# SOUNDING ROCKET COMPERE EXPERIMENT (SOURCE) MODULE ON MASER 11

**A Vaernéus[(1)], M Lundin[(1)], M Ångerman[(1)], K Löth[(1)], P Andersson[(1)],**

*[(1)] P.O. Box 4207, SE-171 04 Solna, Sweden, Tel: +46 8 6276200, Fax: +46 8 987069, e-mail: alf.vaerneus@ssc.se*

## ABSTRACT

SOURCE is a benchmark type of experiment on fluid behavior in tanks to test hypotheses and numerical predictions. The experiment does partially fill in the objectives of the ESA MAP project about convective boiling and condensation. The SOURCE experiment will also serve the needs of the COMPERE research group whose mandate is to investigate the behavior of propellants in spacecraft launcher tanks. Main objectives include:

- To observe the effect of wall heat flux on the contact line and the free surface
- To observe the boiling bubble behaviour on a local heater
- To observe the effect of depressurization

SOURCE main part of interest is the experiment cell, where the liquid behavior could be studied in detail. This cell contains components that can put stimuli of mainly three types to the experiment, pressurization/depressurization, heating/cooling and liquid filling/draining.

In microgravity, phenomena as marangoni effects and boiling bubble behavior are example of scientific focus in SOURCE

*Figure 1: MASER 11 launch*

SOURCE was chosen as one of the scientific payloads on MASER 11, launched May 15, 2008, providing almost 6½ minutes of microgravity. SOURCE was built by Swedish Space Corporation, with DTM, Italy as sub-contractor.

## 1. EXPERIMENT PRINCIPLE

The experiments carried out in SOURCE are much about the behavior of liquid within a propellant tank. Key concepts include what impact a hot wall has on a cool liquid, and how the pressure affects the liquid, especially during periods of pressure changes.

The experimental liquid chosen for SOURCE has an appropriate boiling temperature for this kind of experiment of about 30°C at 1 bar. This makes the thermal conditions much easier to achieve and control.

Prior to launch, the experiment cell is heated from the top and cooled from the bottom to create a thermal gradient over the cell. The experiment liquid is stored in a separate reservoir and cooled during the same period.

At the start of microgravity, the cool liquid is pumped into the experiment cell. The hot walls of the cell versus the cool liquid will in absence of gravity visualize other effects and forces which are not visible during normal 1G circumstance.

After a period of observation, the scientific focus is switched to study the effect of local boiling. A small square-formed heater is located in the lower part of the transparent cell, so that it is entirely covered by the experiment liquid. When activated, it will heat the liquid just above the heater, causing it eventually to boil if sufficient power is applied. During this phase of the experiment, also the effect of depressurization will be studied. Starting from 3 bars, the pressure will be reduced in discrete steps during 2-3 minutes.

## 2. SYSTEM DESIGN OVERVIEW

The module mainly consists of the experiment system, control electronics, imaging system, thermal control and the outer structure.

### 2.1. EXPERIMENT SYSTEM

The experiment system is fit on a thermal controlled deck in the outer structure. On the upper side of the deck, the main experiment cell is located, along with all other liquid circuitry, valves, pumps and heaters.

