SIX YEARS, SIX TECHNOLOGIES

2012
2018

6 years Combustion Bay One e.U.,
a review

FIRE = POWER + RESPONSIBILITY

We are more and more people on this small planet. Natural resources are limited. Exhaust emissions are compromising the air we breathe, and climate change is a reality.

This is called the energy trilemma. And this is precisely what we intend to tackle at CBOne, because combustion technologies are improvable.

Renewables are growing fast, which is excellent. However, they need time to achieve the order of magnitude of conventional primary resources. We can help to buy this time. Furthermore, any improvement made in combustion technology has a positive impact on the environment comparable to the progress made on alternative energy resources.

Founded in 2012, Combustion Bay One has become an established Austrian company with a significant record in R&D on advanced combustion technologies. We built up over these 6 years a solid know-how on experimental combustion. We can make a good use of it.

The progress on the technologies presented in this brochure were possible within this time frame because CBOne is a dynamic group with a lightweight structure. It is reactive, international, well-connected with the industry and with the university. I wish at that point to thank all the participants, the partner institutions and the organisations mentioned in the following (plus the Science Park Graz, where it all started). They share this ideal with us, where combustion expertise and motivation for an exciting work are the seeds of success.

The future. Imagine a place where the level of expertise is so good, that fuel costs can be reduced by 5% compared to conventional. Imagine a place where new thermal system can be tested at full scale and optimised before being deployed. Imagine a place where new ways are investigated to make a better use of combustion. Towards less fuel burn, less emissions, more safety and more flexibility: Combustion Bay One.

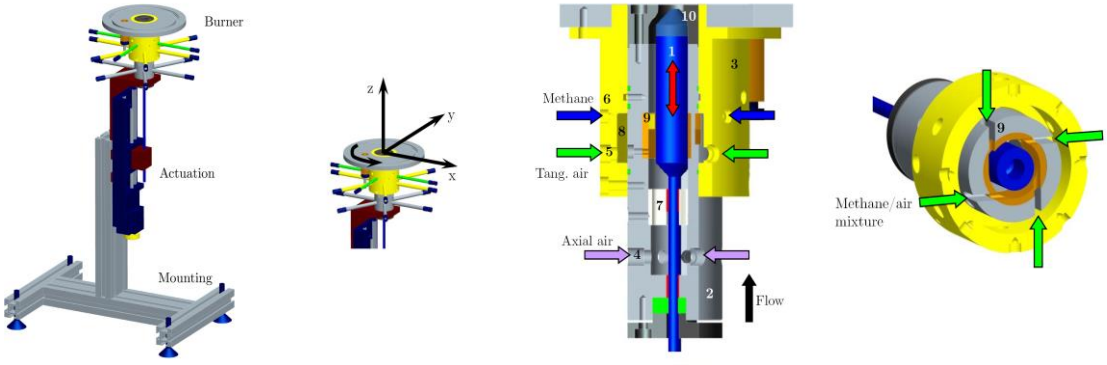
Dr. Fabrice Giuliani, CEO

THE BURNER WITH VARIABLE GEOMETRY

Incentives

This is a joint-work performed with TU Graz in the frame of the project NEWAC (NEW Aeroengine core Concepts, EU FP6). This work was conducted by Thomas Leitgeb-Simandl in the frame of his PhD at TU Graz.

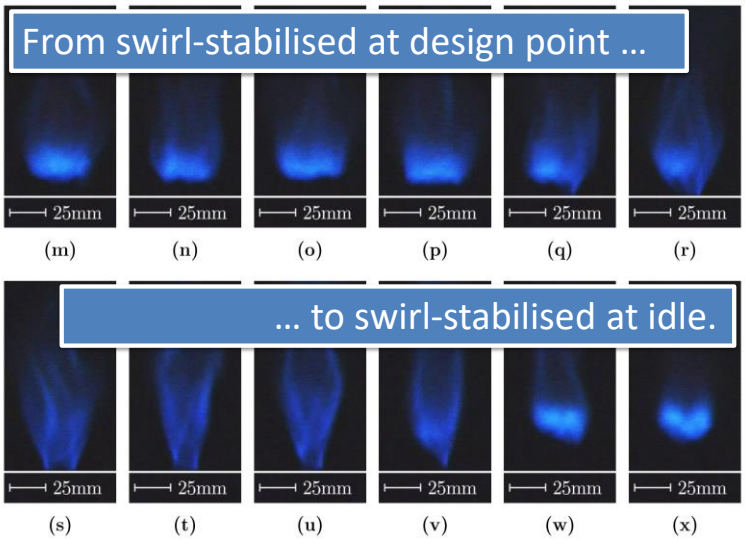
The variable geometry burner adapts its shape to the operating conditions, to generate "the perfect flame" (compact, swirl stabilised, with enlarged operating range in the lean operation domain).



