prefer to wait until benefits are clearly demonstrated by others. Safety concerns, and the need for safety assurance of new technologies, are also cited. For this reason, the industry is arguably behind developments in other sectors.

IMechE held a seminar in Aberdeen during October 2018, which reviewed some of the current technology and approaches, and this report draws significantly on the technology and opinions expressed at that conference to form a perspective on the subject, but that perspective must be treated as one of many. The seminar identified a number of challenges still to be overcome before digitisation can be widely applied:

- Data quality, trust and curation. Huge amounts of data are generated already from instrumentation and simulation, but there are no accepted processes for assuring the quality of data, or for managing its storage and usage. This leads to a problem of trust: operators do not trust their digital data sufficiently to make otherwise unsupported decisions based on it – or to allow automated systems to make decisions.
- Design for Digital. At this point in time, a designer could not provide an entirely autonomous fully digitised design for a production asset. The technology and understanding exist, but the assurance processes and accepted methodologies do not. There are also commercial barriers: adding digital technology increases capital cost while reducing operational cost, yet the Engineering, Procurement, Construction (EPC) model for new developments frequently applied in the industry, may incentivise reductions in capital cost only, if an operator is not fully engaged in the process.
- Training and skills. Different skill sets are required to design and operate a digitised asset, at every level. At the time of writing no university offers either undergraduate or postgraduate courses on the subject (or digital-specific modules), and the provision at vocational level is even worse. If systems are to be deployed that provide the trusted data that is essential for a digitised asset, much greater understanding of the topic is required across the industry.

This report reviews the latest developments in the various elements of digitisation already being deployed offshore, principally advanced instrumentation, data and asset management, and simulation. It also provides a discussion of the challenges the industry faces in more detail.

This report summarises the presentations made and discussions held at the IMechE Digital Oil Platform seminar held in Aberdeen on 17 October 2018, augmented with some subsequent research by the authors to illustrate key points. It must not be taken as a comprehensive survey of the topic, but only as a snapshot of a point in time and space where certain issues of interest were raised and discussed.

DEFINITIONS

The following definitions are used in this document

Term	Explanation
CTA	Common Technical Architecture
EIP	Energy Industry Profile (standard)
EPC	Engineering, Procurement, Construction
ISO	International Organization for Standardization
NUI	Normally Uninhabited Installation
OAIS	Open Archival Information System
V&V	Verification and Validation

INTRODUCTION

The purpose of this report is to review the latest developmentsbe regarded as a snapshot in both time and scope, but is hoped that it will provide a valuable contribution to the debate on the potential benefits of digital technology, and the barriers to adoption. It is not provided as a comprehensive survey of the subject.

The following topics are discussed:

- An introduction to digitisation
- The potential benefits
- A review of current developments in:
    - Control and instrumentation
    - Simulation
    - Data fusion and management
- The challenges still to be overcome
- The next steps for the industry

This report does not address the needs of the industry completely, and notes that there is still much work to do – full digitisation faces a number of technical and cultural barriers. The potential benefits, however, are significant.

WHAT IS DIGITISATION?

"Digitisation" has become something of a buzzword, recognised as something that an organisation must have, but without an agreed and clear definition of what it is. Research conducted by DNV GL[1] revealed that nearly half (49%) of senior oil & gas executives believe digitalisation is necessary to boost profitability.

This report does not attempt to provide a global definition, but in the context of this document only, digitisation will be defined as:

"The seamless integration of the large amounts of digital data either gathered from a combination of comprehensive instrumentation and automation systems with real-time system simulations, or generated from a digitally-orientated design process."

The fundamental aspects of digitisation already exist, and have over the last 40 years. Two things have now made full digitisation possible:

- The amount of instrumentation data gathered has increased exponentially. Data storage capacity is now immense, sampling frequencies have increased, and new technology allows for instrumentation to be retrofitted to existing assets.
- The speed and accuracy of numerical simulation have increased exponentially, with chip clock-speeds continuing to follow Moore's law. This allows comprehensive, real-time system models to run alongside the actual asset for the first time.
- The challenge is combining these two data streams into something that can be used to improve the design and operation of the asset. There is a two-way exchange of information:
- Instrumentation data can be passed to the simulation system to allow continuous model validation and correction.
- Simulation data can be passed to the control system to provide a prediction of future events.

