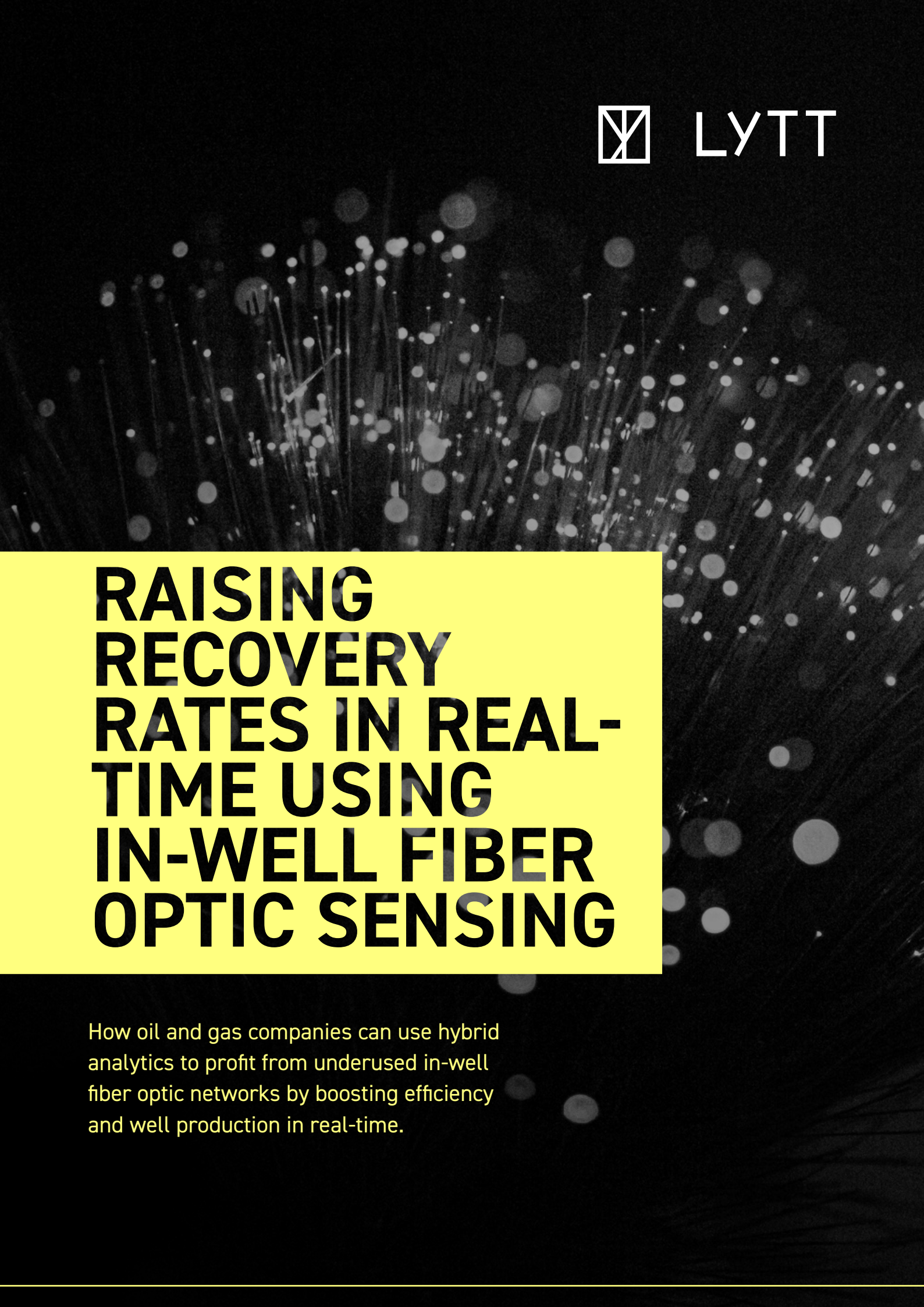
