I. Publishable Summary

The main objective of the project is to improve the knowledge and techniques necessary for future space missions cryogenic propulsion, with emphasis on Low Thrust Cryogenic Propulsion (LTCP), with liquid oxygen and hydrogen or liquid methane as propellants.

Achieving this goal requires:

- To improve knowledge on LOX/methane combustion through research on injection, ignition, combustion, soot formation and engine cooling.
- To improve the embrittlement characterization of different materials in presence of hydrogen: by designing and operating a fatigue testing set up for characterization of materials performance in high-cycle fatigue regime, under different environments and for positive strain ratios. Also by theoretical analysis and modelling of embrittlement behaviour.
- To investigate the tribological behaviour of materials in oxygen for demanding thermodynamic cycles and develop an oxidation model. Design a tribometer for methane conditions.
- To improve the knowledge of the performance and constraints for the design of LTCP with heat accumulators: modelling of phase change accumulators and thermal cyclic testing of a water / ice heat accumulator.
- To design and test of a high speed - light weight cryogenic propellant electric pump, demonstrate the feasibility of a high performance small centrifugal pump.

During the first year, the technical progress was as follow:

- A reference set of parameter ranges was determined for the LOX-methane combustion work package.

  Thermodynamic and fluid mechanic properties for methane were established; global reduced kinetic models for low pressure ignition and combustion were established and have to be validated. Work is ongoing on global reduced kinetic models for soot formation.

  A combustion test campaign was performed on ONERA's cryogenic test bench Mascotte on a coaxial injection configuration with gaseous oxygen and methane, with CARS measurements. Data reduction is underway.

  Study of LOX/methane Liquid/Liquid injection: two configurations of injectors were selected, their design is underway.

  Oxygen/Methane Ignition Studies: a new injector was designed and manufactured. Tests were performed in order to evaluate the actual domain of ignition and stabilized flame. CFD simulation of ignition began.

  Methane film cooling: the design of a gas/gas injector head, of a segmented water cooled combustor, with instrumentation, was achieved.
- The design of the experimental setup for testing hydrogen embrittlement was achieved and the parts are now being manufactured.
- The choice of materials for compatibility and tribology study in Lox and methane cryogenic environments was performed according to both objectives of modelling tribological oxidation and meeting the identified operational needs. Associated test plans and test conditions were set, first test results made available.

  A bibliographic study for the study of oxidation models is underway, and the specifications for a methane installation for tribological testing were achieved.

- The heat accumulation concept and the characteristic features of the accumulators were defined. A series of new concepts for a Low Temperature Accumulator, was analysed. Two of them were chosen for numerical models validation by experimental results.

  A 2D stationary model of the straight tube heat accumulation device was set up and a parametric study performed.

- The conceptual design of the Propellant Electric Pump was achieved, the Preliminary Design Review held. The specifications for the design of the different parts of the pump were issued.

From this work, the next steps are:

- RANS and LES approach for the assessment of kinetic mechanism in LOX –methane combustion. Injection studies: manufacturing and testing (cold flow) of two types of injectors. Low pressure ignition tests, film cooling tests.
- The realization of the fatigue testing set up for hydrogen embrittlement.
- Tribology and compatibility tests in LOX.
- Test facility modification and heat accumulator bed realization.
- Design of each module of the Propellant Electric Pump, detailed Design Revue.