MethaneSAT™

A NEW ERA OF TRANSPARENCY FOR METHANE MEASUREMENT

Technicians at Ball Aerospace examine the instrument before testing and integration begin.

Photo: Ball Aerospace

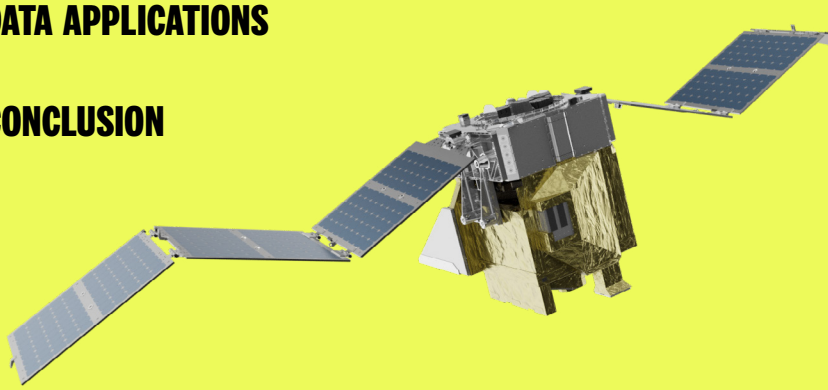
Authors
Fiona Liao
Steve Hamburg
Ritesh Gautam

Contributors
Andrew Baxter
Joshua Benmergui
Susan Kasper
Alba Lorente
Tom Melendez
Mark Omara

Partners
Ball Aerospace
Blue Canyon Technologies
Harvard University
Smithsonian Astrophysical Observatory
New Zealand Ministry of Business, Innovation and Employment

Design and Data Visualization
Kelsey Robinson

CONTENTS



EXECUTIVE SUMMARY

Around the world, industries and governments are taking steps to cut emissions of climate-warming methane.

Demand for actionable, reliable data on methane emissions is growing among buyers and sellers of oil and natural gas, regulators, the financial community, and the public. The global race to manage methane emissions reflects that it is the cause of about 30% of current warming. Cutting oil and gas methane emissions is the single fastest, most impactful opportunity today to slow the rate of warming over the next few decades.

This keen focus on methane underscores an urgent need for high-resolution data to quantify oil and gas methane emissions and enable efforts to quickly find and fix leaks. Fossil fuel production and use is one of the biggest sources of anthropogenic methane emissions, with at least 80 million tons of methane emitted each year along the oil and gas value chain. Historically, methane emissions have been estimated using generic figures that often under-estimate total emissions while offering limited value for assessing individual sources or evaluating the results of operational changes. Thus, methane emissions are widely underreported and underestimated in official inventories, but technology solutions, such as satellites, are emerging to address these gaps.

MethaneSAT, a satellite mission and wholly-owned subsidiary of Environmental Defense Fund, will measure methane pollution from the oil and gas sector globally, and make that information easily accessible and free for the public. Now in its final testing stages, MethaneSAT will be ready for launch in late 2023. Once in orbit, it will provide regular monitoring of methane emissions in regions accounting for more than 80% of global oil and gas production, quantifying methane emission rates and identifying where those emissions are coming from and how they are changing over time.

Two spectrometers aboard MethaneSAT will collect data on varying concentrations of methane in the atmosphere using reflected sunlight. A cloud-based data platform will use that information to calculate methane emission rates, accounting for winds and atmospheric conditions. These data will be used to create high-resolution heatmaps of emissions across oil or gas fields and basins, and identify high-emitting point sources. With the ability to know how much and at what rate methane is escaping and from where, and to accurately monitor changes in emission rates over time, MethaneSAT will be a powerful new tool to map global methane emissions with greater precision and spatial details than ever before.

MethaneSAT is designed to catalyze real-world methane reductions through unprecedented transparency. Operators around the world will be able to find and fix problems faster, and stakeholders will be able to evaluate performance against methane goals, commitments, and legal obligations.

OVERVIEW OF METHANE EMISSIONS DATA

Methane emissions data available today has quality, coverage, and transparency gaps.

Scientists have known for decades that methane is a potent greenhouse pollutant, and that fossil fuel operations are a major source. But until recently, it was impossible to know how much was coming from where.

Beginning in 2012, EDF organized a series of independent studies that produced 50 peer-reviewed scientific papers involving more than 150 academic and industry experts to assess methane emissions at every stage in the U.S. oil and gas supply chain. A 2018 synthesis of this work published in *Science* found that the U.S. oil and gas industry was emitting at least 13 million metric tons of methane a year in 2015—nearly 60% more than government estimates at the time. Subsequent analysis indicates that the industry faces similar problems worldwide.

On-site monitoring and measurements have recently become a priority for companies, due in part to research by EDF and its hundreds of collaborators.

Put simply, there was previously very little incentive to measure or reduce these emissions.

This is due to an absence of regulatory, investor, market, and societal pressure. Instead of direct measurements, companies and countries have typically used engineering calculations and generic emission factors to quantify emissions. According to the International Energy Agency (IEA), this approach uses operational activity data (e.g. a count of equipment) multiplied by emission factors (e.g. estimated leak rates for a particular type of equipment).

This method is subject to high uncertainty, and fails to account for the variable nature of emissions, atypical releases, accidents, or changes in operations. As a result, it does not effectively track emission changes over time.

More recently, some operators have started to use direct measurement methodologies such as ground-based and aerial technologies to determine emissions.

Handheld devices with infrared cameras can be used to make equipment, or source level, leaks visible to direct repair crews.

Aerial technology, such as drones and planes, or vehicle-mounted sensors can be used to identify larger leaks and measure total site emissions.

When direct measurement is conducted at both the source-level and site-level on a representative sample of facilities, a more accurate picture of an organization's methane emissions can be created.

Thanks to the work of climate advocates and scientists, awareness of methane's potency and the cost-effectiveness of mitigation is increasing.

Once this source-level and site-level data is empirically reconciled, operators can demonstrate high data integrity.

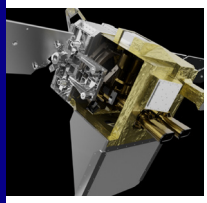
The Oil and Gas Methane Partnership 2.0 (OGMP) which is managed by the United Nations Environment Programme (UNEP) and provides a reporting framework for oil and gas companies to measure and report methane emissions, requires that operators conduct this reconciliation step. However, only 30% of global oil and gas production is represented in the partnership.