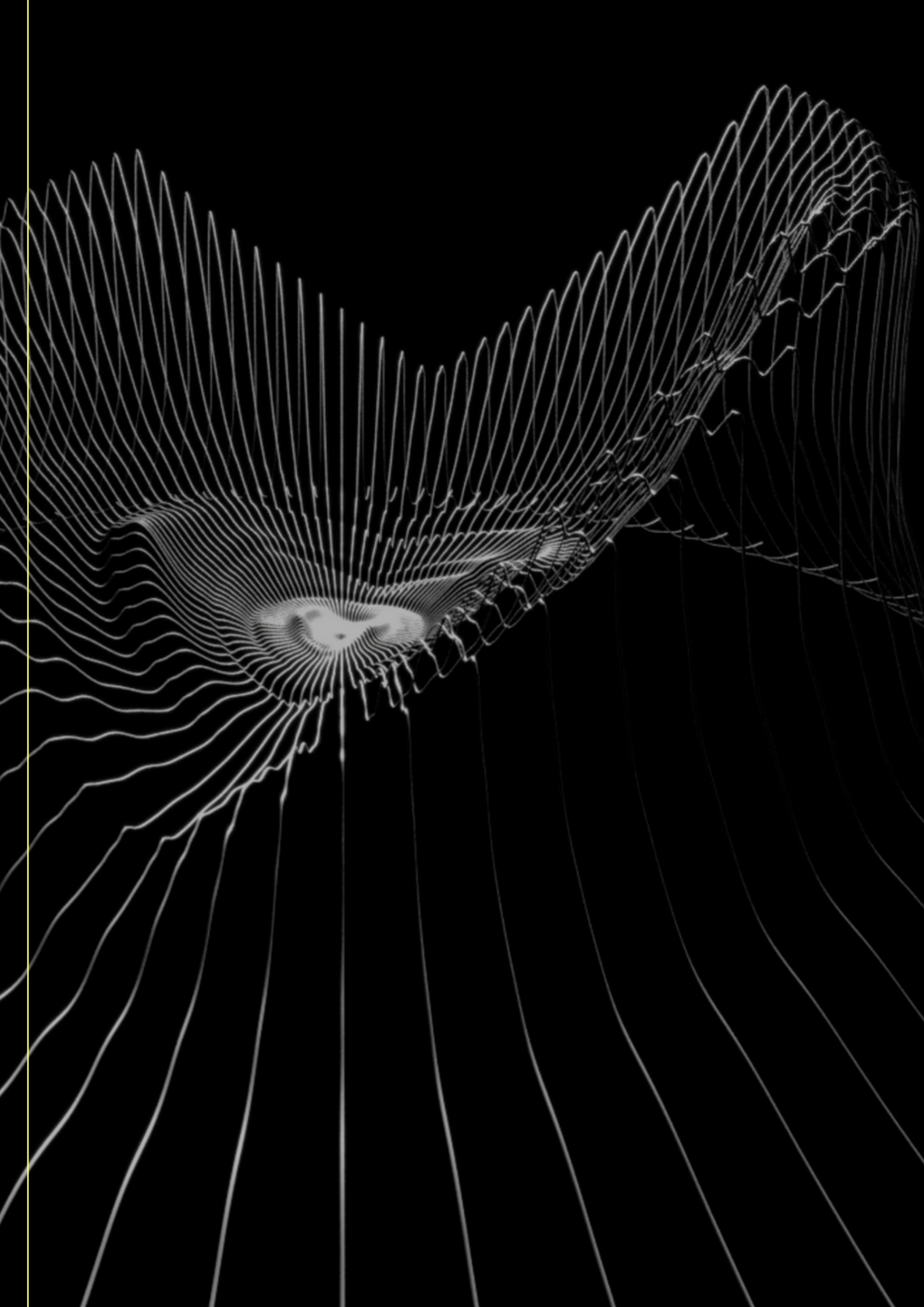


