# Numerical simulation of the acoustical properties in rocket combustion chamber


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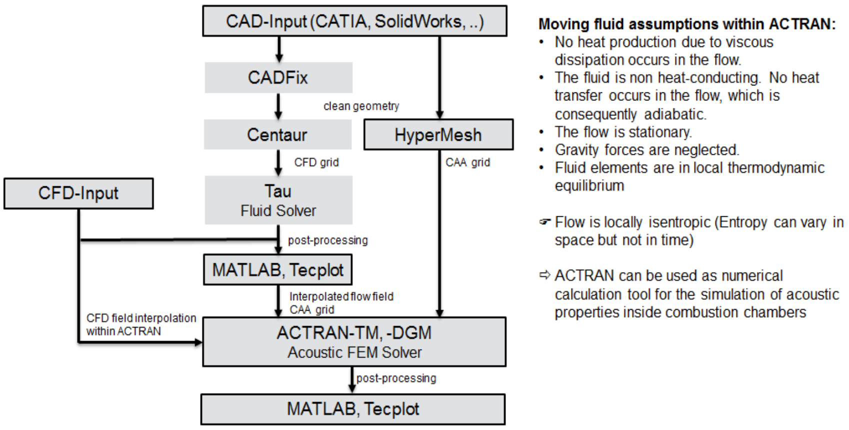
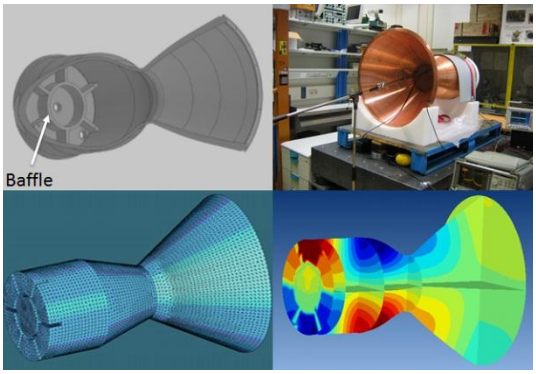
## Introduction



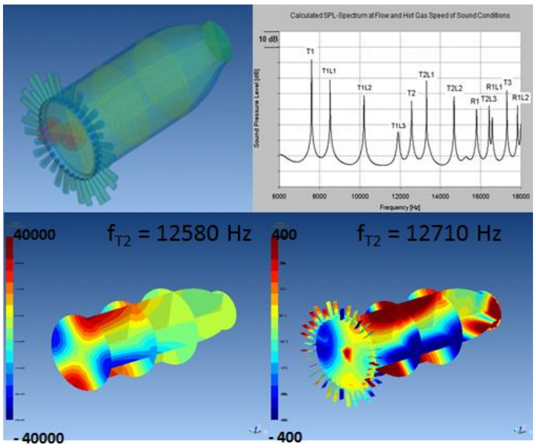

Issues, which should be answered by the preliminary numerical simulation regarding combustion chamber applications, can be summarized in the following topics: First estimation of the expected acoustic frequency spectrum and modal composition inside combustion chamber; Consideration of complex flow conditions and gas parameter gradients inside combustion chamber; Estimation of complex geometry variations on the acoustic spectral behaviour (baffles) and study and optimization of acoustic cavity tuning and design. These all points are necessary for optimal design of the combustion chamber under aspect of the acoustics behaviour and consequently essential for the combustion stability. At EADS Innovation Works these numerical simulations were performed by commercial acoustic finite element method solver ACTRAN™, which was included into the internal numerical tool chain. Some examples of the numerical acoustic calculations performed at EADS-IW are shown below.

## Estimation of complex geometry variations on the acoustic spectral behaviour of combustion chamber (Baffles)



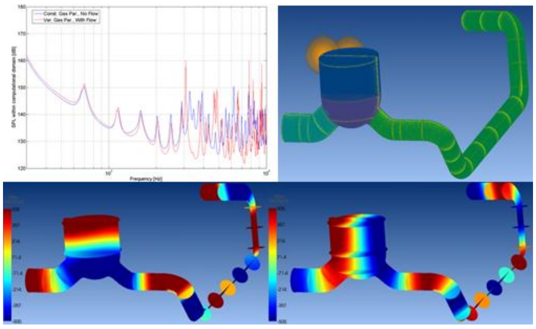

Different hub-baffle configurations with variations in baffle length and in number of radial baffle blades were tested by pure acoustic experiments and by numerical study. The numerical model could be successful validated by the experimental data, gathered without flow. The numerical model allowed the simulation of the various baffle geometries on the spectral characteristics of the resulting sound field inside the combustion chamber with and without simple non-rotational, axial flow. The experiments enabled the validation of the numerical model and made the determination of the acoustic damping by baffles with different number of radial blades possible.

## Cavity design at complex geometrical conditions for prevention of the combustion instabilities




For the selected combustion chamber a cavity has been designed. Hereby two main objectives have been studied: Effect of geometry variations of an annular gap between combustion chamber and cavities and design and necessary amount estimation of the cavities. The gap geometry variation parameters have been gap depth and gap width. The study was done numerically by using the ACTRAN™ code for pressure distribution calculations inside the combustion chamber including hot gas fluid conditions and a potential flow field. As a first result, the sound pressure spectrum of the untreated combustion chamber is given. The estimation of necessary amount of cavities has been done using available in-house codes based on MATLAB. The numerical model shows a drastic reduction of the modal sound pressure levels inside the combustion chamber if tuned cavities were included.

## Acoustic frequency spectrum estimation for coupled volumes under complex gas parameter



Using HyperMesh™ and ACTRAN™ a full 3D model of the gas generator geometry including fuel and oxidiser duct from the chamber to the positions of the turbines was build. For the flow field and the hot gas parameter the expected sound pressure spectra and spatial pressure distributions have been calculated. The boundary conditions at the duct terminations were built by taking into account the expected pressure drop due to the turbines. At the end the gas generator combustion chamber acoustics could reliably be characterized under consideration of hot gas parameter, flow and boundary condition as given.

## Conclusion

With the numerical and analytical tools already available at EADS-IW the expected combustion chamber acoustics can be estimated reliably. The effects of flow and varying gas parameters can be considered and complex geometries can be handled. Finally, the effects of de-tuning and damping devices can be studied (baffles and cavities design is possible). Simulated results compares very well to experimental data.