The work-in-progress title was the "Barbapapa-burner"!

Ideally, the flame dynamics are homothetic. The flame dimension is then a function of the desired power. To achieve this behaviour, two parameters are kept under control:

- The reference velocity (or bulk speed of the reactants as they are injected)
- The swirl number, by playing on the cut axial/tangential main air



Results / Publications

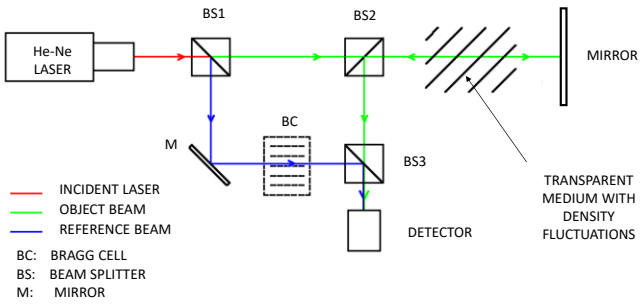
- Extended operation range
- Control of the flame front position and shape
- Pushing forward the Lean Blowout Limit
- Retarding the transition of the detached flame to attached

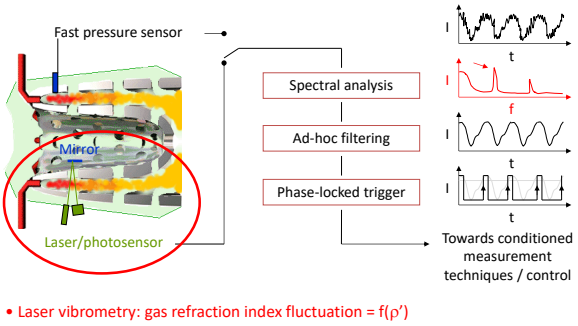
Giuliani, F., Woisetschläger, J., and Leitgeb, T., 2012.
Design and validation of a burner with variable geometry for extended combustion range.
In Proceedings of ASME Turbo Expo, American Society of Mechanical Engineers, pp. 155–165.
GT2012-68236.

MEASURING DENSITY FLUCTUATIONS IN A FLAME USING LASER VIBROMETRY

Incentives

A lightweight and straightforward optical measurement technique was designed to monitor in a very refined way the turbulence in a flame. Compared to more demanding measurement techniques, laser vibrometry allows to quickly identify the presence of coherent turbulence in a flame, as shown on the maps below.

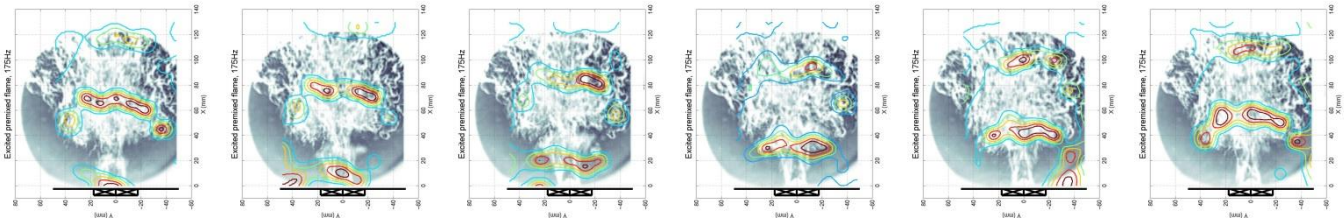




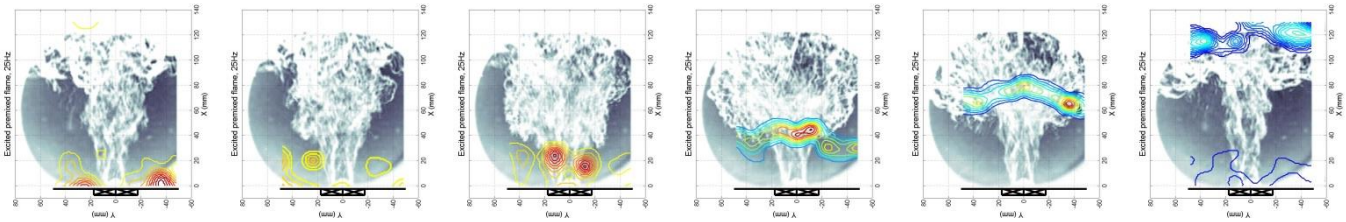
• Laser vibrometry: gas refraction index fluctuation = f(ρ')