LYTT

# RAISING RECOVERY RATES IN REAL-TIME USING IN-WELL FIBER OPTIC SENSING

How oil and gas companies can use hybrid analytics to profit from underused in-well fiber optic networks by boosting efficiency and well production in real-time.



# Summary

This white paper shares insights from LYTT about how oil and gas companies can maximise hydrocarbon reservoir recovery in real-time by using in-well fiber optic sensing alongside advanced analytics methods.

Such fiber optic cables are often already installed – but are frequently under-used – as sensors to monitor production processes in their wells.

We will discuss how these can be used as invaluable downhole sensors when paired with powerful machine learning and cloud computing technology, demonstrating a few real world examples where the technology has been deployed to add tremendous production gains. Finally, we will look at three common problems that oil and gas firms find in their wells, and explain how powerful real-time analytics can solve them.

LYTT

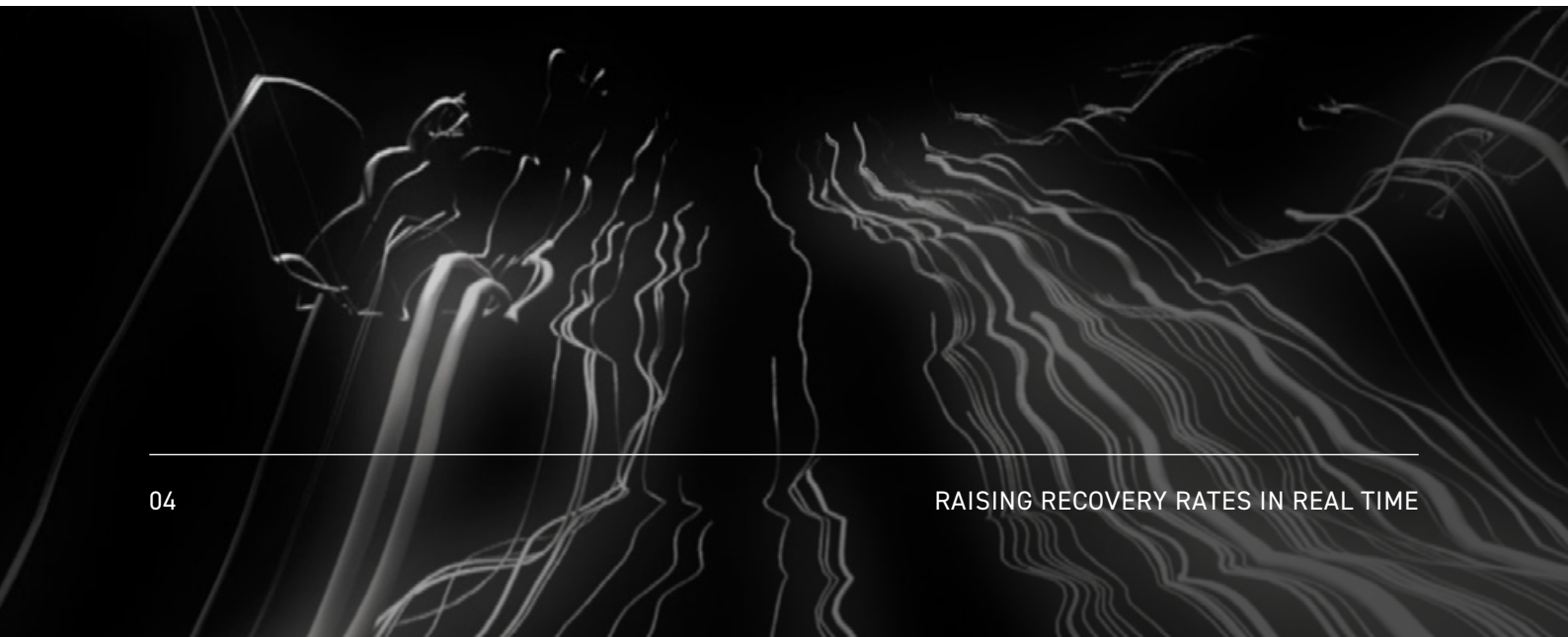
LYTT is a highly-innovative start-up that was founded in 2018 by Tommy Langnes, who has worked in oil and gas for 18 years at bp, Norsk Hydro and Shell, and
Prad Thiruvenkatanathan, who previously spent six years in bp as an upstream data scientist. LYTT is part of Launchpad, formed by bp in 2018 to back breakthrough technologies and business models. With over 100 patents filed, LYTT's technology is set to transform the way oil and gas companies manage their wells.

# Introduction

It has been three decades since companies in the oil and gas industry started to install fiber optic cables in hydrocarbon wells. But all too often, these networks are under-used.

This doesn't have to be the case. Recent advances in machine learning and cloud computing mean that oil and gas companies are better placed to take advantage of these networks than they have ever been. Used properly, fiber optic cables can lead to production improvements in the order of several hundred million dollars per asset and sometimes, even per well – **in 2019, LYTT added over $400 million of gross revenue to bp's upstream operated assets**.

This demonstrates that machine learning-based, real-time analytics, when properly applied, can enable a major boost in production for oil and gas companies – and a significant benefit to their bottom line.



## How did we get here?

Companies started deploying fiber optic sensing in hydrocarbon wells in the 1990s, after the introduction of distributed temperature sensing (DTS). This is when the industry started to see the potential of in-well fiber optics for thermal profiling to identify zonal fluid ingress along the length of the well.

More recently, there has been a surge in the use of distributed acoustic sensing (DAS). This essentially turns a fiber optic cable into a distributed microphone array, and enables the tracking of sounds made by different fluids and solids entering, exiting or moving around a well.

The challenges that companies have failed to grapple with however, are the sheer quantity of data that is generated by DAS and the ability to effectively translate the acoustic and thermal data into real-time insights that can immediately add value to operations.

The old management adage of 'what gets measured, gets managed' is all very well, but oil and gas companies have found that the sheer quantity of these data is a barrier to effective production management. What gets measured can only be managed if you can recognise the trends that are being shown. Without that, it's a daunting wall of data.

This means too few companies have been able to take full advantage of the fiber optic cables they installed in their hydrocarbon wells. It is only in recent years that machine learning and cloud computing networks have caught up and are able to transmit data from downhole to desktop instantly. They have now, and this will drive huge change!