POTENTIAL BENEFITS

Logically, the evolution of these developments should lead to autonomous operations by a fully instrumented and automated system. Such systems are now becoming a feature of manufacturing industries, yet the oil & gas industry remains far from this point. Equinor is perhaps the most advanced with its Oseberg development[2], although many unattended platforms still require frequent visits from crew.

Note that complete digitalisation must incorporate human factors. To add value, data must become knowledge and the process of rationalisation and interpretation is an integral part of the digital process. It was notable that the presentations at the seminar only touched on these issues, and it is perhaps an area that requires more work.

Digitisation requires investment in hardware, software and training, if it is to be fully implemented. The benefits seen must be commensurate with the investment required, and can be listed below:

- **Safety**
  There are two ways in which digitisation improves safety. The first is by better measuring, predicting and designing against safety hazards. The second, and perhaps the greater, is that with improved automation, human beings are removed from hazardous environments. Indeed, many operators see this as the principal benefit and this is explicitly stated by Equinor[3].
- **Performance**
  The most obvious benefit comes from the rapid and accurate diagnosis of operational issues through improved access to measurement data, coupled to the improved understanding of performance issues given by simulation. In practice, significant performance benefits have also been seen from the improved management of shutdown, turnaround and commissioning events, often reducing the time taken by days and accelerating returns to service. During operations, a greater number of specialists are able to instantly access and analyse data than are available on the asset. A final benefit is found when digital twins are used to study and optimise alternative operational scenarios.
- **Integrity**
  Finding, monitoring and managing integrity anomalies generates large amounts of data, and by combining this data with integrity simulation, maintenance priorities can be identified and schedules optimised.
- **Design**
  Most current applications of the simulation aspect of digitisation are deployed in the design of new assets and equipment. However, it is arguable that there is scope to increase the implementation of the more advanced methodologies (such as the large-scale use of 3D Computational Fluid Dynamics to optimise process system design), partly because the way in which they could be applied is not understood throughout the design community. Historically, simulation took time and lagged behind the design process, so was mainly used for confirmation of design activities. However, simulation now routinely leads the design loop in advanced sectors such as aerospace. Oil & gas has made some moves in this direction, but design is still dominated by proscriptive code-based rules, which limit the ability of simulation to provide disruptive alternatives.

- **Cost**
  As mentioned previously, there is a cost to implementing digital technology, whether at the construction stage or through retrofitting. These cost increases are balanced by operational cost reductions, in the form of reduced manpower, optimised maintenance schedules and improved productivity. As we are at the beginning of this process, it is hard to quantify the benefits, but Equinor has estimated that the improved operational efficiency created by full digitisation of its North Sea fields will be worth about Kr10 billion (about £1bn)[4].

CURRENT DEVELOPMENTS

This section summarises some of the latest developments in the oil & gas digital arena. This is a rapidly evolving topic, with a preponderance of new companies and approaches, so no claim is made that every development has been described, nor is the mention of any specific technology or company an endorsement.

CONTROL AND INSTRUMENTATION

There are many control and instrumentation systems, either newly on the market or in development, that take advantage of digital technology. Specific enablers are:

- The ability to safely deploy wireless technology offshore, allowing non-intrusive technology to be retrofitted.
- The development of reliable, steady-state, data storage devices with minimal power requirements.
- The development of new sensing techniques, especially those that use algorithms to search visual or other complex data for anomalies.

These technologies continue to be developed and are spreading to subsea and even downhole applications.

The growing levels of instrumentation present new challenges, as illustrated by some of the presentations at the Aberdeen seminar:

- DNV GL gave a case study of a new drilling vessel, built with almost 15,000 sensors, of which only 10% were found to give reliable readings.
- Eni and Safetec gave a joint presentation, in which they demonstrated how the management of safety barriers in such a complex environment can be improved by careful design of control system interfaces.