The basic principle is the measurement of change of the diffraction index of the gases in the flame. If integrated in a gas turbine, this line-of-sight, laser-based technology can survey in real time the combustion turbulence. More recent works driven by J. Woisetschläger at TU Graz tend to quantify in real-time the unsteady heat release in the flame.

Results: mapping the density change in a pulsed flame



These maps combine the schlieren image of an excited flame with the zones of denser flow measured with LV. The top sequence shows a 175Hz ring vortex detachment, the lower one is excited at 25Hz.



Publications

Giuliani, F., 2010.
Advanced Combustion Management
Habilitation memorandum, TU Graz.

Leitgeb, T., Schuller, T., Durox, D., Giuliani, F., Koeberl, S., and Woisetschlaeger, J., 2013.
Interferometric determination of heat release rate in a pulsated flame.
Combustion and Flame, vol. 160, band 3, pp. 589–600.

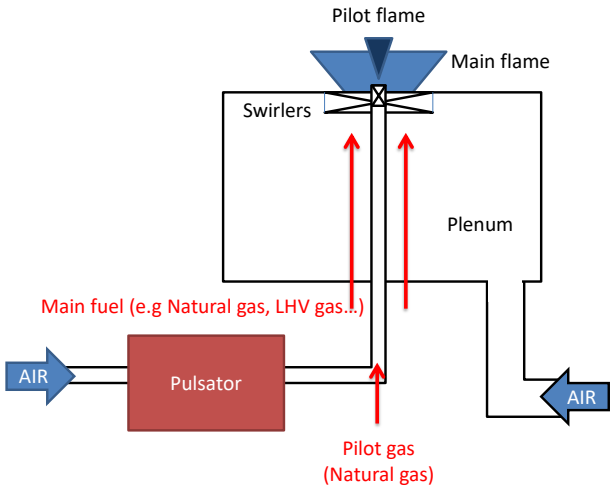
A BETTER COMBUSTION USING WELL-CONTROLLED PULSATIONS

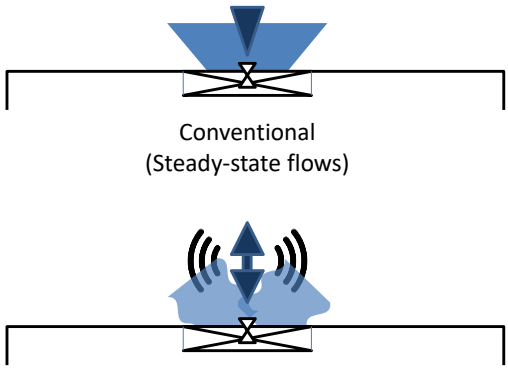
Incentives

MethaNull is the project name for "Towards zero Methane Emissions". This stand-alone technology at CBOne was supported financially by the AWS from 2013 to 2016.

METHANULL

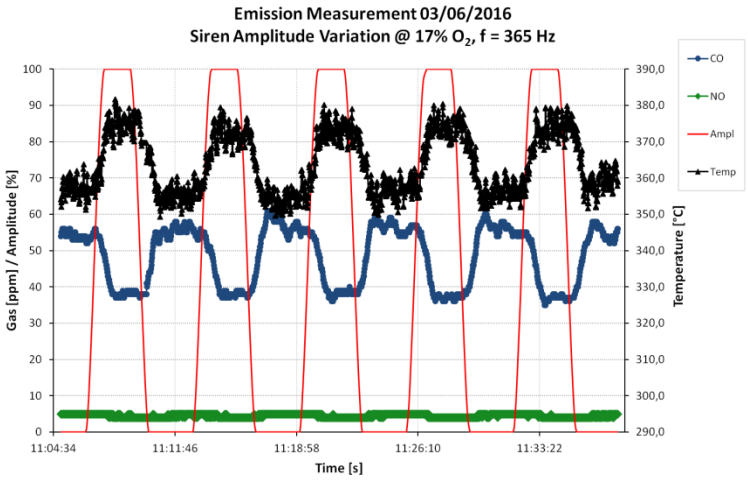
The idea is to change the conventional physics of combustion by bringing in a controlled turbulence in the reactant flow of the burner. If the frequency is well-chosen, a thermo-acoustic drive can be generated. In this case, the pilot stage is used as an acoustic driver, with an effective drive on the main flame.





