The following review was accomplished on DOI #10.1109/ICSpT.2011.6064657, *Spacecraft outgassing, a largely underestimated phenomenon.*

This paper looks at outgassing associated with the Rosetta spacecraft which launched in 2004 on a mission to study comet 67P/Churyumov-Gerasimenko in 2014. The extended time required to accomplish the mission is due to saving energy by accomplishing flybys of Earth, Mars, and two asteroids. This is the first spacecraft to have the gaseous envelope arising from outgassing to be measured with very high sensitivity. The measurements cover 6 years and heliocentric distances ranging from 0.8 to 4 AU. Measurements were performed using three instruments of the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA): the reflectron-type time-of-flight (RTOF), the double focusing mass spectrometer (DFMS) and the cometary pressure sensor (COPS).

Due to the nature of its mission to measure cometary gases, Rosetta was built under very clean conditions and outgassing requirements for the materials used was very stringent. The “meat” of the paper is divided into four sections: the mechanism of outgassing, the background composition, changes in the background, and modeling of the environment.

The COPS gauge showed a decrease in pressure of $2 \times 10^{-9}$ to $7 \times 10^{-11}$ mbar over a period of 1100 days after it was turned on. At these low pressures the COPS has large error bars but these pressures are backed up by the DFMS which is more sensitive to these lower pressures and lies within the COPS errors.

The spacecraft outgassing is explained by three different mechanisms. The first is desorption which depends strongly on temperature and has an exponential decrease over time and the lowest
activation energy of the three processes. The second is diffusion which is the transport of volatiles from the interior and bulk materials to the outside over time with the time dependence being inversely proportional to the square root of the time. The third mechanism is nearly time independent and arises from decomposition of material which is negligible at the outset but I extrapolated to increase over time. The combination of these three mechanisms creates a nearly constant background pressure in the vicinity of the spacecraft of about $10^{-11}$ mbars.

The background composition has four main identified groups. The first is water since a lot of adsorbed water is sealed inside interior areas. Desorption of water from surfaces dominates the first few weeks but after that diffusion is the process responsible for the outgassing of the remaining water. The second group consists of hydrocarbons which are postulated to originate from polycarbonate compounds making up the spacecraft structure as well as solvents used on the spacecraft. The third group is halogens and lubricants with possible sources being remnants from brazing and fluorocarbons contained in the structure as well as in tapes and lubricants used for mechanical points such as on the antenna mechanism. The fourth group consists of propellant and nitrogen compounds from the thruster fuel and oxidizer.

Over the 6 years of the mission examined in this paper there have been numerous changes over time in the background pressure. These are correlated with spacecraft maneuvers. The instruments mounted on the spacecraft are fixed so to maintain sensor pointing at an object being analyzed the spacecraft must slew. This brings areas that may have previously been in deep cold conditions with adsorbed materials into direct sunlight which can heat these areas up and significantly increase outgassing. These increases are observed as spikes in the measured pressure after maneuvers are executed.

Modeling of the background is one of the most critical aspects for success of the mission.
The spacecraft is designed to measure the cometary atmosphere created by outgassing from the comet nucleus due to heating by the sun. To obtain a clean spectrum of the materials of which the cometary atmosphere is composed it’s necessary to understand the spacecraft’s inherent background atmosphere due to outgassing.

Initial modeling results don’t agree with the actual pressures determined by the COPS measurements. Proposed reasons for this discrepancy include uncertainties in the actual materials used in the spacecraft’s construction as one of the lubricants used has 24 different types with a possible range of mass loss values determined using ASTM E 595 standards; that material may degrade even faster in space under the influence of UV radiation and high-energy particle bombardment; and there have been some anomalies detected in helium pressurization tanks during maneuvers that could be caused by miniscule leaks.

The authors conclude by stating outgassing and contamination are underappreciated aspects of space conditions requiring test set-ups to better characterize the materials and the effects of the environment and certainly important to understand in missions such as this designed to study outgassing phenomena of celestial bodies.