Data quality, and the human factors implications of high data volumes, will increase in importance as higher levels of automation are adopted. Designers and operators will also have to address the question of the optimum instrumentation fit, that provides the best data quality for the minimum cost. Excessive instrumentation adds to human overload and is expensive to maintain.

SIMULATION

This section discusses the use of simulation as part of the digital environment but, like digital technology itself, would benefit from a definition.

Simulation – definition and examples

Simulation refers to any computer-based representation of a physical system. Any form of mathematical model is a simulation, provided it is embodied within some form of software. Examples are varied, and include:

- Governing equations describing entire systems, modelled in mathematical scripting codes such as Mathcad.
- Heat and mass or thermodynamic balance codes that simulate reactions and changes of state, such as HYSYS.
- One-dimensional flow or stress analysis codes, such as Flowmaster or CAESAR II, or software used to model hydraulic power systems.
- Generic mathematical software capable of all of the above, such as Amesim or MATLAB.
- Full three-dimensional continuum mechanics codes, such as the CFD codes STAR-CCM+ and Fluent, or the FEA codes ABAQUS and ANSYS.
- Gaming-based software which, while lacking in physical accuracy, provides an immersive environment, often referred to as Virtual Reality (VR).

The software products listed above are obviously not a comprehensive list, but just examples chosen to illustrate types of analysis.

A discriminator between these models is the "order" of the simulation. A fully-transient, three-dimensional simulation based on accurate

Simulation in Digital Oil & Gas

The oil & gas industry has long been reliant on an almost standard set of tools for operational simulation. Software tools like OLGA for flow assurance and HYSYS for process modelling, do not have a complete monopoly, but are sufficiently well entrenched that competing tools can take time to become established. New developments that aim to provide a single digital approach, can either challenge the established software providers, or incorporate them.

Emerson has chosen the latter path, providing a native data link between its process control system software and HYSYS, in what appears to be a first application of data fusion in the industry. The agreement between Emerson and AspenTech, the developer of HYSYS, is not exclusive, and so it is possible that other control and instrumentation companies may follow Emerson's lead. Most software companies have decided not to partner with any specific instrumentation system, keeping their systems open and capable of continuous validation from any data source.

Another example is that Siemens AG and Process Systems Enterprise (PSE) are collaborating to bring PSE's gPROMS process modelling[5] with the aim of providing solutions for long-term equipment and health monitoring, soft-sensing, prediction of future process performance, real-time optimisation, and operator training incorporating high-fidelity models.

Until now, all these approaches to linking operational data to simulations, have been based on system models, rather than continuum models.

DATA FUSION AND MANAGEMENT

Every major oilfield equipment and services company now has a digital offering. These usually take the form of a simplified interface to its existing products, with perhaps improved data exchange between each application. There are two platforms that seem to go beyond this approach, and provide a true data management functionality:

- DNV GL has established a data management and trading platform for the industry, Veracity[6]. The principle is that operators will use the site not only to manage their data, but also to share and even trade it. The development environment is open, so that third parties can develop and sell applications through the platform.
- Schlumberger has a similar system available to its customers, DELFI[7]. As might be expected, DELFI is particularly strong in subsurface data, but lacks the trading and sharing aspects of the DNV GL platform.

Recently, DNV GL and Siemens have come together in a strategic partnership, combining deep technical domain knowledge from oil & gas projects and operations, with product lifecycle management (PLM) technology, with the aim of creating a more powerful digital asset model. Siemens (MindSphere) and GE (Predix) both offer cloud-enabled asset connectivity and data tools, that are essentially operating systems that allow equipment to communicate via the internet, including data sharing and storage. However, they lack the data trading aspect of the DNV GL and Schlumberger platforms.

PwC, Deloitte, McKinsey, Accenture and EY all advertise digitisation service specific to the oil & gas industry. These focus on walking businesses through the stages of digitisation, rather than providing any specific technology solutions of their own, and mainly for the benefit of senior managers.