**Operators are already seeing the benefits.** Massive production gains being realised thanks to the way that this technology changes the way wells are managed - using real-time insights to inform decision-making, instead of relying on snapshot data.

# DAS and downhole sensors

Fiber optic cables are perfectly suited to acting as downhole sensors that can provide the insights that solve some of the fundamental challenges to production in hydrocarbon wells.

These challenges include sand ingress into wells; well integrity; and phase and flow profiling of well inflow and outflow.

Unlike traditional production logging tools, fiber-based insights offer a real-time view of changes in production, enabling operators to act upon the downhole insights dynamically. This ability to act on downhole insights instantly is new, but has already proven to be a game changer. Production processes can now be altered based on data captured a few seconds previously, rather than based on a snapshot of well performance taken months or years previously, as is common practice today.

This can be achieved by using intelligent signal processing methods alongside machine learning analytics to help to make sense of the wealth of DAS and DTS data, alongside other contextually relevant sensor information. This results in unprecedented, high value insights that enable oil and gas companies to make more informed decisions in real-time on production and management of their wells.

## Why is real-time analysis vital?

Oil and gas operators have become accustomed to making decisions on how best to manage their wells based on data that only offers a snapshot of well performance.

Typically, operators will extract all of the data about what a well is producing in a small time period. For example, by running production logging tools through an intervention to provide a view on zonal production contributions, an expensive process that typically takes weeks to plan, execute and analyse. This information is then used to guide optimisation decisions for months or years afterwards, particularly when the well is offshore and the cost of acquiring new data can be significant.

This is suboptimal. To understand why, let's consider the road network.

If a traffic engineer is going to find ways to optimise traffic flow then they need a full view of how the road network is performing throughout the week – from busy rush hours to quiet periods in the middle of the night. It makes no sense to make decisions on how to optimise the road network based on any short period considered in isolation. It's far too inexact.

But all too often, that's how it works at hydrocarbon wells owing to the costs involved. Operators only look at a snapshot of their well data and then make decisions based on that. This means that the operator has a very limited view – if any – of how the dynamics of the wells change through time. They are then forced to make multi-million-dollar production management decisions based on these fragments of out of date information.

This is why we need to move away from this so-called 'snapshot' data – and towards data that gives operators a deep and dynamic understanding of their hydrocarbon wells.

**This is why real-time analysis is shaking up the industry.**

With in-well fiber optic cables we can gather data 24/7, profiling the sounds, strain and temperature through time across every metre in the well. This has proven to be extremely valuable to operators as they can now not only make long term decisions around well target selection and field development, but also daily production optimisation.
This means:

1. **No cost of running tools downhole**
2. **No HSE and executions risk**
3. **No interruption to production**
4. **Reduced OPEX**

However, acquiring data every second, across every meter along the length of well on top of all of the otherwise routine sensor measurements results in a big data challenge, requiring clever methods of processing to extract meaningful and contextually relevant insights that can be packaged in a way that enables real-time decisions.

Real-time analytics, underpinned by machine learning, can enable this complete transformation in well production surveillance capabilities. Recent advances in data-driven acoustics and thermal 'fingerprinting' capabilities can help operators to learn from the past and make sense of DAS and DTS data in real-time. Forward-thinking oil and gas companies are already using such frameworks to make production gains that equate to hundreds of millions of dollars, and are making huge returns on their investment.

In many cases, the fiber optics networks are already there. Now oil and gas companies just need to make the most of cables in their existing assets – and doing so will give them a competitive edge in a tough market.

# Turning data into operational insights

There are solutions to the challenges of too much data and flawed interpretation methods. These are physics-infused machine learning (aka 'hybrid analytics') fuelled by the advances in cloud computing.

Here we will briefly explain the role of each in well optimisation.

## Physics-infused machine learning (aka 'hybrid analytics')

Machine learning has grown in popularity in recent years as a method to excavate useful insights from large volumes of data. Machine learning is the process of teaching computers to make accurate predictions based on the data fed to it.

Models based on machine learning underpin technology that most of us use every day, from internet search engines and email spam filters to GPS traffic predictions and online fraud detection. We expect it to drive huge changes in the oil and gas industry too.

Machine learning generates operationally relevant information by processing downhole data,  enabling insights that are otherwise near impossible to uncover. However, the application of these models must be infused with contextually relevant training to generate true value adding insights as machine learning algorithms are usually only as good as the data that they have been trained with. In short, if the algorithms are fed generic data, the results will reflect this.

## Cloud computing

Cloud computing refers to the delivering of computing services – from servers and storage to software and analytics – via the internet in real-time.

