4th Round Table on Micro/Nano Technologies for Space, Estec

# Scanning Micromechanical Mirror System (SMMS)

**(ESA contract 15390/01/NL/CK, GSTP-3 program)**

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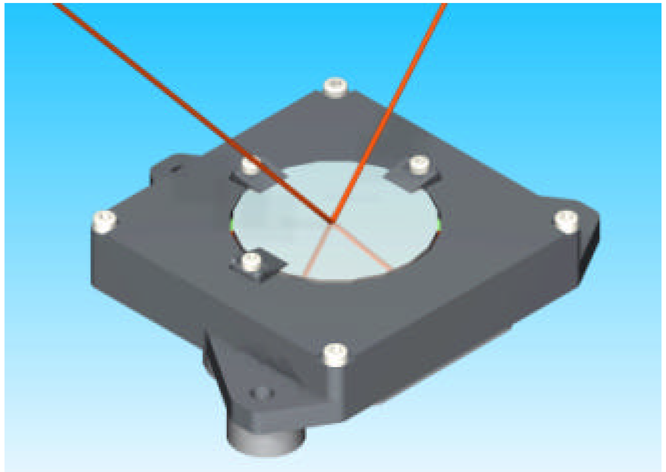
# SMMS

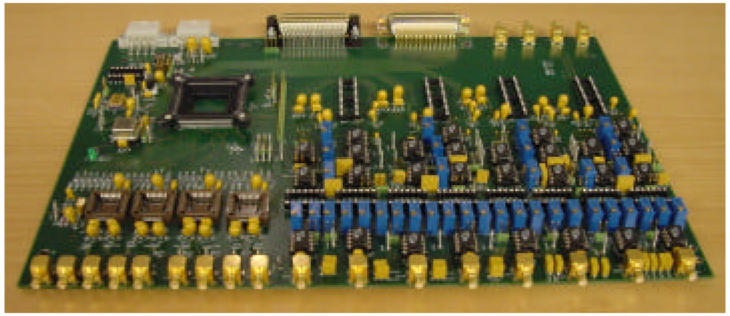
Motivation for development :

- Development and manufacturing of a fine pointing mirror equipment
  - A fine pointing mirror module for optical space equipment, movement ± 3 mrad.
  - 2-axis tilting function, movement control up to 1000 Hz frequency
  - New MEMS technology based core component available from ESA TRP-phase study, the actuator
  - SMMS equipment to consist of two parts : MMP (Micro Mirror Package) and MCE (Mirror Control Electronics)