CURRENT TRENDS SUMMARY

The following trends can be identified for each of the areas above:

- Novel instrumentation systems are starting to proliferate and large volumes of data are becoming available, but the management of data quality (both accuracy and attribution) is lagging behind.
- Simulation companies are all claiming to offer digital twins, but most are merely offering a continuous validation functionality coupled to cloud-based hosting. As with instrumentation, the data curation and user accessibility issues are not primary. Consumers of these services require trustworthy offerings that benefit from thorough validation and allow a seamless transition between real and virtual environments.
- A number of engineering services companies are now offering data management services, but these are mostly based on the bundling of existing products with enhanced interfaces.

Overall, it is hard to escape the conclusion that despite the industry's evident enthusiasm for digitisation, very few concrete steps are actually being taken. The next section examines the reasons in more detail.

CHALLENGES AND NEXT STEPS FOR THE INDUSTRY

At the end of the IMechE Digital Oil Platform seminar in October 2018, a group of selected panellists were asked whether a fully autonomous, automatic oil production facility could now be installed, and if not, what the barriers were. There are currently a number of Normally Uninhabited Installations (NUIs), but these are still often temporarily inhabited for maintenance and monitoring purposes form significant periods. A truly autonomous, "robot" installation is still seen as a distant aim.

TRUST

The most significant, yet the most nebulous, objection is trust in the data. Individuals generally do not immediately react when a fire alarm goes off in an office, tending to wait until further evidence emerges for the severity or otherwise of the incident. The same is true of alarms raised by instrumentation or warnings from simulation – there is a tendency to wait until there is substantiating information. Allowing a computerised system to automatically take decisions on issues ranging from production to maintenance, requires considerable trust that the digitised data is correct.

A digital system therefore needs to be verified and validated, a process known as V&V (Verification and Validation). Verification refers to the process of checking that every element of it is working correctly, including the proper placement and functionality of sensors and the coding of simulation models. Validation is the process of checking the outputs of the system against known performance. Although aspects of V&V are incorporated within most conventional quality assurance processes, the wider requirements of digitisation are not understood.

The principal global standard for V&V is published by the IEEE[8]. This originated as a software standard using systems engineering principles, but now covers all stages of the hardware, software and systems lifecycle.

Machine learning poses a particular problem. If a system possesses the power to learn through neural nets or similar processing approaches, how are the resulting algorithms to be validated and verified? This is an area of active research in the academic community, and there are currently no accepted standard approaches for industrial applications, although the defence community is pressing for greater certainty.

Beyond V&V, trust is driven by a number of other factors, and these are described in detail in the following sections.

DATA CURATION

Another new topic imposed by the course of digitisation, is the need for proper data curation. Curation is the process by which data is:

- Gathered, logged, timed, tagged and identified
- Stored and secured
- Accessed and interpreted
- Ultimately deleted

Other industries have previously tackled the issue of data curation, and there are comprehensive standards already in existence. The Institute of Asset Management, which previously generated the widely implemented PAS 55 standard for Asset Management, is in the process of developing a similar standard for data, but at the moment there is no commonly accepted standard for data curation in the oil & gas industry. The closest is ISO 14224[9], which is restricted in scope to reliability data, but does mandate common data standards and verification methodologies.

The global general standard for data curation is produce by the ISO[10]. This provides a reference model for an Open Archival Information System (OAIS), a methodology for classifying and accessing data based on an information ontology. This type of structure is entirely non-specific, and so for data exchange between different oil & gas businesses, an agreed, common OAIS would need to be defined.

There is a precedent for collaboration across the oil & gas industry on data standards. Energistics[11] is a joint venture company initially established by five major exploration and production companies, and now with over 100 members. It sets standards for data exchange, as opposed to data curation, and while predominantly focused on reservoir data, its Common Technical Architecture (CTA) and Energy Industry Profile (EIP) standards are designed to provide common metadata definitions across all aspects of the industry. The EIP could form the basis for an industry OAIS fully compliant with the ISO data curation standard.

Accurate curation will not address all the requirements for trust, but it will ensure that users of data will have a common appreciation of definitions and processes.

