



## **MethaneSAT: Putting the Brakes on Climate Change**

### **Key Technical Considerations**

May 2019

#### **What makes MethaneSAT special**

MethaneSAT, an affiliate of Environmental Defense Fund (EDF), is building a satellite that will provide data to catalyze action that rapidly slows the rate of global warming. It will measure methane emitted by oil and gas infrastructure worldwide at a level of precision and on a fine scale never before achieved — and at a fraction of the cost of most space missions. MethaneSAT will be a key tool in EDF's strategy to reduce methane emissions from the oil and gas industry by 45% by 2025 and nearly eliminate emissions by 2050.

MethaneSAT will collect information that will be useful and actionable. It will combine the most advanced instrumentation and groundbreaking data analysis techniques to detect where methane emissions are coming from and measure how much is being emitted better than any other satellite, either flying or planned. Detecting even low emission levels is critical because it is estimated that roughly half of the methane being emitted from oil and gas infrastructure comes from smaller sources, which are largely unidentified.

Other existing and planned endeavors can either detect methane emissions across large geographic areas or measure emissions from specific locations. MethaneSAT combines both capacities and will achieve the degree of precision required to give industry and governments the confidence they need to act on and enforce the commitments they are already making to drastically cut methane emissions from their activities.

MethaneSAT has the potential to take a big step forward in making remote sensing of greenhouse emissions a policy-relevant tool in efforts to develop effective targeted mitigation strategies.

#### **Providing the precision industry and governments need to act**

A high degree of precision and accuracy in our measurements is critical to achieving EDF's goal of reducing methane emissions from the oil and gas industry by 45% by 2025 and nearly eliminating emissions by 2050. Precision enables action by identifying the location/area and severity of emissions and measuring reductions in emissions from those sources over time. Accuracy provides industry, governments and the public with the confidence in the data they need to take action.

MethaneSAT will employ a highly sensitive spectrometer that measures light at the specific wavelengths where methane absorbs light within the shortwave infrared spectrum. This approach allows us to detect differences in concentrations of methane as low as 2 parts per billion (ppb). When combined with groundbreaking new data analytics, MethaneSAT's small

pixel size (1-2 km<sup>2</sup>), and wide view path (200 km<sup>2</sup>) will be able to quantify small emission sources over large areas that, in the aggregate, are significant sources of methane emissions, but to date have been undetectable by satellites. In addition, MethaneSAT is able to collect finer resolution data (with less precision) that will allow larger emissions to be pinpointed to within 400 meters of their source.

For a major oil and gas field, MethaneSAT anticipates being able to quantify the methane emission rate with an expected 25-35% error. In other words, the emission rate will be no more than 17.5% above or below the measurement from MethaneSAT on average. This represents a very high level of accuracy for space-based detection, which will give industry and governments confidence in the data MethaneSAT provides. This detection threshold is better than what is necessary to achieve the reductions needed. This confidence is critical to EDF's ability to turn MethaneSAT data into action that will result in emissions reductions sufficient to meet our reduction goals.

Prior to launch, an aircraft based instrument that produces the same type of data as MethaneSAT will take measurements flying over areas with known methane emission rates to refine algorithm development and validate the precision and accuracy of MethaneSAT derived data. It is estimated that this effort, known as MethaneAIR, will shorten the time from initial data collection to first policy-relevant data product by three to six months.

### **Tackling the challenge of measuring methane from space**

To measure methane emissions from infrastructure at the surface of the earth — from 500 km above the earth — with the precision needed for industry and governments to take action is an enormously complex technological challenge. MethaneSAT is designed specifically to address this challenge.

The first challenge is making sure that the instruments on board the satellite are sensitive enough, using a very small amount of light, to collect the data needed to do the math that allows for robust emission quantification. To overcome this challenge, MethaneSAT will use a highly sensitive spectrometer that can detect the presence of differences in methane concentrations at very low levels by separating out the narrow bands of wavelength where methane absorbs light within the shortwave infrared spectrum.