These systems give companies access to huge compute power and processing capabilities on demand, negating the need to own internal systems. This enables quick and easy access to computer power as and when needed – a capability that we at LYTT have fully adopted for running the computer-intensive, real-time event detection and pattern recognition that oil and gas companies need.

## How they work together

Traditionally, the way to solve upstream engineering challenges involved physics-based modelling. This is where we solve problems by trying to understand the impact of a set of variables on an output. This approach involves making a number of assumptions which, when used alone, often results in incorrect predictions.

But what if we could combine the power of machine learning to uncover the hidden trends in data and use these trends to validate the assumptions in our physics-based models - in real-time?

This is the approach we take at LYTT.

When the LYTT system receives the sound data from the well, it can quickly discount any information that is irrelevant using the acoustic fingerprint recognition framework built on our cloud-based software infrastructure. These acoustic fingerprints are then further contextualised by presenting the outputs as zonal flow profiles that combine the real-time DAS and DTS fiber data with information from downhole and surface sensors.

This method provides a clear understanding of what the hidden data patterns look like for different downhole events, and provides a clear understanding of the 'why?' behind the patterns we observe. This gives a level of confidence that simply isn't possible through physics or machine learning models on their own.

The insights generated through hybrid analytics, shared and processed via the cloud, can be used to understand and predict events indicated by the DAS and DTS data, plan optimisation procedures, and help operators make decisions that improve safety and sustainability in real-time.

# Applying hybrid analytics to DAS/DTS data to optimise your well

The basis of LYTT's technology is our proprietary acoustic feature extraction system.

Have you heard of Shazam? This is the smartphone app that can identify music, movies and TV shows based on a short sample of sound. LYTT's system acts in a similar way. By applying machine-learning-based analytics to the data generated by the fiber optic network and contextualising this with data from other on-site sensors, LYTT can identify events and issues relevant for production optimisation in oil and gas wells as a unique acoustic fingerprint.

## How it works

We have talked in general terms about how large the data challenge is for oil and gas companies, but let's quantify that. A fiber optic cable in a hydrocarbon well generates about a terabyte of data every hour, which is made up of 10,000 samples per second across every metre of a 10,000-metre fiber optic cable. That is 100 million data points generated every second.

To put it in perspective, **that is the data equivalent of streaming 1,000 full movies every hour**. It is little surprise that operators have so far struggled to make sense of these data and build data management systems that make effective use of these data for production optimisation.

Typically, operators reduce this volume of data by around 40% using lossless compression methods, but this is still too great a volume of data to be useful. The trick here is to not compress the data, but to only extract the features that are relevant to operations.

LYTT uses selective feature extraction methods that draw out important features in real-time from huge DAS datasets. These methods are informed by real world production and laboratory data and data sourced from additional sensors within the well. We do this with proprietary software written into high-performance 'edge' servers that we refer to as a 'real-time processing unit' (RTPU) that runs at the well site alongside the DAS and DTS systems.

Now just as songs or musical genres have distinctive sounds, so do the common production problems in wells. We have identified those sounds in real field data and lab experiments.

Such a targeted approach to processing and contextualising information enables the volume of DAS data to be reduced 1,000 times without compromising real-time data quality, allowing operators to view and make decisions dynamically unlike ever before.

Our system is completely unique in that it draws on more than five years of continuous, real world well production data and a library of laboratory data to filter out the "noise" and recognise exactly what is happening in each well, right now.

Crucially, our algorithm not only considers the huge amount of data generated through DAS, it also considers DTS data, data sourced from additional sensors from across the well (surface production values, pressure sensors, downhole gauges) and lab data, drawing out insights in context and in real-time.

In short, this helps oil and gas companies to ignore masses of irrelevant data generated from fiber optic sensors and focus on the analytics that matter most when they are looking to optimise the production at their well. No matter how complex the well, these insights are delivered and contextualised with other pertinent information sets within seconds to help drive real operational decisions and impact.

**We believe this is the start of an oil and gas data revolution.**

# Tackling common challenges

Using hybrid analytics helps oil and gas companies tackle major industry challenges. Here are three of the most common:

## Challenge 1: Sand detection

The first area where we tested our systems was to help bp address problems with sand production at its oil wells in Azerbaijan.

Uncontrolled sand production occurs at hydrocarbon wells when oil and gas are being produced from unconsolidated rock formations which suffer from ineffective sand control. Uncontrolled sand production in the system causes a problem for operators, as it raises risks of erosion, consequently resulting in a reduction in the amount of oil or gas they can effectively extract, and means they need to identify where the sand is coming from before they can design a remediation.

In our first tests in Azerbaijan, we saw that our technology could use DAS data to help companies identify with a high degree of accuracy where sand was entering their wells based on the distinctive sound it makes. This can give operators vital information before they make costly interventions – which often run to millions of dollars – to fix the problems.