DESIGN FOR DIGITAL

The panellists were also asked what standards and approaches they would apply, if they were asked to design a fully digitised asset. As with data curation, there is no common industry standard approach, or any appreciation of what an approach might resemble. While simulation-based design is now common practice for components or even sub-systems (for example, the process train), nobody has attempted to design a complete asset for autonomous operation using simulation as a basis. Unanswered questions include:

- How to determine the optimum amount and location of instrumentation systems
- How to ensure that instrumentation systems are accurately reporting the information they are supposed to report, both when installed and throughout their lives
- How to design structures and systems so their maintenance and operations can be automatically monitored
- How to optimally balance the requirements for redundancy with reliability
- How to identify and categorise the various decisions that can be automated, and what level of assurance is required
- How to incorporate the necessary level of human factors analysis in the design, or even how to identify what that level is

V&V will form an important part of this process, as the wider design must be subject to verification and validation and not just the software elements. Systems engineering thinking[12] will be of considerable benefit, as it emphasises the need to specify detailed requirements, and then verify that these requirements have been met using test requirements specified in the original requirement.

The dominance of design codes must also be addressed. Simulation allows for less conservatism and hence cheaper, smaller and more efficient solutions, but these solutions often violate design codes. Design methodologies need to evolve to allow the best application of simulation.

TRAINING

An issue repeatedly raised at the seminar, was the question of training and education. It was noted that no major UK university currently provides either undergraduate or postgraduate qualifications in digitisation of engineering systems (with the exception of the Robert Gordon University Graduate Certificate in Petroleum Data Management, which is focused entirely on reservoir data), and this problem was especially acute in the education of senior managers. Without the skills to appreciate the benefits, risks and techniques of digitisation, the industry's innate conservatism would dominate.

At vocational level, the challenges were even greater. The skills required would change from an ability to understand the underlying process or structural system, to understanding the digital technology monitoring it. Control and instrumentation skills are already regarded as scarce, and the additional requirements of digitisation will only make the challenges greater.

However, the greatest challenge of all was felt to be at senior management level. Very senior managers are likely to be the most remote from the technology of digitisation, yet are often either pushing hardest for it to be implemented, or providing the greatest opposition. Managing expectations and an understanding of both opportunities and risks becomes very difficult for the staff charged with implementing the technology. Although "training" is not usually seen as a requirement at such elevated levels, the rapid changes in technology perhaps demand a more cost-effective approach than retaining the services of management consultants. This requirement was clearly expressed by a number of contributors to the IMechE Aberdeen seminar.

BUSINESS MODELS

Every participant in the debate on digital technology has a different definition of what it means, usually determined by how it affects their own business model. For example, software companies all regard their products as essential elements of the digital environment, and seek to promote digital concepts that match the products they already possess. Many instrumentation and plant operating companies have similar perspectives: adapting to digital is something that requires greater effort from others than is required from themselves, as their systems are already significantly digitised.

This misses the point. Digital technology makes the possession and interpretation of data easier, and moves the value from those activities to the act of interpretation. The data itself, whether generated from instrumentation or simulation, has limited value without interpretation. This trend is yet to be seen in engineering applications, but in the consumer world, data is freely traded. Some software companies in this domain are even making their products freely available, as the service of interpreting and using the data is much more valuable.

It might be observed that industry sectors that promote collaboration between elements of the supply chain – defence and automotive for example – have generally been more successful in the adoption of digital technology than oil & gas. The limited number of common standards and approaches to digital implementation in the industry, is partly a function of the reluctance to collaborate and a hope that your own company will eventually provide the effective standard.
If the operators required their supply chains to form teams instead of hierarchies, disruptive technologies would be more easily adopted and common standards implemented.

It is not clear what a successful, fully digital business model will look like, especially in an industry with the raw capital requirements of oil & gas. Perhaps instrumentation companies will be replaced by data curation businesses, which will provide a single service encompassing the installation of instrumentation, data gathering, curation and assessment. Perhaps software companies will be replaced by businesses that provide the outputs operators require, fully verified and validated and in real-time. The future is opaque, but it is clear that many in the oil & gas industry are neither prepared for the changes nor making the investment necessary to achieve them.