For those that do not participate, the use of measurement methodologies can vary widely from organization to organization. The availability of measurement technology and skilled personnel to acquire and process the data ranges considerably across the globe. There is no transparent and standardized approach to measuring emissions that enables comparison across the global oil and gas industry.

More and more companies are now paying attention, setting methane reduction goals, and signing on to OGMP. Similarly, more and more regulators are creating and enhancing legislation and rules around oil and gas methane. Yet there is still much work to be done for the world to meet the target of the Global Methane Pledge, under which more than 150 countries have committed to collectively reduce methane emissions by at least 30% from 2020 levels by 2030.

But without better technology to determine how much is being emitted, where the emissions are coming from, who is responsible and how emissions are changing over time, it is difficult for stakeholders to make and track progress against goals and for others to hold companies and countries accountable to their commitments.

METHODS USED TO DETECT AND VERIFY METHANE EMISSIONS



SPACE-BASED

Satellites monitor emissions across the globe from a unique vantage point.

AERIAL-BASED

Drones or airplanes identify larger leaks and measure total facility emissions.

GROUND-BASED

Handheld devices identify and measure equipment level leaks.

THE METHANE-MEASURING SATELLITE ECOSYSTEM

An emerging satellite ecosystem will enhance global transparency and accountability.

Satellites can not only detect high-emitting point sources, but also monitor emissions across the landscape – from a square kilometer to sub basins, regions and nations. This data can be used to determine how methane emissions are changing over time and how they compare across companies and countries.

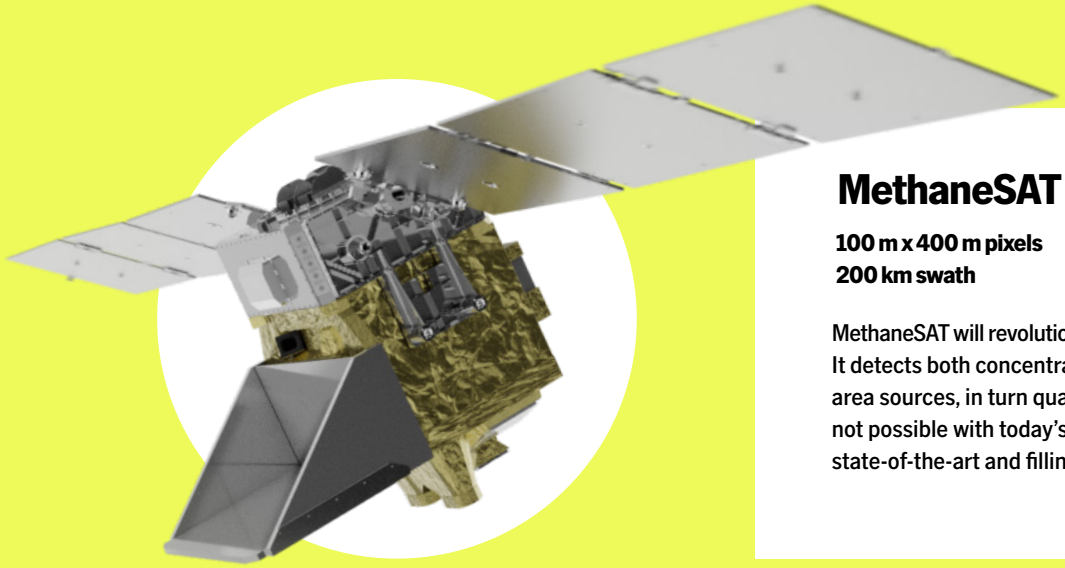
Once launched, MethaneSAT will be a key part of an emerging ecosystem of satellites that observe atmospheric methane emissions around the world. Each satellite has been designed with distinct capabilities, intended to serve complementary purposes and achieve synergies in this ecosystem. Some satellites have global coverage but can't detect emissions from the many smaller sources responsible for a large proportion of total emissions. Others have the ability to attribute emissions on a facility level but can't see beyond small areas. Together, they paint a fuller, more accurate picture than ever before.

An example of a satellite with daily global coverage is the TROPOspheric Monitoring Instrument (TROPOMI), launched by the European Space Agency in 2017. TROPOMI has a 2600 km wide viewpath, can revisit targets daily, and has the ability to detect a wide range of pollutants such as nitrogen dioxide, methane, and ozone. Because of its limited spatial resolution of 7 km x 5.5 km, however, TROPOMI cannot attribute emissions to individual sites - except for the strongest and most isolated point sources. Because of its precision of 14 parts per billion and the resulting detection threshold, areas with lower emissions are hard for TROPOMI to characterize, which accounts for many regions of interest. Moreover, TROPOMI provides methane concentration data regularly, but not methane emissions data. Atmospheric scientists can use the concentration data to quantify emissions, which is a complex task and can take weeks to months.

On the other end of the spectrum, there are satellites that have very limited geographical coverage but can examine emissions at individual facilities. For example, GHGSat is a commercial company that launches satellites capable of measuring methane emissions from industrial facilities. It currently has six satellites in orbit, with more launches planned in 2023. GHGSat technology cannot quantify total regional emissions or diffuse sources but can quantify emissions from high-emitting point sources. The non-profit Carbon Mapper is another "point-source" mission that promises methane emissions measurement at predetermined locations.

Even with these tools, there remain gaps in understanding the magnitude of total emissions, what proportions are from diffuse and smaller point sources, and how emissions change over time – as well as limited actionable, quick, and accessible information. MethaneSAT is designed to fill those gaps.

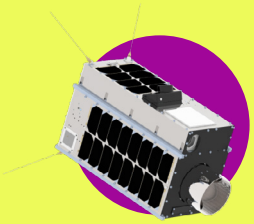
TOGETHER, THESE SATELLITES PAINT A FULLER, MORE ACCURATE PICTURE THAN EVER BEFORE.



MethaneSAT

100 m x 400 m pixels
200 km swath

MethaneSAT will revolutionize methane measurements. It detects both concentrated point sources and dispersed area sources, in turn quantifying total emissions – not possible with today's satellites – thus advancing the state-of-the-art and filling major data gaps globally.



GHGSat

30 m x 30 m pixels
10 km swath

An industry-oriented constellation of commercial point-source satellites.

TROPOMI

7,000 m x 5,500 m pixels
2,600 km swath

European Space Agency's global mapper launched in 2017 on the Sentinel-5P satellite.