This is a major improvement on current industry responses because the ability to pin point sand entry into the wellbore was previously very limited. Our technology also removes guesswork for companies that wouldn't otherwise have insight into where the well needs fixing.

The real-time relay of sand detection data also helps flag early warning signs that enable operators to respond quickly to sanding events. The system can track the sand all the way from entry point into the wellbore to the surface, highlighting sand depositions in tubulars – which can be an unrecognisable source of intermittent sand production that leads to unnecessary choking back of a well and production losses. bp has deployed the system in more than 100 instances, generating hundreds of millions of dollars in value.

# Challenge 2: Well integrity

The second main area where our systems have helped operators is to identify well integrity anomalies in their ageing oil and gas wells. The technology can be used to show locations of unintended fluid flow in the wellbore and can also be used to evaluate barriers behind pipe (casing) for proper well abandonment designs when the wells are no longer economic.

Integrity of well barriers is one of the fundamental requirements for safe operation of wells. Ageing wells; the shift of development of reservoirs to more challenging operating conditions; increasingly complex well designs; and tightening in regulatory requirements are four factors that often result in integrity challenges.

There are many ways that unwanted fluids can move into shallow permeable zones outside of well designs. Unintended consequences of these fluid migrations can include contamination of shallow fresh water sources, uncontrolled release of wellbore fluids to surface, and cross flow from higher pressured to lower pressured intervals behind pipe resulting in lost resources and future drilling hazards.

This unintended migration of fluids can further lead to deferred or lost production, increased operational costs associated with remediation of failure and its consequences, harm to people or the environment, and negative publicity. That latter point applies to individual operators and the whole industry.

## How can we solve this?

Historically, companies have sought out well integrity issues with surface-based observations or mechanical systems and intervention logging. These methods require the tool to be at the right place at the right time to detect the source of the leak.

In contrast, LYTT's system allows operators to measure performance along the length of a well through a single length of fiber optic cable. LYTT's real-time analytics can show multiple downhole well integrity events such as tubing leaks, flow behind the casing, and overburden integrity.

We have deployed this technology more than 40 times in the North Sea, Trinidad and Azerbaijan to help make hydrocarbon wells safer, more reliable and more profitable.

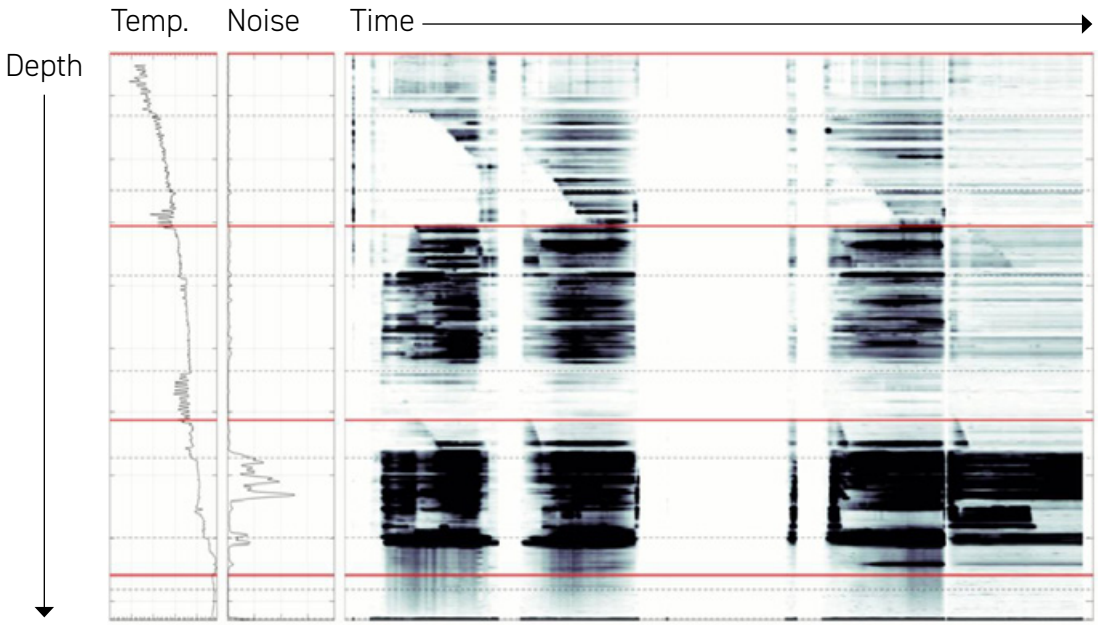
# Challenge 3: Flow profiling

The third core area where our systems have helped operators is in monitoring the profile of inflows and outflows in their wells - both of oil and gas but also unwanted water or sand. It shows which wells are operating as designed and those that need attention.