In addition to the challenges of gathering data, the analysis of that data poses perhaps an even greater challenge. The MethaneSAT mission is developing new, groundbreaking data analytics to turn raw data into actionable information.

Among the most significant of the data analytics challenges is the need to account for the scattering and absorption of light by the earth's surface, and other sources of atmospheric interference such as aerosols and clouds. Where methane is detected by the satellite instrument is not where it originated. Measurements from the atmospheric column must be analyzed to trace the methane detected back to the source and quantify the emission rate. This analysis requires sophisticated atmospheric transport modeling, based on a state-of-the-art inverse modeling framework. While such calculations have been carried out for specific areas, they have

not been operationally automated such that they become an integral part of the mission and are applied to all of the data collected.

MethaneSAT will sense plumes of methane — patterns of higher concentrations, created from point sources or diffuse emissions from larger areas. Inverse modeling factors in wind patterns and other atmospheric conditions around the methane plume to determine the location and quantity of point sources or area emissions that would be required to create the methane plume that was detected by the satellite. In essence, inverse modeling runs the plume back in time to show the location and magnitude of emissions (leak rates in kg/hr) required to create the detected plume.

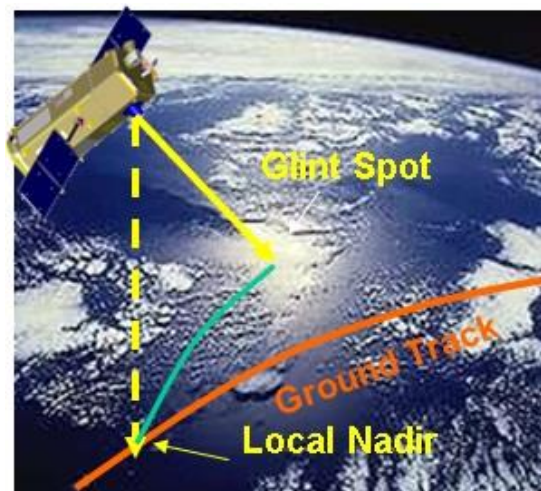
### **Limiting factors and how they can be addressed**

The primary factor limiting the amount and precision of data on variation in methane concentrations is the amount of light being reflected at the Earth's surface. The amount of light that can be detected by the satellite sensor is affected by cloud cover, high latitudes in winter, and dark surfaces.

1. Cloud cover: Clouds affect all optical and infrared-based remote sensing systems. MethaneSAT has built forecasting for clouds into its mission planning algorithms that point the satellite to cloud free areas when possible. To accomplish this, the satellite can orient up to 45 degrees to the left or right of the flight path (slewing).

The small pixel size will also eliminate the effect of smaller areas of cloud. MethaneSAT is designed to image global oil and gas operations weekly, more frequently with slewing, thereby maximizing the opportunity to take measurements when there is no cloud cover and where significant variability has been observed.

2. High latitudes in winter: MethaneSAT will not make observations over high latitudes, such as Siberia, during the darkest time in winter when there is insufficient light to obtain useful data.
3. Dark surfaces: The majority of the Earth's land mass will provide enough reflectance to support imaging. To address the challenge posed by surfaces that do not reflect enough light (primarily over water where offshore oil/gas production targets are located), MethaneSAT is using an alternative measurement that points the sensor to the bright glint spot over oceans where solar radiation is directly reflected off the Earth's surface (glint mode).



To deal with surfaces that do not reflect enough light, MethaneSAT is using an alternative measurement method that points sensors to the glint spot.

Deploying multiple satellites would increase the frequency of measurements and potentially overcome some of the challenge posed by cloud cover. However, MethaneSAT does not believe that cloud cover will limit the ability to create a robust picture of emissions over time across most regions of the world to an extent that warrants the additional expense of building, launching and operating multiple satellites.