PRISMA

30 m x 30 m pixels
30 km swath

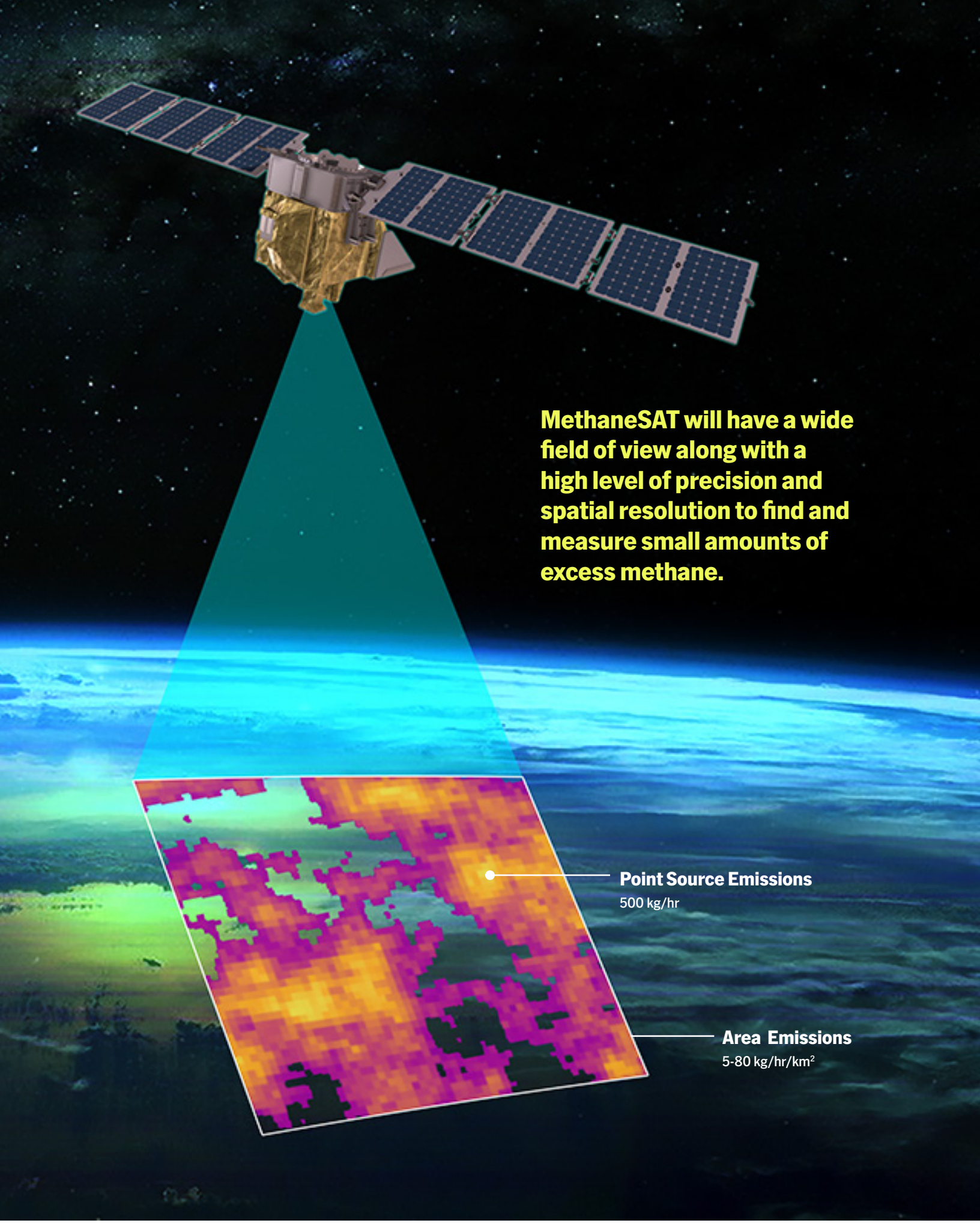
Launched by the Italian Space Agency in 2019 it combines a hyper-spectral sensor with a high-resolution camera.

Carbon Mapper

30 m x 30 m pixels
18 km swath

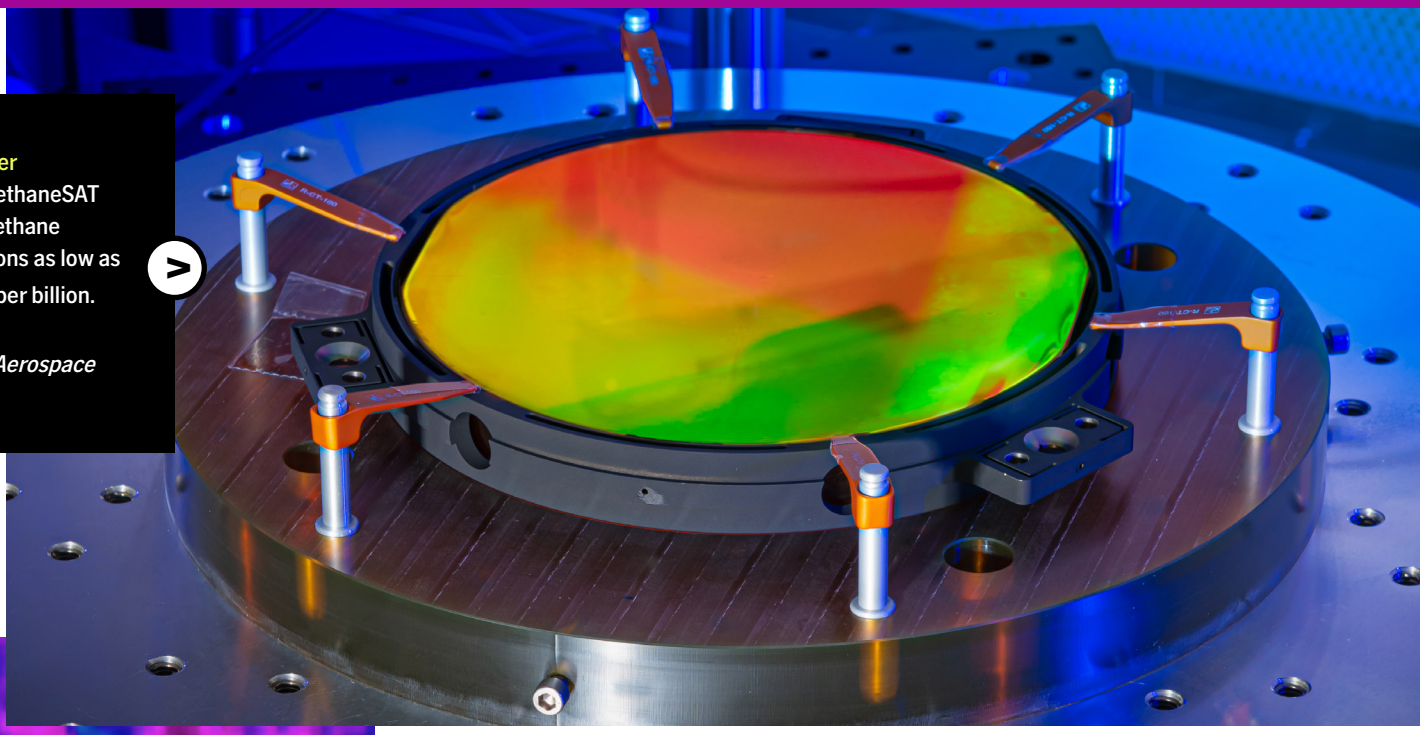
A point-source instrument announced in 2021 by coalition of organizations together with commercial satellite provider. Planned for launch in 2023.