Results: same power, 2% less consumption and CO2, 15% less other pollutants (CO and NOx) than conventional

- A methodology was demonstrated including an ON-OFF thermoacoustic drive
- Controlled thermoacoustics can improve the combustion at some impaired operating point
- The warm-up rate, the combustion efficiency, and the production of CO and NOx emissions could be improved simultaneously



Publication

Giuliani, F., Pfefferkorn, L., and Kraft, G. E., 2017.
Improvement of impaired combustion conditions at some off-design operation by driving a precisely controlled modulation of the burner air feed.
In Proceedings of ASME Turbo Expo, Charlotte, North Carolina, USA. GT2017-64429

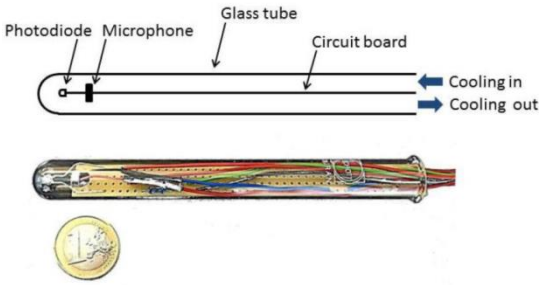
THE EYES AND EARS INSIDE THE GAS TURBINE COMBUSTION CHAMBER

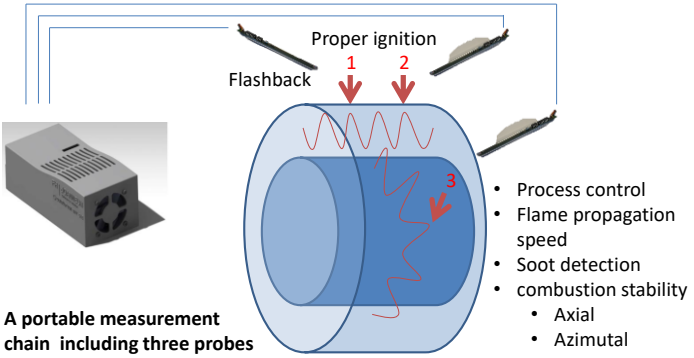
Incentives

Emootion stands for "**E**ngine Health **MO**nit**O**ring and Refined Combus**TION** Control Based on Optical Diagnostic Techniques Embedded in the Combustor". Combustion Bay One initiated and implemented this project together with the FH-Joanneum (Institute of Aviation) and is supported financially by the Austrian Research Promotion Agency (FFG) and the Federal Ministry of Transport, Innovation and Technology (contract no. 850470).

A set of probes allow taking a look inside the GT combustion chamber. Real-time precision combustion monitoring has issues on combustion fine-tuning and on reduction of operation costs via adapted maintenance. The miniaturized combined optical and acoustic flame monitoring system was designed for the following:

- Is there a flame or not?
- Was the combustion sequence successful?
- Is there a combustion instability?
- Are the current operating conditions consistent with the set point? (radiative power, presence of soot?)

