IMPROVE

Executive summary report

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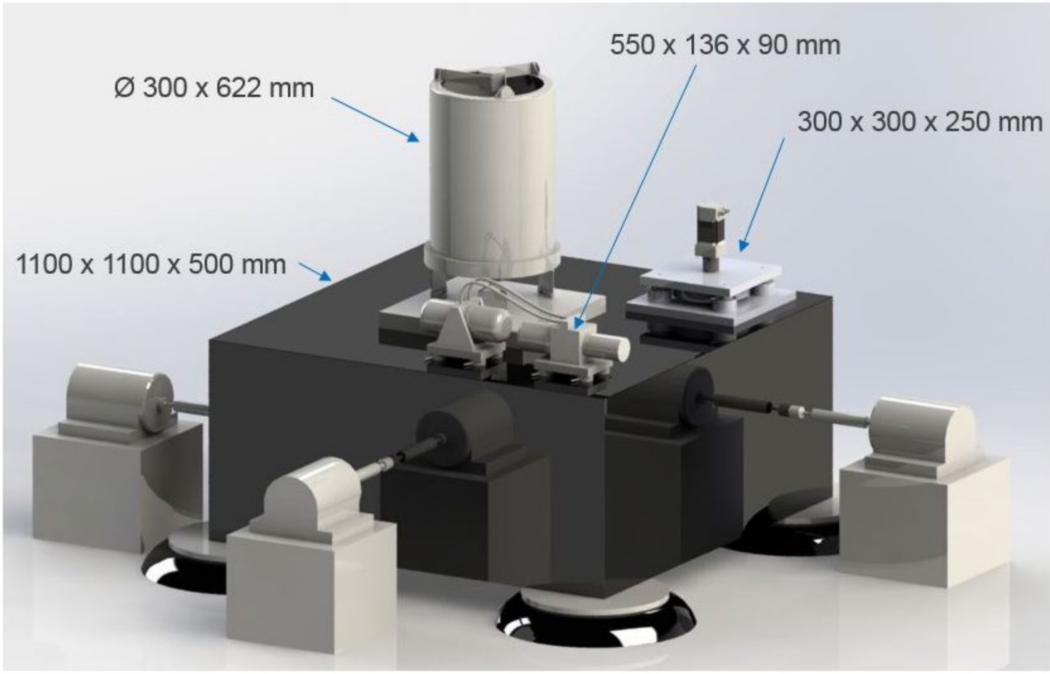

Content and scope

IMPROVE, IMPROVEment of Microvibration Prediction and Verification Methods, aimed at supporting the analysis of key micro-vibration sources and their effect on sensitive payloads

At the end of the activity, IMPROVE delivered:

- a stepper model microvibration source model, including its gearbox and a flexible load;
- a cryo-cooler microvibration source model;
- S/C pointing performances prediction model;
- emissivity and susceptibility simplified test methods.

This document is the Executive Summary Report.

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Applicable documents

AD-01 IMPRROVE proposal (Proposal_241-ES.2113_IMPROVEpdf)

AD-02 Appendix 1 to ESA AAO/1-9477/18/NL/BJ, Statement of Work, 1r0, 12.06.2018

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1 Introduction

Space missions, especially science and Earth Observation, have more and more stringent micro vibration requirements. Reaction Wheels, Cryocoolers, Stepper Motors, are among the main sources of micro vibration aboard the satellite.

Stepper motors are widely employed for motorization in space applications, including deployment, orientation, and accurate pointing positioning mechanisms (e.g., SADM, APM). These motors can either be used in direct drive mechanisms or associated with a gearbox. Their advantages include precise positioning and repeatability and the ability to be accurately controlled in an open-loop system.

Large Pulse Tube Coolers (LPTC) for Infrared focal planes are used in several missions such as the MeteoSat Third Generation (MTG) program. These coolers are split machines with a compressor generating the pressure variations needed for the thermodynamic cycle and a cold finger where the heat pumping takes place. The cold finger has no moving parts but generates perturbing forces due to lateral gas injection and inner pressure gradients.

2 Stepper motor modelling

1.1 Model architecture

The model architecture of the stepper motor assembly is displayed in Figure 2-1. The input is the stepping rate, and the output the exported forces and torques.

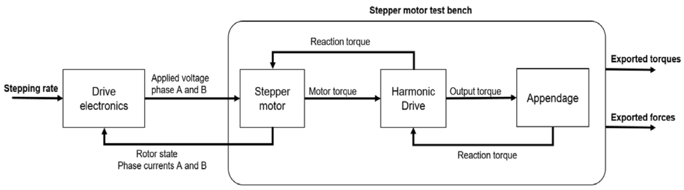

Figure 2-1: stepper motor model architecture

IMPROVE based on the Henke model, established on the electro-mechanical equations for the motor (Phytron ZSS 57.500.1,2-I, equipped with the harmonic drive GPL 52 100:1).

The complete stepper motor model is displayed in Figure 2-2. The motor model is composed of an electromagnetic part and a mechanical part.