GLOBAL MAPPING	AREA MAPPING	LOCAL MAPPING
Global & large-scale regions **Large point sources**	**Area sources** **Point sources** **Sector-wide quantification**	**Point sources** **Facility level attribution**
TROPOMI, SCIAMACHY, GOSAT, GOSAT-2, CO2M	MethaneSAT	GHGSat, PRISMA, EnMAP, F-5, ZY-1, Carbon Mapper



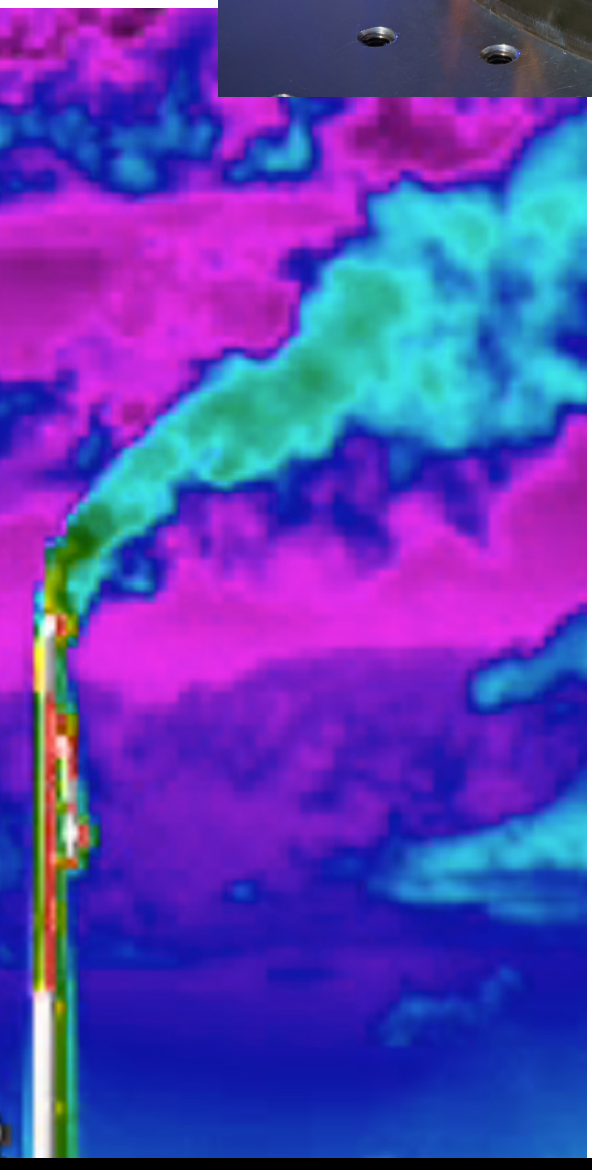
Example Schematic

THE CAPABILITIES OF METHANESAT



Spectrometer will allow MethaneSAT to detect methane concentrations as low as three parts per billion.