This is arguably the best example of why the industry's 'snapshot' approach to data belongs in a bygone era. As mentioned previously, production logs are typically acquired using wireline logging – a process carried out infrequently – and the insights drawn from this are used to explain production changes for months and years to come.

This is inadequate because flow behaviour is complex and may change dynamically based on a number of factors: flow rate, geological complexity, and water breakthrough, for example. In order to properly understand production dynamics, therefore, we need to answer not only the three fundamental questions – where, what and how much? – but a fourth: when?

Sample flow profiles



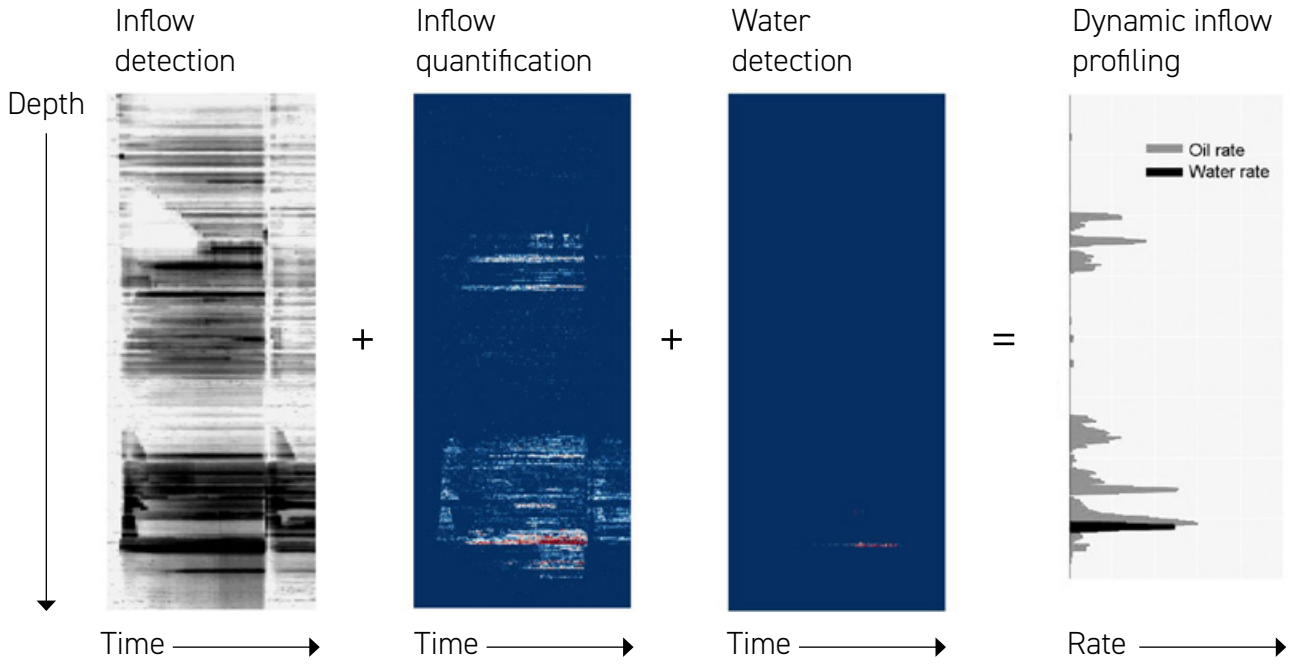
## Knowing the 'When?'

The real-time element of LYTT's analytics, enabled by our physics-infused machine learning and cloud capabilities, allows operators to make decisions about how to optimise inflow from different parts of the well, and detect unwanted breakthroughs of water and gas as and when they happen.

Companies can then optimise their assets in real-time based on accurate knowledge of what is happening in the well and when it happens. This enabled a bp asset to carry out the industry's first ever water shut-off operation based solely on insights from fiber-based analytics, and also to dynamically throttle the well performance, resulting in significant production benefits.  This is something that will become more important as pressures grow for oil producers to become more efficient.

On outflows (i.e. injection), we help operators understand how they can safely inject more water into their wells, and where, to boost production. This significantly boosts production over the life of the well and helps the industry address long-standing efficiency challenges.

Sample dynamic fluid phase classification and flow allocation



# Conclusion

Oil and gas companies have an important data choice to make.

On one hand, they can continue as they have been. Basing multi-million-dollar production decisions on snapshots of well data collected years previously, leaving fiber optics as an unloved add-on. This doesn't offer the real-time insights they need.

On the other, forward-thinking operators can grasp the huge opportunity that fiber optics and hybrid analytics offer. Production boosts and efficiency savings that mean millions more barrels a year and millions of dollars on their bottom line. Not much of a choice, is it?