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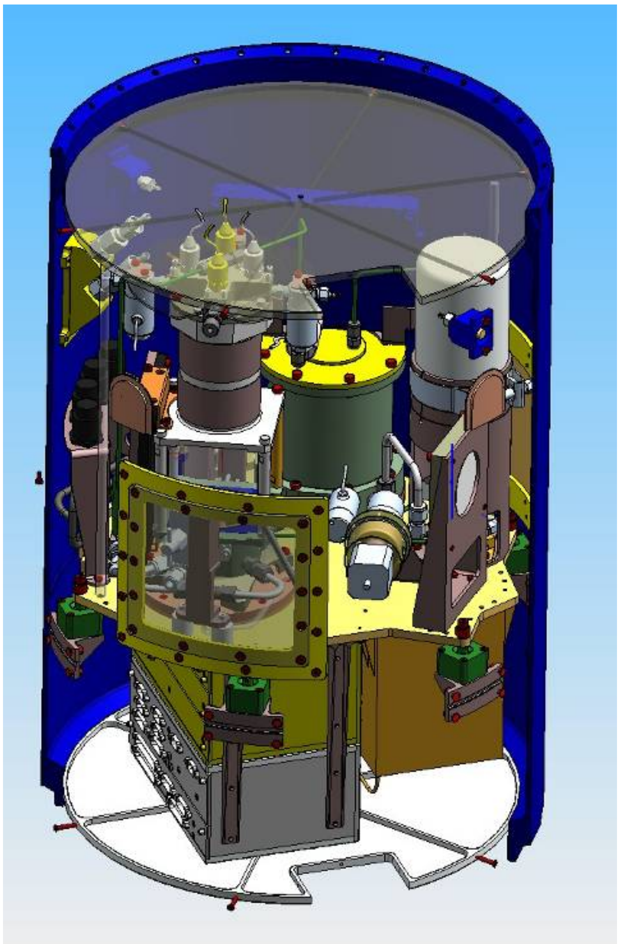

*Figure 2: Cross section of the SOURCE module (pic. by DTM)*

The lower side contains the control and sensing electronics, computer system and batteries. Also the main components of the imaging system, except the camera itself, are located here.

The module has an overall length of 660mm and a dry mass of 46,1 kg. Added to this comes the liquid with a volume of just below one liter.

All together, the experiment system comprises:

- Experiment cell, composed of transparent material, so that visual observation is possible.
- Liquid and gas transportation system
- Heating system.
- Visualisation system
- Electronic and computer system

## 2.2. INTERFACES

The module is entirely self-powered during flight. On ground the module is powered through an umbilical connector, which contains ground based communication lines, battery charging and other control logic.

During flight, the module communicates with ground via the MASM (Maser Service Module). There are two communication lines, one low-speed serial link for TM/TC, and one high-speed Spacewire link for image downlink.

There is a liquid interface that on ground is connected to a cryostat, which is connected to the main deck in the module that works as the cooling source for the rest of the components in the module.

Behind two hatches there are connectors to the liquid/gas system. These are used for late access filling of experiment liquid and gas. Custom made filling equipment was manufactured for this purpose.

## 3. EXPERIMENT CELL

The experiment cell, pictured below, is about 25 cm high and mainly consists of three parts, the bottom aluminium part which contains the liquid inlets to the cell. When pumped into the cell, the inlet is actually divided in four just before entering the cell. This is to get a uniform filling during microgravity.

The cell was pressurized using nitrogen gas prior to launch to simulate different pressure situations in combination with heating of the liquid. At pre-defined occasions in time this pressure was decreased to reach different states of boiling. This boiling could both be actively forced boiling as well as spontaneous boiling due to pressure decrease.