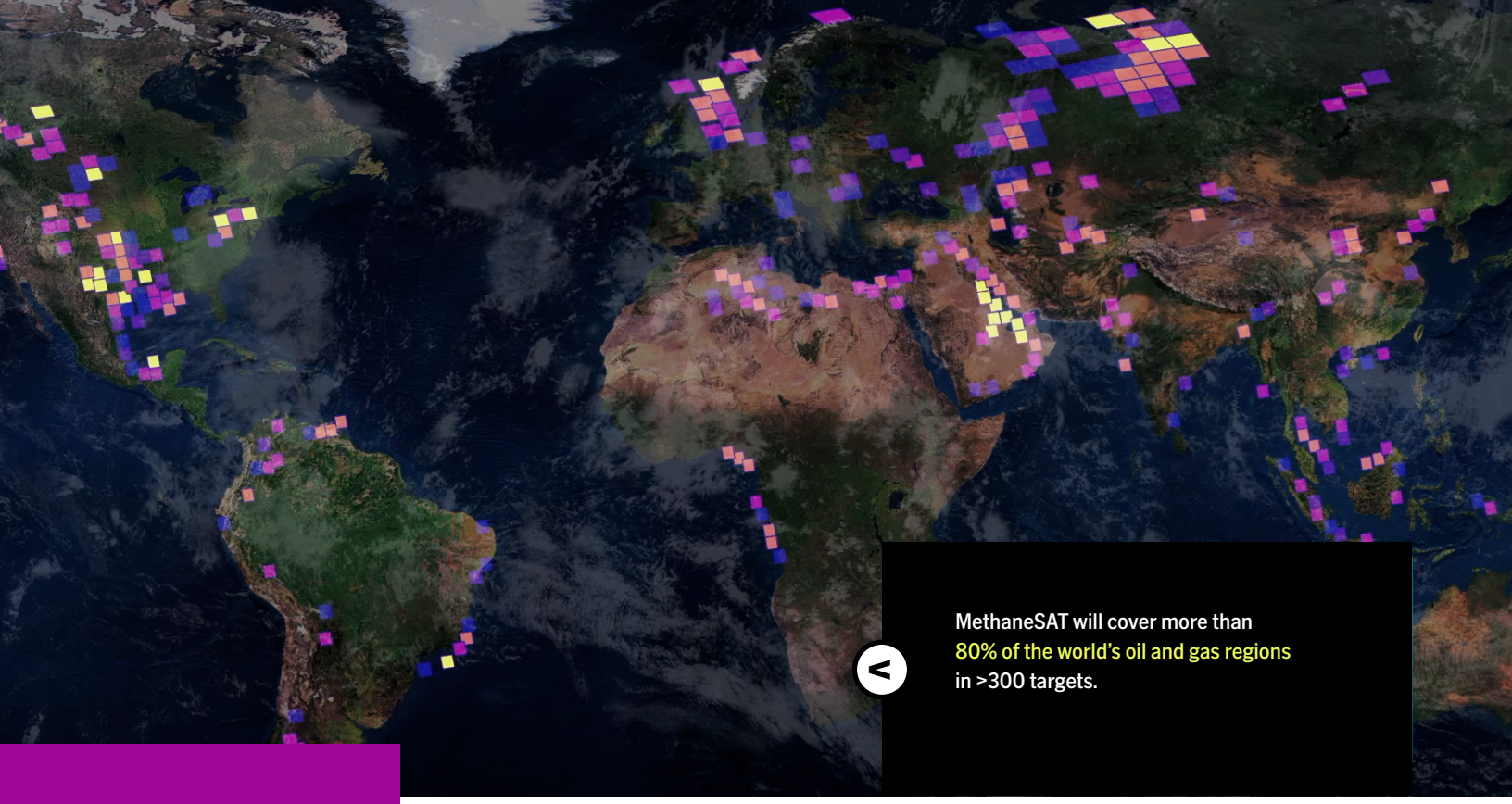
Photo: Ball Aerospace



MethaneSAT fills a significant gap in the data provided by the methane-sensing satellite ecosystem, complementing the capabilities of existing satellite technology like TROPOMI and GHGSat. It will have a wide field of view along with a very high level of precision and fine spatial resolution to identify and measure even small amounts of excess methane. The goal of the mission is to quantify methane emissions from the vast majority of global oil and gas production regions, providing the data required to catalyze significant emissions reductions.

MethaneSAT will have a 200-kilometer (124-mile) view path with 100m by 400 m native pixels, and will orbit the Earth approximately 15 times a day, taking 95 minutes to complete each orbit. With this wide field of view, MethaneSAT will be able to measure emissions from more than 80% of global oil and gas production using just 150 targets (200 km x 200 km; and 90% in about 300 targets) and revisit targets every 3-4 days.

Operational planning is designed to maximize high quality data collection based on available light, Earth angles, and daily weather patterns. The imaging spectrometers on the satellite will separate a narrow band within the shortwave infrared part of the spectrum where methane absorbs light, enabling MethaneSAT to detect excess methane concentrations as low as three parts per billion.



MethaneSAT will cover more than 80% of the world's oil and gas regions in >300 targets.

MethaneSAT will process the observed spectra to calculate quantitative emission rates, revealing how much methane is emitted and how it varies across the landscape.

Users from around the world will be able to compare and contrast where emissions are occurring and who is responsible.

This is a key capability of the MethaneSAT platform - rapidly processing raw sensor readings into usable data. After spectrometer readings are transmitted back to Earth, the MethaneSAT cloud-based data platform will automatically calculate emissions, providing users with a regular stream of actionable data.

This data will be visualized on a platform that will be publicly available free of charge. The platform will show high-resolution emission heatmaps across oil and gas fields. Users from around the world will be able to compare and contrast where emissions are occurring and who is responsible.

With its 200 km swath, another key capability of MethaneSAT will be its ability to quantify spatially distributed emissions across an entire region with high spatial resolution. Areas mapped can range from entire oil and gas basins or prominent sub-basins to individual oil and gas fields or main production hotspots, or large facilities which often spread out over multiple square kilometers.

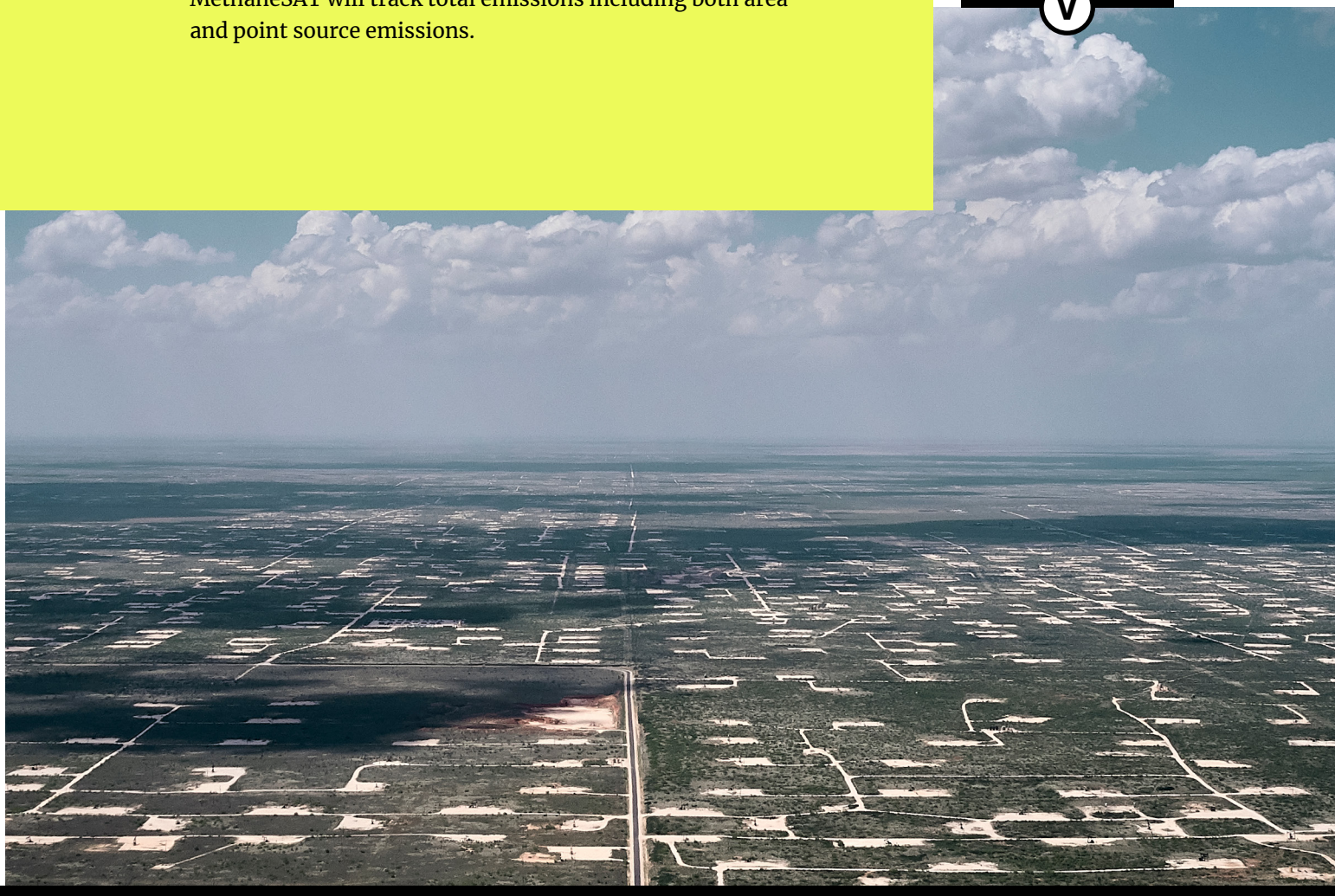
For example, MethaneSAT will be able to cover an area as large as the Permian Basin, one of the world's largest production basins, in four target acquisitions. This wide area measurement approach captures emissions that are usually too dispersed for point source monitoring satellites to quantify and often too diffuse to be detected by TROPOMI.