NEXT STEPS

There is no doubt that more work is needed before digitisation is fully implemented in the oil & gas industry. As an industry that has always tended to work towards agreed codes and standards in order to satisfy safety and regulatory requirements, much of the future work will take the form of developing such approaches. The following activities are proposed:

- Promulgation and recognition of standards that already exist covering data curation and V&V, but are not understood nor adopted by the industry. While it is tempting to suggest that new, industry-specific standard should be developed, this is frankly unnecessary and will lose the benefits of commonality with other industries.
- However, new industry-specific guidelines for designing for digitisation are required, that will help improve the understanding of what digital technology can do. The oil & gas sector has specific safety and environmental requirements that cannot be supported using standards from elsewhere, and the relationship between design, safety and environmental requirements needs to be carefully explored.
- Education institutions need to rise to the challenge of the digitisation of the industry, by providing modules within existing courses, and specific courses at undergraduate and postgraduate level where the demand exists. The professional institutions should use the accreditation process to ensure courses include these elements, as well as investigating joint initiatives to provide training workshops suitable for every level of seniority.

CONCLUSION

The potential benefits of digitisation for the oil & gas industry appear to be considerable, but the benefits and challenges are not being addressed and, for many, digitisation remains no more than a buzzword.

This is partly a problem with understanding what digitisation means in practice, but there are also some specific barriers to its effective adoption:

- Data quality, trust and curation. Huge amounts of data are generated already from instrumentation and simulation, but there are no accepted processes for assuring the quality of data, or for managing its storage and usage (although there are some agreed standards for data exchange). This leads to a problem of trust: operators do not trust their digital data sufficiently to make otherwise unsupported decisions based on it – or to allow automated systems to make decisions. Many continue to use different systems for different assets, rather than having a common standard for all.
- Design for Digital. At this point in time, a designer could not provide an entirely autonomous fully digitised design for a production asset. The technology and understanding exist, but the assurance processes and accepted methodologies do not. There are also commercial barriers: adding digital technology increases capital cost while reducing operational cost, yet the EPC model for new developments almost exclusively applied in the industry, incentivises reductions in capital cost only.
- Data ownership models are also inadequate for the evolving digital world. Contract terms and conditions covering data generated appear clear, but disagreements quickly develop in practice. Operators usually state they own all data, but is it necessarily in their interest to limit the ability of their suppliers to develop new technologies in this way? There are also legal implications on the use of improperly validated data, or the mis-use of data that is valid only under certain conditions.
- Training and skills. Different skill sets are required to design and operate a digitised asset, at every level. At the time of writing, no university offers either undergraduate or postgraduate courses on the subject, and the provision at vocational level is even worse. If systems are to be deployed that provide the trusted data that is essential for a digitised asset, much greater understanding of the topic is required across the industry.

These challenges are not insurmountable, although they may require greater collaborative intent in new technology than the industry is used to. If a co-ordinated approach can be agreed, then it should be entirely possible to deploy a safe, environmentally friendly and efficient, fully automated production facility within the next ten years.

RECOMMENDATIONS

1. That the UK Government funding body UKRI looks across its funding programmes to create a cross-cutting programme of funding to investigate data and digital decision-making. This programme will need to establish systems – whether AI or not – that enable good decision-making and ensure trust in the data and trends. The involvement of the Oil & Gas Technology Centre (OGTC), or a similar industry body, would be helpful.
2. That the UK Government looks across its engineering programmes from science and technology, to health and communities, to BEIS, to establish a Design for Digital code. This means that all new engineering and technology are future proofed and ready for the IoT. The oil & gas industry, specifically, should co-ordinate to develop agreed standards for Design for Digital.
3. The UK Government must begin a much stronger programme of digital skills across all subjects taught, from primary school through university. These skills should not just be found in computer science and ICT. For the oil & gas industry, academic institutions and industry should work together to amend the current provision of postgraduate or vocational training, to cover digital aspects such as data curation, verification and validation.