The oil and gas industry is at a crossroads. There is increasing pressure on governments and corporates to cut their environmental impact; and recent events show that oil and gas companies aren't immune from economic shocks and geopolitical battles. Profitability and efficiency will both be vital in the 2020s.

There is no question that oil and gas will remain important parts of the global economy for many years to come, despite moves to decarbonise heating and transport. But companies need every edge they can get – and smart analytics, like that provided by LYTT, can help to the tune multiple hundreds of millions dollars as we have already seen.

Fiber optics and hybrid analytics that deliver actionable insights into what is happening in your wells as and when it happens can make a huge contribution to the success of your organisation in the 2020s and beyond. Oil and gas companies need to recognise that we're at the start of a data revolution and embrace it. They can't afford not to.

Please get in touch with the LYTT team if you'd like to find out more.

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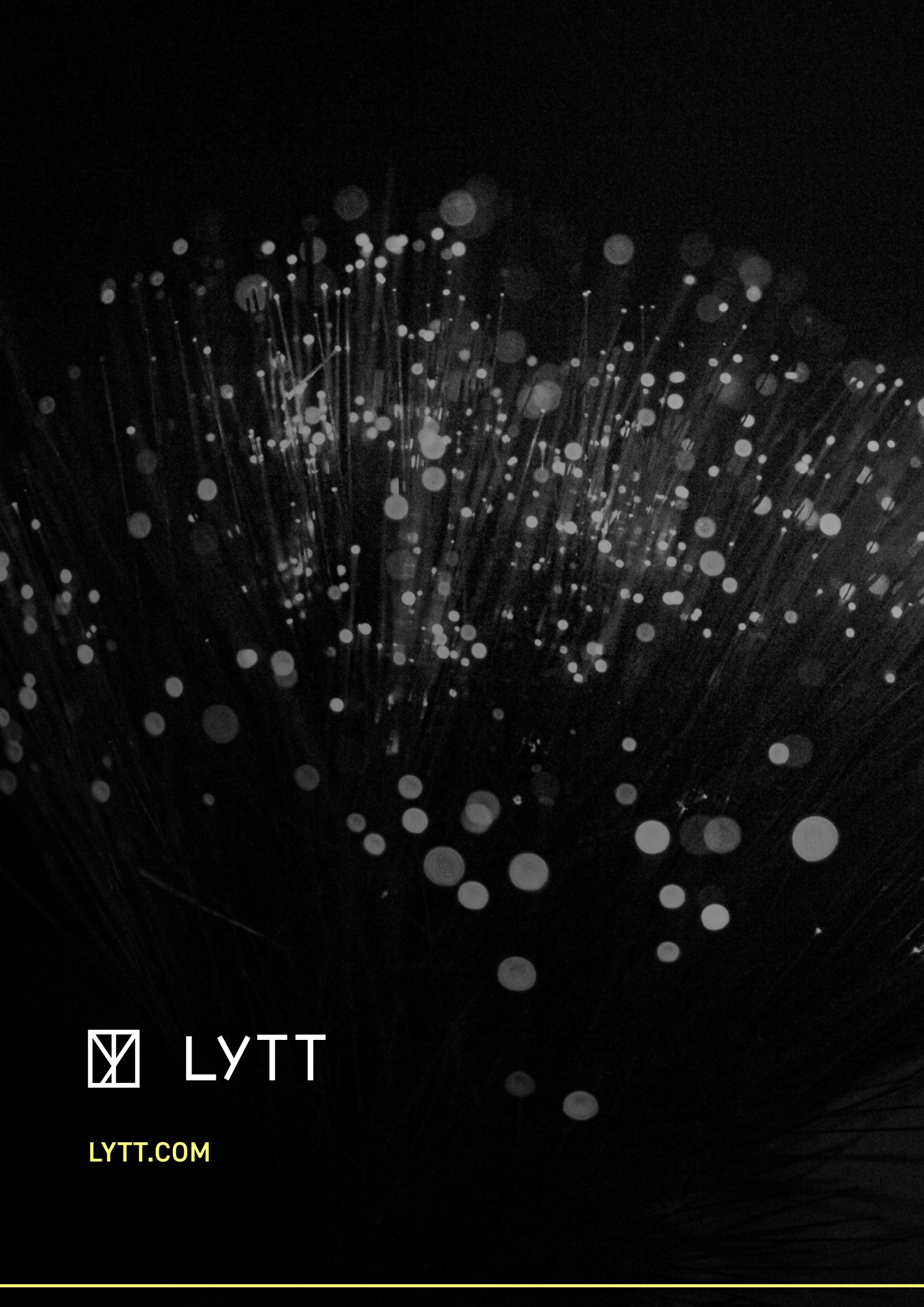

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