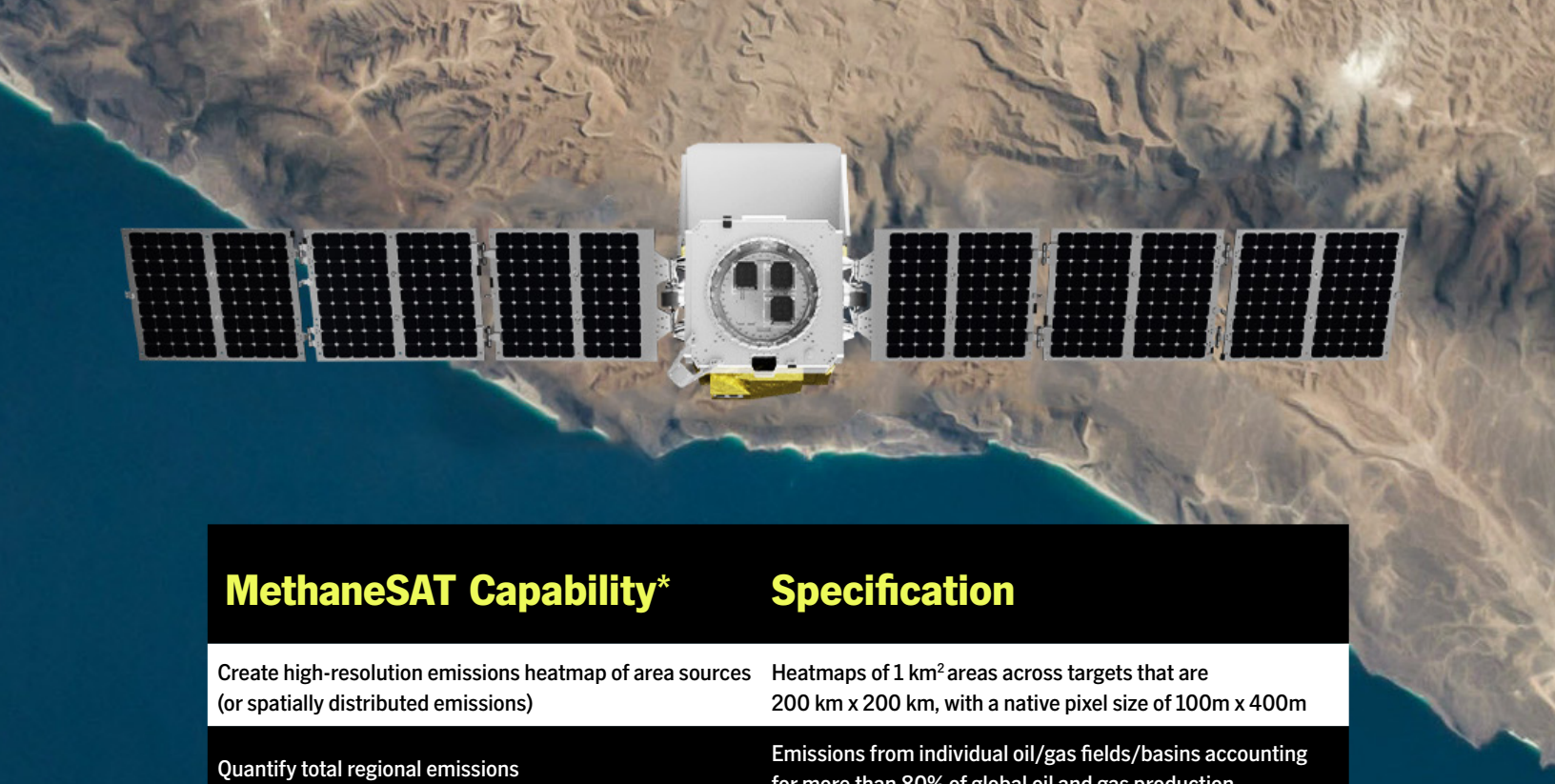
MethaneSAT will also be able to attribute emissions to high-emitting point sources, thus tracing emissions back to facilities or clusters of facilities belonging to specific oil and gas infrastructure.

Combined with its ability to measure wide areas, MethaneSAT will be able to identify high-emitting sites that fall outside the narrow viewing range of other satellites.

However, tracking high-emitting point sources alone is not sufficient to quantify and address total emissions, or in many cases the majority of emissions. Therefore, it is notable that MethaneSAT will track total emissions including both area and point source emissions.

MethaneSAT will be able to cover an area as large as the Permian Basin in four targets.





MethaneSAT Capability*	Specification
Create high-resolution emissions heatmap of area sources (or spatially distributed emissions)	Heatmaps of 1 km^2 areas across targets that are 200 km x 200 km, with a native pixel size of 100m x 400m
Quantify total regional emissions	Emissions from individual oil/gas fields/basins accounting for more than 80% of global oil and gas production
Automate computations used to measure emission rates, cutting a process that can take months down to days	Actionable emission rate data will be accessible in a few days
Broad area coverage	Orbit Earth in 100 minutes, with a swath width of 200 km. Revisit targets every 3-4 days based on a predetermined schedule and atmospheric circumstances.
Point source attribution	Trace larger single emission events back to their point source
Quantify methane concentrations with high precision	Detect excess methane at 3 parts per billion (highest precision compared to satellites currently in orbit)
Transparency	Free public data access

*For now, oil and gas producing regions, though there is potential to expand into agricultural methane emissions.