The electromagnetic part was implemented in Simulink 2019b with a Level-2 M file S-Function. This part integrates the motor current and generates the electromagnetic torque (including the detent torque). The model considers 4 spectral components of the detent torque but can be extended to higher harmonics if necessary. The mechanical part is implemented in Simulink by integrating Simscape Multibody 3D components. It consists of a shaft (1 DOF rotational connector) connected to an inertia. The shaft takes the input torque and computes the mechanical angle between the Base frame (B) and the Follower frame (F). A purely Simulink based model has also been developed, results are similar.

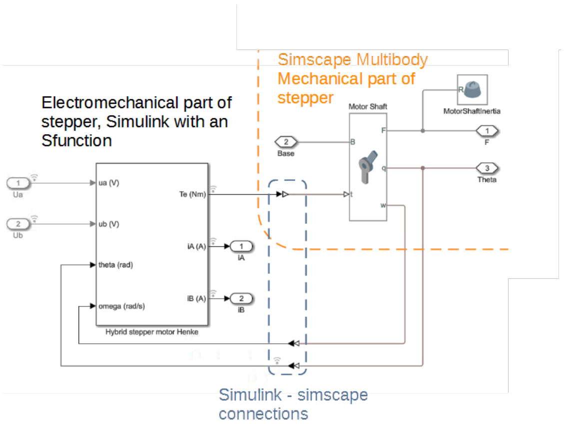

Figure 2-2: hybrid stepper motor model

The model was completed by addition of a harmonic drive and electronics model

A dedicated successful validation and correlation campaign was performed in CSEM.

3 Cryocooler modelling

3.1 Model development

Cryogenic coolers of pulse tube type are frequently used in the space industry as they have reached for years a maturity level in term of performances, compactness and reliability that make them very attractive on one side and on the other side they can be split coolers with a compressor separated from the cold finger as shown in Figure 3-1.

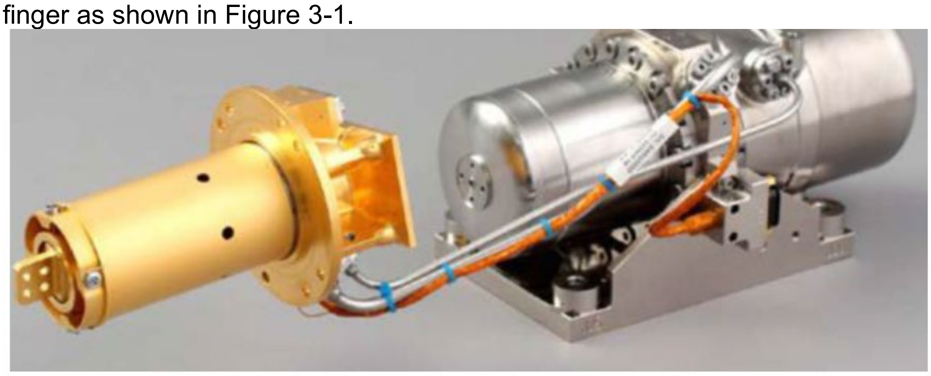

Figure 3-1:Large Pulse Tube Cooler developed under CEA license by Thales Cryogenics Bv and Air Liquide Advanced Technologies)

Several functions were modelled in Matlab / Simulink.
- Electrical circuit of the linear motors
- Magnetic circuit of the linear motors
- Flexure bearing for the piston guidance
- Dynamic of the compressor and cold finger
- Thermodynamic of the working gas