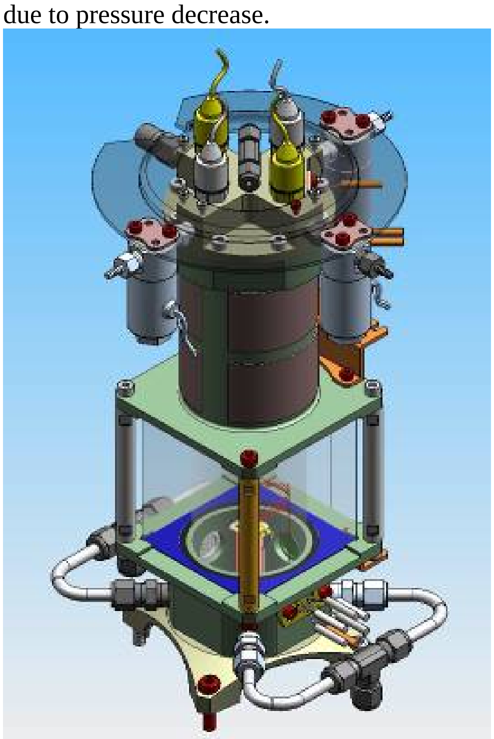

*Figure 3: The experiment cell (pic. by DTM)*

The middle part of the cell is made of transparent quartzglass, so that visual observation can be done. The amount of liquid filled into the cell will be as much so that the free surface will be clearly visible in the transparent part. Housed in this part will also the local boiling heater be which is used for boiling studies.

Around the cylindrical top two heaters are located, used for preheating the cell and to achieve a thermal gradient over the cell. This gradient will eventually reach steady state as the cell is mounted on the cooled deck. At the very top of the cell there are three gas outlets used for depressurization. These outlets are controlled by valves with different orifice size, so that the grade of depressurization can be controlled.

There are several temperature sensors housed within the transparent part of the cell. Temperature measurements are one of the key sensing methods of SOURCE. In total there are 20 sensors available in the cell. These are sampled with 25 Hz along with other sensors.

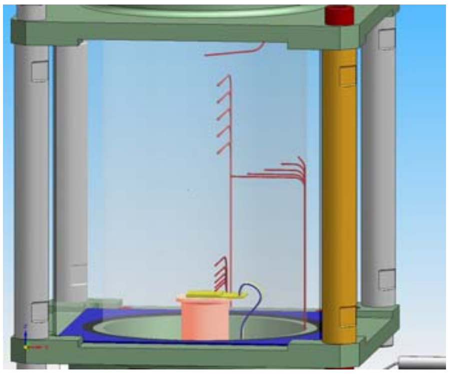

*Figure 4: Thermocouples within the cell (pic. by DTM)*

The cell is illuminated by a diffuse background light source, comparable to parallel light. The monitoring camera is a high-performing area-scan camera with a resolution of 1600x1200 pixels. At 16 Hz, it will deliver images to the digital video system (DVS), which is custom designed for this application and camera. The DVS will store all the images in raw format locally. Every other image is also compressed and downloaded to the ground station for real-time observations.

## 4. IMPORTANT REQUIREMENTS

A selection of the most important requirements is listed below.

**Overall requirements:**

- System must withstand vacuum as the module is not pressure proof.

**Hydraulic system (liquid/gas circuitry)**

- Transparent experiment cell
- 0 – 10 Bar
- 0 - 105 °C
- Compatible with experiment liquid
- Pump flow rate > 15ml/s

**Sensor requirements**

- Temperature: 0 - 100°C, ±0,5°C, 25Hz
- Pressure: 0 – 10 Bar, ±10mBar, 25Hz

**Imaging system**

- Resolution: > 10px/mm
- Exposure time: >1ms
- FOV: 80mm in height direction in the middle of the cell
- Sample rate: 16 Hz

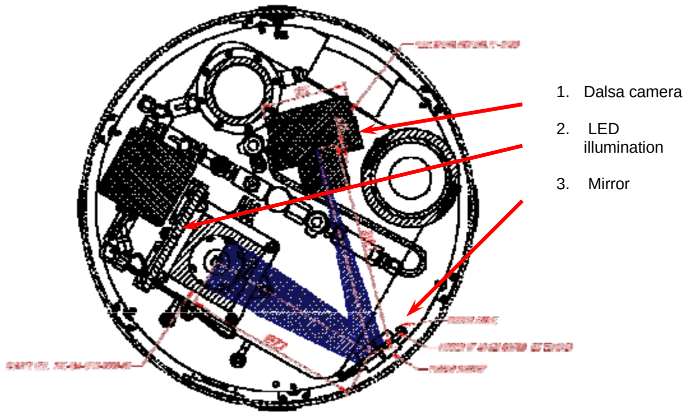


*Figure 5: Imaging system seen from above*

## 5. CHALLENGES

As in every development of an experiment module of this kind, there are a large number of challenges to face and solve. From SOURCE point of view, some of them were more critical than others, from which the most important ones are listed below:

The liquid used in the SOURCE experiment was chosen on the basis that it had a suitable boiling temperature of about 30°C at 1 bar, making it easy to handle which enabled a simplified thermal design. This liquid, however needed to be degassed, or clean from other substances. Air, as an example, will saturate into the experiment liquid changing its boiling temperature and behaviour. To degas the liquid, custom designed equipment was built and used to effectively remove all other substances.

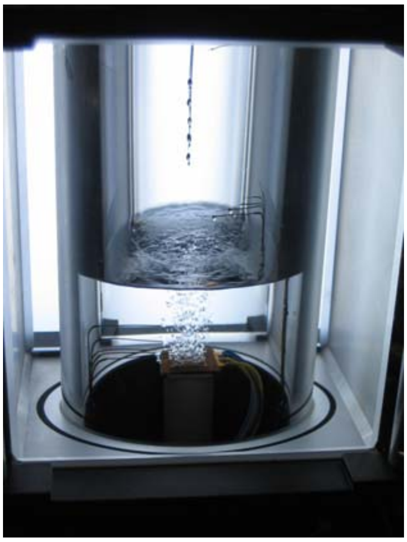

*Figure 6: Transparent part of the cell during test*

There were many thermocouples with a small size that were to be placed and measured in the experiment cell. This required an extra effort to achieve, both from a mechanical and electrical point of view. The thermocouples are also extremely sensitive to electrical disturbance and noise.

The visualization system was to be designed in a way that clearly visualized the free surface, bubbles and liquid currents. This required much elaboration and very accurate optic settings to give satisfying combination of contrast, brightness and exposure time.

The filling of the cell was to be done as quickly as possible after start of µG, but also in a controlled, smooth mode. The filling sequence also needed to be stopped very accurately, as any post adjustments of the fill level will consume time from the actual scientific observation taking place immediately after the filling sequence.

For the boiling phase of the experiment, there should be an appropriate amount of power applied to the heater, so that right level of boiling occurred. This was also needed to be done interactively, which maybe was the biggest challenge of them all. The experiment was highly relying on the real-time downlink provided, as the decision was to be taken on the basis of current status of the experiment. As the conditions for a liquid in µG will differ a lot from ground tests, there was much effort taken to rehearse the procedure before flight.

## 6. CAMPAIGN

MASER 11 and SOURCE was launched at may 15$^{th}$, 2008. The launch was preceded by 10 days of preparation on site. There were one test count down and three hot count downs before launch.

*Figure 7: Ground control for SOURCE*

SOURCE performed nominal throughout the flight, Several interactions with the module was done by the PI:s, depending on the real-time status. Preliminary data with low resolution could immediately be studied after end of µG. The recovery was also nominal, and the module could successfully be restarted again and the high-quality data and images could be extracted.

## 7. CONCLUSIONS

SOURCE was an overall success. All experiment phases were performed nominally during countdown and flight. Thermal and pressure measurements were good and the image quality of the uncompressed video was very good.
As three different PI teams were part of the SOURCE experiment, good communication and cooperation was needed. This cooperation worked well.
The execution of the experiment during flight highly required a good knowledge about the sequence, as well as good cooperation between scientists, engineers and operators. The team spirit of the SOURCE team was excellent, which improved the operations and the result in many ways.

In 2009, a study phase of a successor of SOURCE, SOURCE-2 has begun, based on the successful results from SOURCE. It will basically cover the same scientific goals as the first SOURCE, but will be modified in several areas due to new scientific requirements. The new SOURCE will, if built, have an imaging system with higher frame rate and resolution, an even higher number of thermocouples and a different pressurization concept among others.