MethaneSAT's capabilities have limitations. Like other passive remote sensing technologies that measure light in the shortwave infrared part of the spectrum, MethaneSAT will not be able to measure methane at night. Clouds and other weather conditions can hamper measurement, which the MethaneSAT control team will factor into day-to-day planning in order to maximize coverage. The small native pixel size allows MethaneSAT to still collect useful data even when some clouds are present, as those pixels can be excluded from the analysis. MethaneSAT will not be able to attribute emissions to smaller point sources, such as individual flares, tanks, compressors or wells, but these emissions will be characterized in its area source data.. It is also capable of measuring spatially distributed emissions with high precision. However, this means in those proportionally few global basins with high operator density, attribution back to specific operators, facilities, or processes will be more difficult.

DATA PRODUCT GENERATION PROCESS

DATA RECEIVED

Data is decrypted, reconstructed and readied to enter into the processing pipeline.

PROCESSING PIPELINE

I. Data Collaboration
Raw data from the spectrometer are corrected for light intensities.

II. Methane Concentration
Data are processed to account for meteorological "noise" (cloud cover, aerosois and reflectivity of the Earth's surface). A retrieval model is used to determine methane concentrations.

III. Gridding and Geolocation
Data are remapped to geographical coordinates to produce maps of methane concentrations, including features such as oil and gas infrastructure.

IV. Methane Quantification
Inverse modeling is used to process concentration data with meteorological data to develop maps of methane emission rates in kg/hour. The amount and location of emissions are integrated with facility information to attribute emissions to specific locations and facilities.

DATA DELIVERED

The data, now processed into information, can be accessed to provide insight such as the source of emissions, how much methane is being released in a region and how emissions change over time.

APPLICATIONS OF METHANESAT DATA

The MethaneSAT mission was designed to enable and motivate faster action to reduce methane emissions.

With growing numbers of oil and gas companies and investors working toward methane reduction goals and governments looking to strengthen methane policies, MethaneSAT will augment and validate the data that these stakeholders need when making critical regulatory, operational, and investment decisions.

INDUSTRY USE CASES

Satellite emissions data can be used by oil and gas companies to make operations more efficient, monitor regulatory compliance, and ensure competitiveness and access to markets that increasingly look for lower emission-intensity hydrocarbons. Companies that integrate MethaneSAT data with their own emissions monitoring can achieve a greater degree of operational visibility, while those with significant gaps in emissions monitoring can use the data to guide planning.

Methane data is important for companies to manage their future costs and avoid regulatory penalties. The 2022 Inflation Reduction Act (IRA) and its Methane Emissions Reduction Program directs the EPA to apply a fee beginning in 2024 on O&G methane starting at $900/ton and rising to $1500/ton by 2026. The law also directs the EPA to update its O&G methane reporting methodology to utilize direct measurement demonstrated to be accurate, impacting O&G companies in the US. Using MethaneSAT data to prioritize emissions management can assist companies in complying with these and other requirements.

Increasingly, energy companies are also being asked by both customers and investors to document their GHG emissions and show reductions over time. Driven by factors such as financial, operational, and reputational risk analysis, voluntary or mandatory emissions reductions frameworks, and company-led targets, timely and accurate data is central to companies' ability to meet these expectations and demonstrate strong emissions performance.

Other operator uses for MethaneSAT data include:

- Prioritize investment in upgrade and repair efforts offering the biggest methane savings.
- Evaluate and prioritize joint venture engagement strategies by identifying high-emitting joint operated assets.
- Monitor emissions over time and compare emissions activity with past performance, competitors, or neighboring companies.

FINANCIAL SECTOR USE CASES

Investors and other financial sector actors are increasingly concerned with financial, regulatory, reputational, and other risks associated with oil and gas company methane emissions, as part of a broader picture of operational competitiveness and energy transition risk. Firms often face limitations in the accuracy and reliability of available data, despite significant research efforts.

In addition, a growing number of investment firms have proactively adopted climate or net zero commitments. The Glasgow Financial Alliance for Net Zero (GFANZ) is a global coalition of financial institutions committed to accelerating the decarbonization of the economy. The organization counts more than 550 banks, insurers, asset owners, asset managers, financial service providers, and investment consultants as members.

In a recent comment letter to the International Sustainability Standards Board (ISSB), a standard-setting body with the mandate of developing sustainability-related financial reporting standards, investors representing $4 trillion in assets under management recently asked the International Sustainability Standards Board to enhance its oil and gas disclosure requirements by requesting companies to report their membership in OGMP and the level of reporting. Likewise the Institutional Investors Group on Climate Change (IIGCC), whose investor members collectively represent $60 trillion in assets under management, is directing companies to join OGMP and achieve Gold Standard in its Net Zero Standard for Oil and Gas.

Using the MethaneSAT platform, analysts can:

- Judge a company's competitiveness in methane management relative to peers
- See how a company's methane emissions change over time

REGULATORY USE CASES

Federal institutions such as the US Environmental Protection Agency (EPA) are creating or enhancing rules regarding methane pollution. For example, a public comment opportunity on EPA's proposed rules to reduce methane emissions from oil and gas operations just closed in February 2023. EPA's proposal seeks to reduce methane emissions by reducing routine flaring, expanding leak monitoring requirements to require monitoring of all sites, including smaller, leak-prone wells, and phasing out polluting pneumatic controllers and pumps in favor of zero-emitting alternatives.

Once EPA finalizes the rule this August, state and tribal governments will have 18 months to develop and submit implementation plans to EPA. For those who choose not to develop a plan, EPA will develop and implement a federal plan for them. However, historically EPA regulations have been based on emission estimates and not data from direct measurement. MethaneSAT and other emerging monitoring technologies will be crucial for filling a big data gap and assessing how effective regulations are once adopted.

Satellite data will also be important for international institutions. The European Union is currently negotiating the world's first regional legislation to reduce methane emissions from the energy sector. The legislation, proposed by the European Commission in December 2021, is now being finalized by the co-legislators. Once adopted, the block will set in place rules for monitoring, reporting and verification and a framework for leak detection and repair. Access to timely and accurate emissions data such as that produced from MethaneSAT will be critical to making policies as targeted and effective as possible.