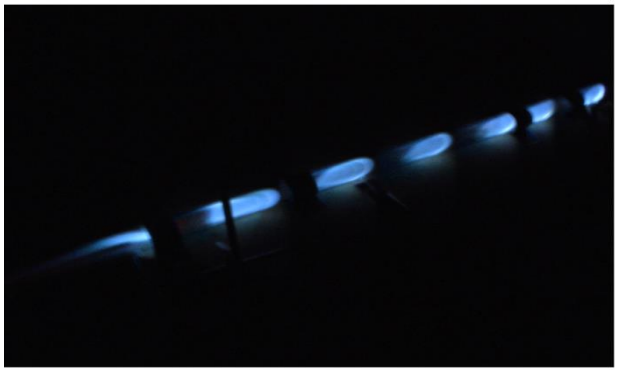


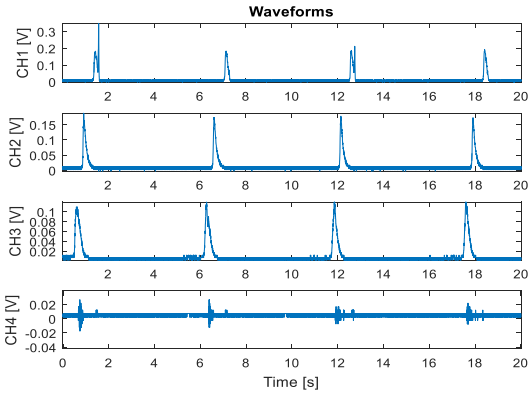


A portable measurement chain including three probes

The portable measuring chain with the probe provides a light but robust stand-alone system for signal evaluation and signal presentation. At the same time, it represents a combination of combustion quality control, real-time engine monitoring and improved safety margin monitoring.

Publication / Example of use: survey of the flame propagation at ignition





Kraft, G. E, Giuliani, F., Pfefferkorn, L, Paulitsch, N., Andracher, L.. Heat Resistant Probe Combining Optic and Acoustic Sensors for Advanced Combustion Monitoring Including Detection of Flame Instabilities. Proceedings of ASME Turbo Expo, Charlotte, North Carolina, USA. GT2017-63626.

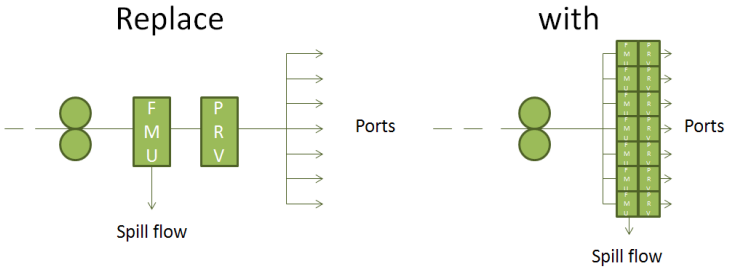
LESS POLLUTANT EMISSIONS & LESS OPERATION COSTS WITH A BETTER COMBUSTION MONITORING

Incentives

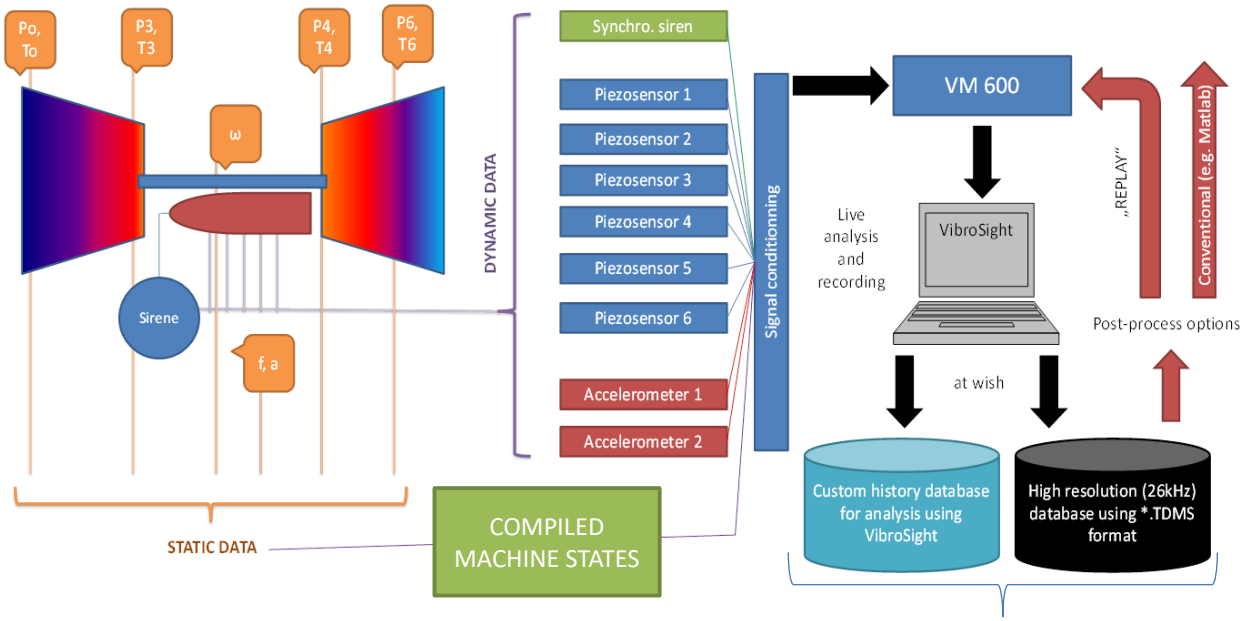
rePorT means “advanced aeRoenginE fuel injection PORTs with embedded flow monitoring technique”. The project rePorT is a stand-alone project of CBOne financed by the FFG in the frame of the Take-Off programme.