Model was used to perform various simulations

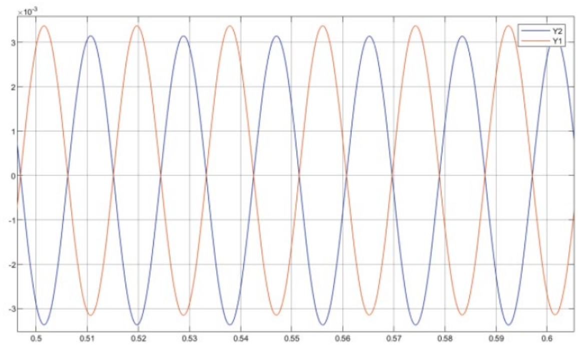

Figure 3-2: Cryocooler piston displacement

A dedicated correlation campaign took place leading to a good correlation

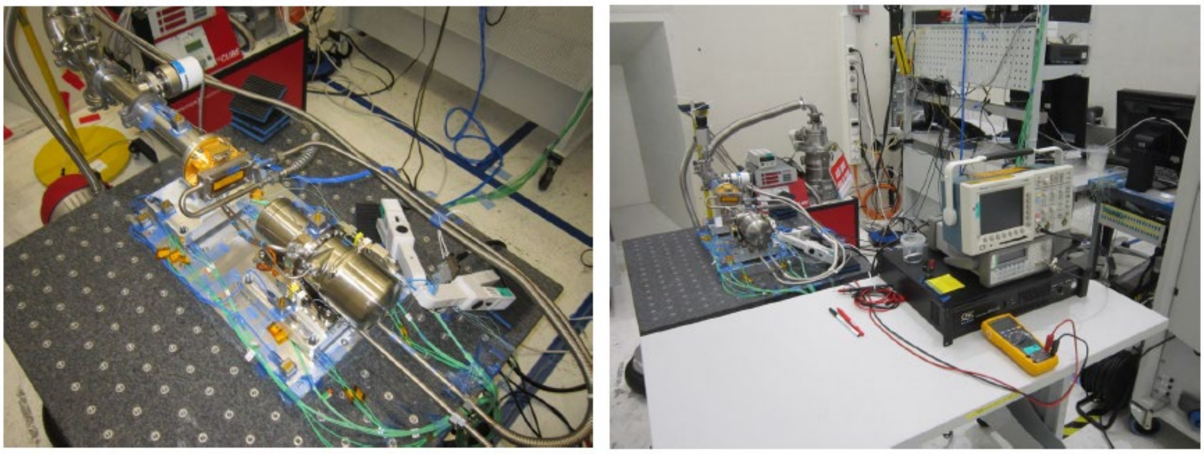

Figure 3-3: Cryocooler test setup

4 Prediction and test methods

4.1 Susceptibility and emissivity techniques

In many cases, a single sine sweep excitation test is enough to assess the susceptibility of the equipment, but specific cases exist where additional parameters shall be considered.

To measure the exported forces, rigid dynamometer in conjunction with passive or actively decoupled platform can be used.

4.2 Time domain

To predict the impact of exported micro vibrations on a payload, time domain approach developed in IMPROVE relies on:

- FEM model reduction (Craig Bampton)
- Completion of the reduced model with adequate damping
- Transforming the model into state space form

5 Summation methods

5.1 Time domain

To predict the impact of exported micro vibrations on a payload, time domain approach developed in IMPROVE relies on:

- FEM model reduction (Craig Bampton)
- Completion of the reduced model with adequate damping
- Transforming the model into state space form
- Source combination @ state space input

5.2 Frequency domain

IMPROVE investigated the potential of the Hoeffding estimator.

It appears that most spacecrafts have a large enough number of on-board disturbing sources to provide a valid configuration for the use of the Hoeffding estimator. This estimator is recommended to replace the linear sum or the quadratic one.

6 Test results

6.1 Test setup

The measurements are performed in a free-free configuration to mimic the structural behavior in flight configuration. A telescope (DSS) is mounted on an Iridium case that is suspended on four hoisting lines as depicted in Figure 6-1.

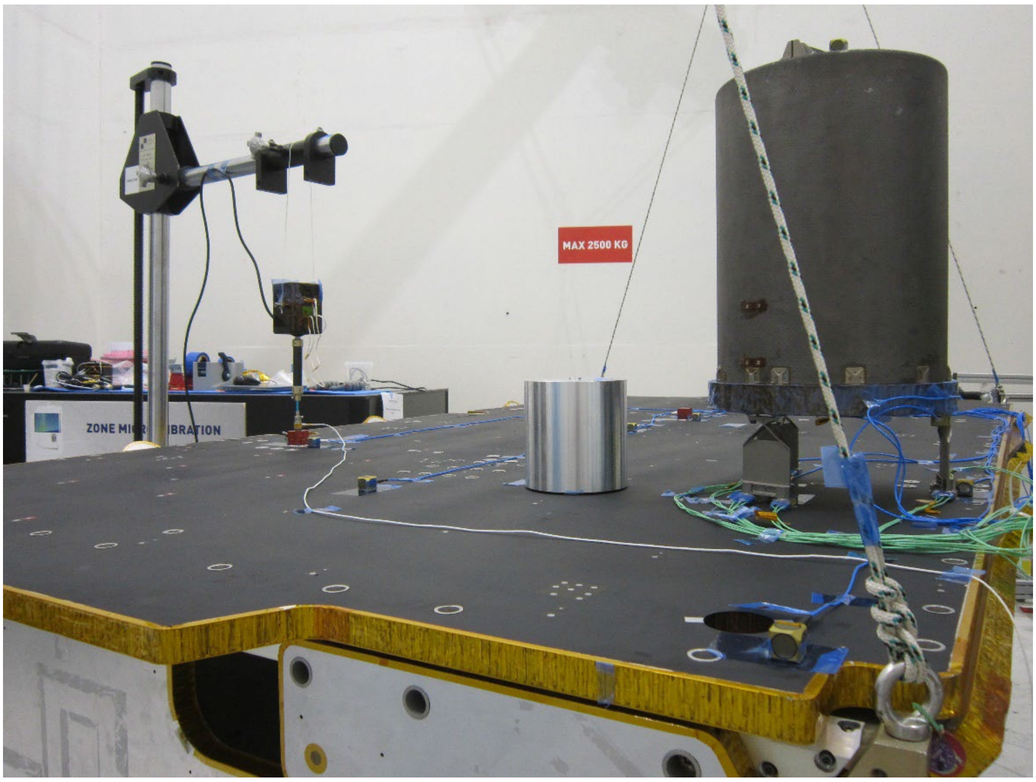

Figure 6-1: Iridium case suspended with mounted DSS

7 Conclusion

Improve investigated the full micro-vibration chain, from source modelling, model reduction, summation methods as well as validation with a comprehensive experiment.

Methodologies were validated, showing the necessity of having a correlated FEM models.