Moreover, the United Nations Environment Programme's International Methane Emissions Observatory (IMEO) will be aggregating and analyzing OGMP member data with emissions data from MethaneSAT and other independent measurement-based datasets to find and analyze reporting gaps.

GAS BUYER USE CASES

Global gas buyers, especially the largest buyers in the major gas-importing regions of Europe and Asia-Pacific, hold enormous influence over their commodity supply chains. Many are increasingly concerned about unnecessary and wasteful emissions in the value chain of the gas they're importing. In some cases, buyers have close linkages with national governments which themselves have adopted climate commitments. To support company and country-level climate goals, buyers might incorporate methane emissions data from MethaneSAT in gas procurement contracts. Additionally, MethaneSAT data can help buyers screen for high-performing supply regions, compare gas suppliers, and assess individual sources in their portfolio

OTHER USE CASES

The accessibility of MethaneSAT data will support additional use cases and may enable unexpected uses for emissions data as well.

Media outlets and journalists can use MethaneSAT data to investigate emissions from specific companies or geographic areas, both for ongoing performance and following super-emitter events.

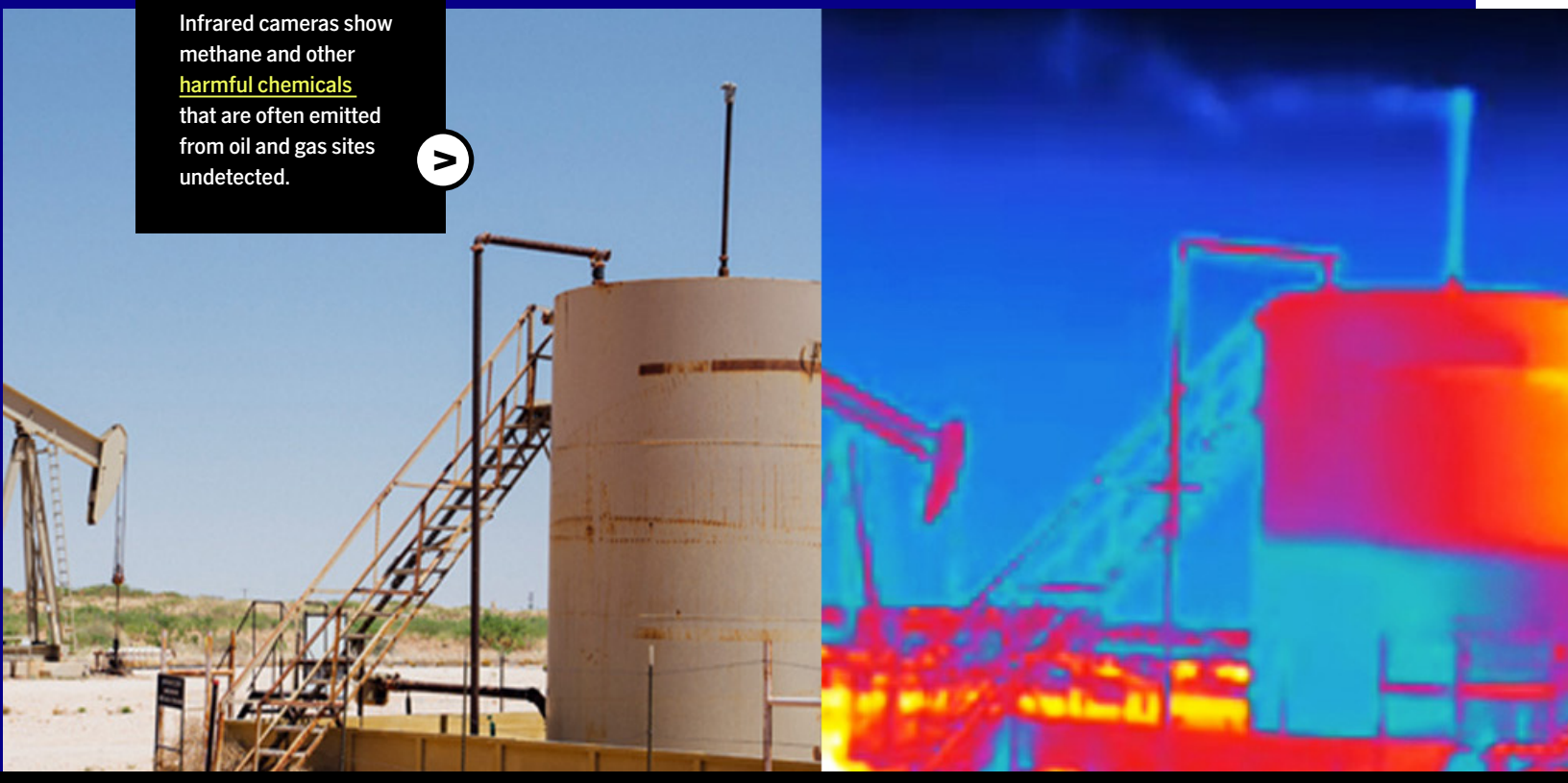
Scientists can use MethaneSAT data to advance atmospheric modeling for emission quantification at different scales, as well as to improve emission inventories to increase confidence in emission reporting that inform climate action.

Public health experts can use emissions data to inform interventions for other toxic pollutants linked to methane, such as benzene, hydrogen sulfide, toluene, and xylene, that harm human health.

The public can use the data in multiple ways, such as:

- To inform decision-making about possible health and safety risks in a given community
- To support advocacy for responsible operation of oil and gas facilities

Infrared cameras show methane and other harmful chemicals that are often emitted from oil and gas sites undetected. >



CONCLUSION

Methane detection satellites play an important role in mapping global methane emissions and providing data with new speed, scale, and frequency.

The data they generate is an important source of information for oil and gas operators, and for stakeholders like regulators, investors, scientists, public health experts, and the general public.

The launch of MethaneSAT will fill a critical gap in the capabilities of existing satellite technologies, combining a wide field of view along with a high level of precision and spatial resolution. For the first time, it will be possible to have near real time methane emissions data on a global scale (currently concentration data is available, and not emission rate data, and the conversion of one to the other is not straightforward). MethaneSAT will rapidly process raw sensor readings into actionable data and make that information publicly available. This new emissions transparency will provide the first global picture of how emissions vary globally while also enabling operators to more fully understand their emissions profile, and empower stakeholders to independently verify operator progress toward their goals and commitments to reduce oil and gas industry emissions of climate-warming methane. In this way, MethaneSAT will be a powerful tool to accelerate climate action.

METHANESAT.ORG

@MethaneSAT