It is known that thermal NOx has an asymptotic behaviour above 1700K flame temperature. If the mass flow rate of a burner is not well-controlled, then the fuel flow distribution per burner can vary. Under such conditions, even the best low-NOx combustor architecture can behave poorly.

A minimal instrumentation per burner is tested, consisting in pressure gauges (P) and thermoelements (T) so that both the fuel and the air flows can be monitored in real-time.



Results / Publication



A strategy of combined acquisition of dynamic and quasi-static measurements was developed in co-operation with Meggitt Sensing Systems. This real time-monitoring offers the possible to document the history of operation of a machine, and detect transients or significant deviations. This strategy fits a programme of adaptive maintenance, and offers the potential to lower significantly the operation costs.

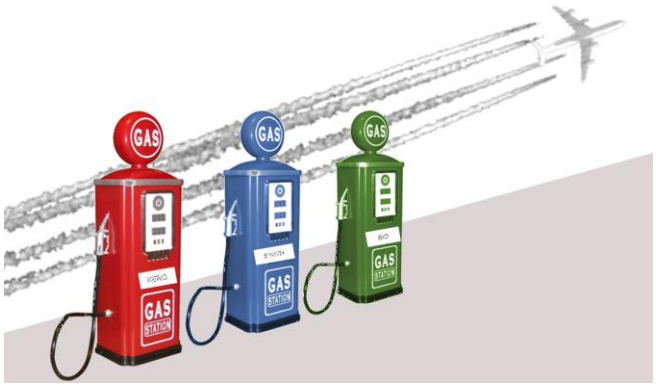
Giuliani, F., Reiss, H., Stuetz, M., Moosbrugger, V., and Silbergasser, A., 2016.
Readings on specific gas turbine flame behaviours using an industrial combustion monitoring system
In Proceedings of ASME Turbo Expo, Seoul, Korea. GT2016-56166.

FUTURE FUELS FOR AVIATION

Incentives

Jet aircrafts fly with kerosene, and there is no short term alternative yet.

The oil prices met a peak in 2007 above 140$/barrel. This was the first time in history that replacement fuels including biofuels had a chance to compete with conventional fossil fuels. CBOne participated together with TU Graz to the project Alfa-Bird (EU FP7, ALternative Fuels And Blofuels for aiRcraft Development). The question was to assess as off today, which replacement fuel has the greatest chance to be deployed industrially.



The study highlighted the potential of synthetic fuels. Gained from "anything that burns" and transformed into liquid fuel, they also offer the ability to fine tune the fuel mixture.

Currently CBOne is involved in the study of fuel tuning regarding thermomanagement with fuel, and more particularly the problem of coking in hot parts manufactured with Additive Manufacturing, in complex pipings that are not easily accessible for surface finishing.

A future future prospect for aviation is based on the use (or conversion) of LNG (liquefied natural gas). Natural gas is considered abundant, and offers at least an option - should one meet a drastic shortage situation on conventional liquid fuel. CBOne is also involved in the early phase of the project LIQORN (LIQuefied natural gas for airport and airbORNe applications, Licorne="Unicorn" in French). A first step is the enhancement of gas-powered vehicles on airport grounds.

Publication

Rajamäki, J., Giuliani, F., Fritzer, J., and Heitmeir, F., 2013.
About low emission combustion with replacement fuels (paper review)
In Proceedings of the ISABE, no. 1333, International Society of Air-Breathing Engines.

Six Years, Six Technologies

6 YEARS COMBUSTION BAY ONE E.U., A REVIEW

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