Similarly, a bigger satellite with larger optics could improve the quality of data collected in situations with limited light but not enough to warrant the added expense. MethaneSAT specifications were established specifically to produce the greatest return on investment and produce the information industry and governments need to take action.

MethaneSAT does not believe that the sensitivity of the satellite's instrumentation represents a limiting factor.

### **How does MethaneSAT fit in the landscape of other methane sensing missions?**

There are several efforts in different phases of development. TROPOMI was launched by the European Space Agency in October 2017 and is providing data. GoSAT2 was recently launched by the Japan Space Agency. The state of California is working with Planet to build a system. In the private sector, a company called GHGSat has launched a demonstration methane detection satellite called Claire. GHGSat plans to launch an upgraded satellite in 2019, with additional satellites planned in the future. There are also one or two other private sector efforts that are in nascent stages.

#### *How is the MethaneSAT mission different from other satellites?*

Each mission is important and has its own role in the ecosystem of satellites. In fact, the different missions can complement and strengthen each other. The main differences in satellite systems come down to scale, precision and data usage.

MethaneSAT is a single satellite with a wide field of view and a high-precision instrument capable of mapping and quantifying methane emissions from large swaths of land — about 200 km or approximately 125 miles. The satellite's primary goal is to survey 80% of global oil and gas operations, measuring aggregate methane emissions from almost all known and previously unknown sources, as well as identifying the location and size of larger sources.

Data from MethaneSAT will be used to create maps of emissions over areas or regions, along with the rate of emissions. This information, combined with the International Methane Studies EDF is conducting separately, will help identify problem emissions that countries or companies don't know about or don't want to publicly acknowledge; define the magnitude of the global problem; and measure changes in emissions over time.

GHGSat and other satellites like it can examine previously known emissions sources within a 20km or less field of view (target-mode instrument). This information can be used by government or companies to monitor specific facilities with larger emissions for regulatory enforcement or operational compliance. By contrast, MethaneSAT is designed to achieve a comprehensive picture of global emissions and have a 200 km field of view that would only be

achievable with many satellites with a 20km field of view. However, even with a constellation of satellites, these data would not include quantification of emissions from diffuse sources, which account for a large proportion of total anthropogenic emissions. MethaneSAT will provide this quantification.

TROPOMI is looking at a much larger swath, 2,600 km, and with much coarser spatial resolution (49 km<sup>2</sup> per-pixel area) and higher detection limit than MethaneSAT. This project seeks to understand very large sources of methane emissions on a global scale. The MethaneSAT team is working closely with the TROPOMI methane science team to help generate as much useful data about oil and gas infrastructure as possible, and to integrate any learnings into the MethaneSAT mission. While data from TROPOMI will start to be made publicly available in 2019, it will not be in a form that is easily actionable without significant additional analysis.

Private satellite systems such as GHGSat do not have plans to release or share data with the public. Instead, they are going to try to sell the data to oil and gas companies. MethaneSAT's data will be made public.

*Are there opportunities for collaboration between satellites?*

Each project has a distinct role to play that overlaps to some degree with the other. TROPOMI provides data about areas across the globe with very large emissions. MethaneSAT will provide ongoing global data that should capture almost all emissions specific to oil and gas operations (and emissions from agriculture and landfills), allowing us to capture the full measure of the problem, determine who is responsible and press for action, and assess whether countries and companies are making progress in reducing emissions over time. GHGSat's technology can be used by countries or companies to measure and monitor emissions at specific facilities, for regulatory enforcement or operational compliance, once those measures are in place.