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This report has been produced in the context of the Institution’s strategic themes of Education, Energy, Environment, Healthcare, Manufacturing and Transport and its vision of ‘Improving the world through engineering’.

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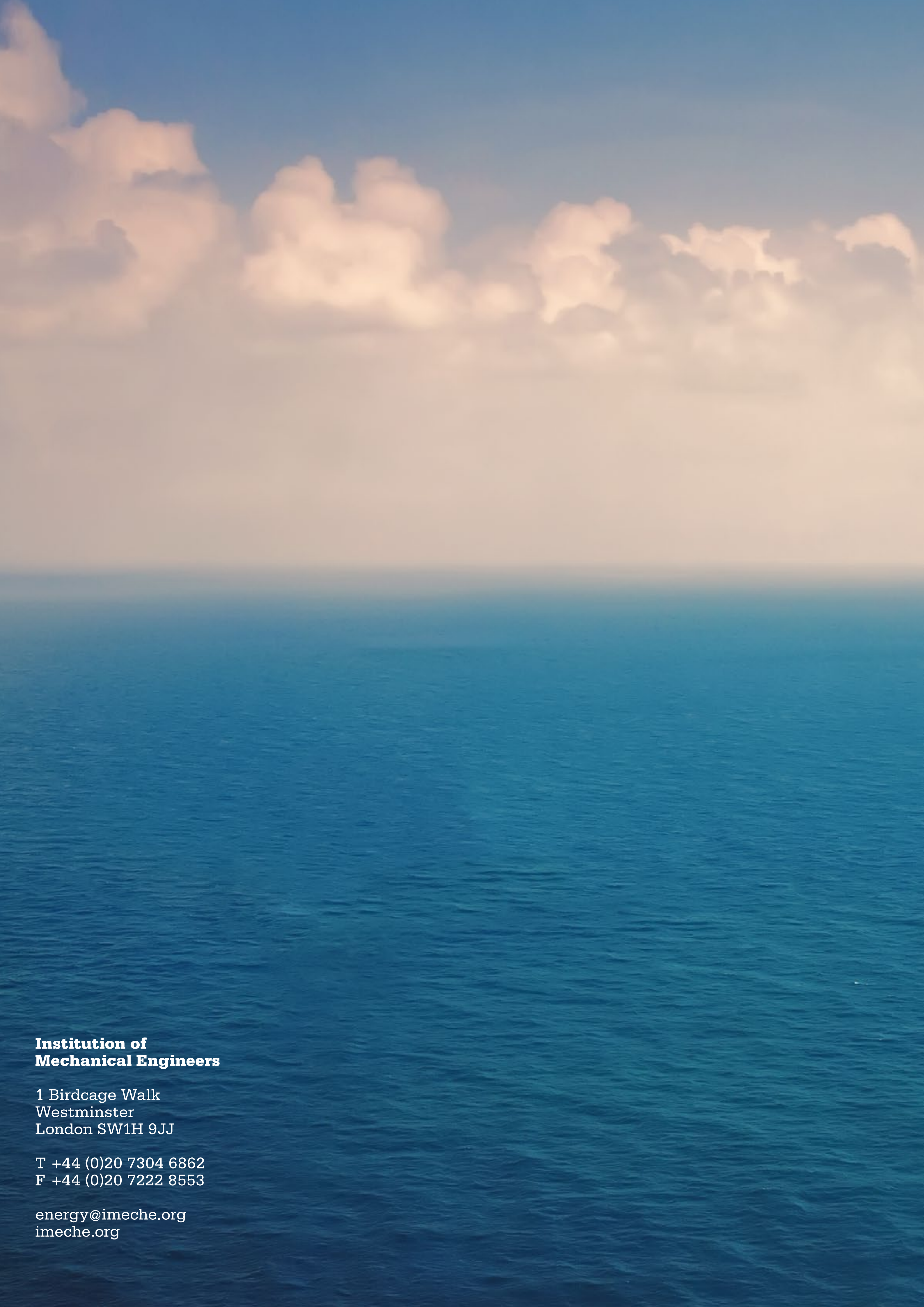

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