**Table 1**

Satellite Instrument	Period	Local overpass time	Pixel size (km)	Swath width (km)	Precision	Detection Threshold <sup>3</sup> (kg/hr)	Regional Source Quantification (Q = 72,000 kg/hr over 300 x 300 km <sup>2</sup> )
<i>MethaneSAT</i>	2021 -	10:00-14:00	1 x 1*	200	0.1 %	100 <sup>1,2</sup>	Single pass (~7 days)
SCIAMACHY	2003 - 2012	10:00	30 x 60	960	1.5 %	68,000	1-year averaging time
GOSAT	2009 -	13:00	10 x 10	3 cross track pixels 260 km apart	0.7 %	7,100	1-year averaging time
TROPOMI	2017 -	13:30	7 x 7	2600	0.6 %	4,200	Single pass (1 day)
GOSAT-2	2018 -	13:00	10 x 10		0.4 %	4,000	4-month averaging time
GeoCARB <sup>4</sup> (geostationary)	2022	continuous	4 x 5		1 %	4,000	Single pass (few hours)

**REGIONAL methane emission source quantification**

<sup>1</sup> MethaneSAT can potentially retrieve CH<sub>4</sub> enhancements at finer spatial resolution (400 m x 400 m pixel size) at 0.5% or better precision, within the 1 km<sup>2</sup> pixels.

<sup>2</sup> For a 50 x 50 km<sup>2</sup> area of an OG field, MethaneSAT's 0.1% precision can detect emissions averaging only 2.25 kg/hr/km<sup>2</sup>.

<sup>3</sup> All calculations assume uniform wind speed of 5 km/hr and CH<sub>4</sub> background of 1800 ppb, following Jacob et al. 2016, which assumed the Barnett shale as a 300 x 300 km<sup>2</sup> region ventilated by a uniform wind speed of 5 km/hr winds.

<sup>4</sup> GeoCARB is a future geostationary mission that will observe North and South America, and will not have global coverage. GeoCARB's precision and detection threshold estimates are not confirmed, and will be updated as they become available. GeoCARB's specs are taken from Jacob et al. 2016.

- Blank cells indicate insufficient or unavailable information.

**Table 2**

Satellite Instrument	Period	Local overpass time	Pixel size (km)	Swath width (km)	Precision	Detection Threshold <sup>3</sup> (kg/hr)	Point Source Quantification within viewing domain
<i>MethaneSAT</i>	2021 -	10:00-14:00	1 x 1*	200	0.1 %	100 <sup>1,2</sup>	YES – single pass – based on full inverse modeling
GHGSAT-D <sup>5</sup>	2016 -	09:30	0.05 x 0.05	12	~20 %	~1,000	
GHGSAT-C1/C2 <sup>5</sup>	2019 -		0.05 x 0.05	12			
Bluefield	2019 -		0.02 x 0.02	38			?
NEMSAT		11:00-13:00	0.03 x 0.03	18			
GeoCARB <sup>4</sup> (geostationary)	2022	continuous	4 x 5				

### **Methane POINT SOURCE Detection and Quantification**

*Note: Precision and Detection Threshold information for GHGSAT-C1/C2, NEMSAT, GeoCARB and Bluefield are not confirmed. Information will be provided as it is made available.*

<sup>1</sup> MethaneSAT can potentially retrieve CH<sub>4</sub> enhancements at finer spatial resolution (400 m x 400 m pixel size) at 0.5% or better precision, within the 1 km<sup>2</sup> pixels.

<sup>2</sup> For a 50 x 50 km<sup>2</sup> area of an OG field, MethaneSAT's 0.1% precision can detect emissions averaging only 2.25 kg/hr/km<sup>2</sup>.

<sup>3</sup> All calculations assume uniform wind speed of 5 km/hr and CH<sub>4</sub> background of 1800 ppb, following Jacob et al. 2016, which assumed the Barnett shale as a 300 x 300 km<sup>2</sup> region ventilated by a uniform wind speed of 5 km/hr winds.

<sup>4</sup> GeoCARB is a future geostationary mission that will observe North and South America, and will not have global coverage.

<sup>5</sup> GHGSAT's precision and detection threshold is an estimate that has not been made publicly available. GHGSAT-C1/C2 precision and detection threshold is proposed estimates. Bluefield's detection threshold has been revised to ~100 kg CH<sub>4</sub>/hr (per personal communication).

- Blank cells indicate insufficient or unavailable information.