- Prequalification activity

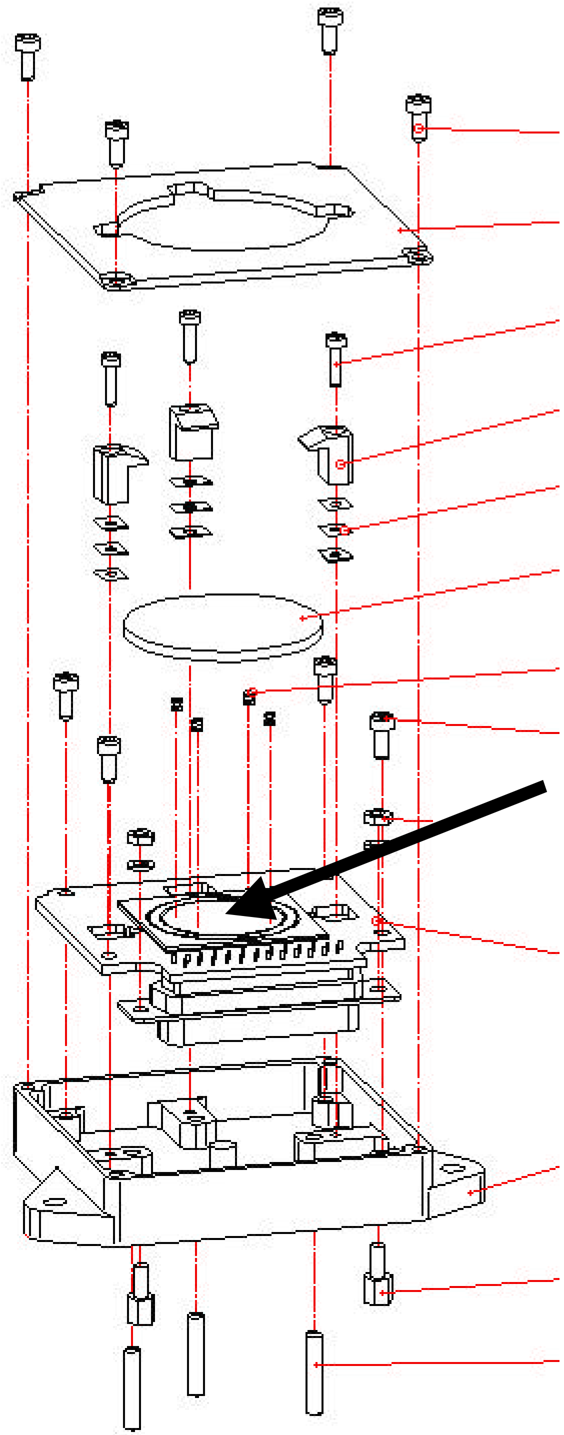


MMP



MCE

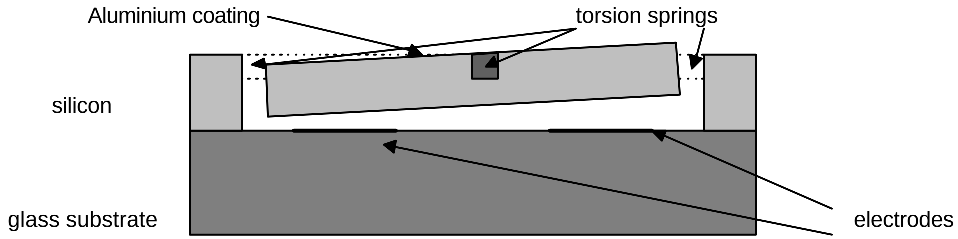
# MMP Structure

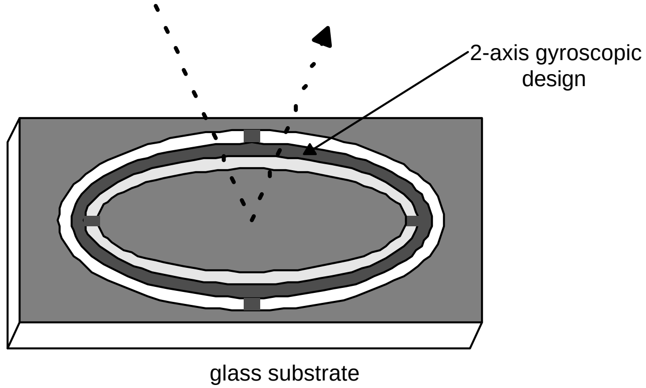


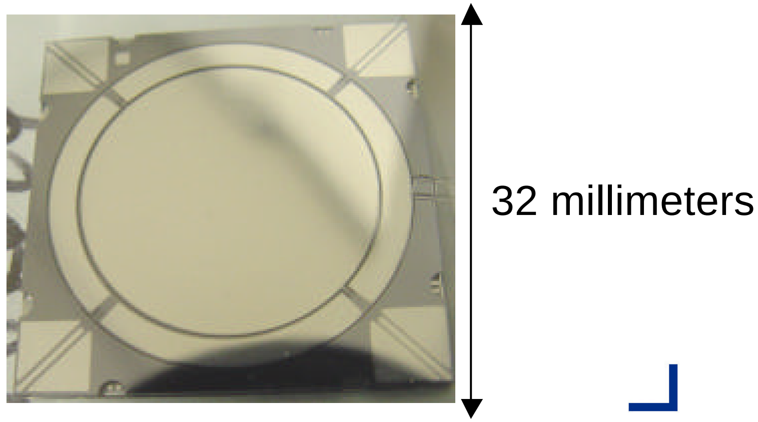
# MEMS technology

## Core component : MEMS actuator

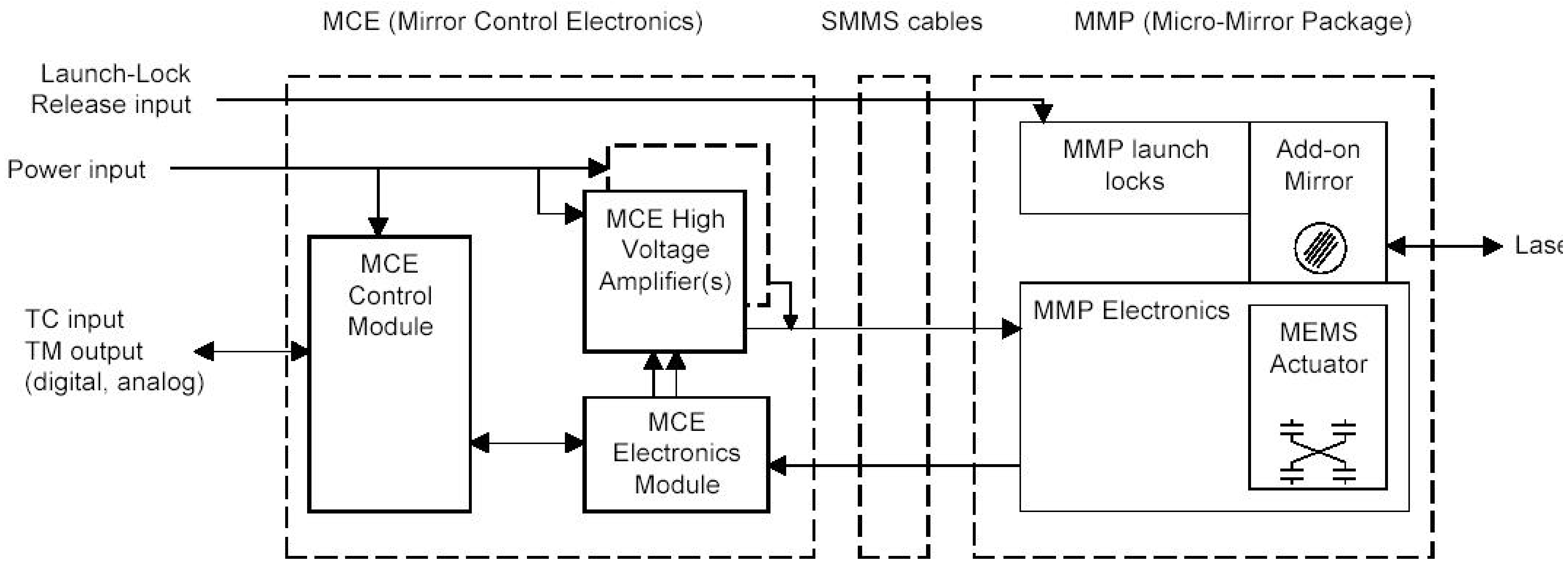
- Use of electrostatic force for torque and movement generation
  - Relatively high control voltage required (600 - 800 volts)
- Capacitive position measurement principle.
  - High sensitivity required in the capacitance measurement ($10^{-16}$ F)
- Torsional hinge structure (gyroscopic hinge)
- MEMS Actuator composed of Silicon top part and Pyrex glass substrate
  - Silicon part etched to the desired shape
  - Pyrex coated with metallic electrode patterns
  - Silicon and Pyrex attached by anodic bonding procedure
  - Silicon coated with aluminium



# SMMS overall block diagram



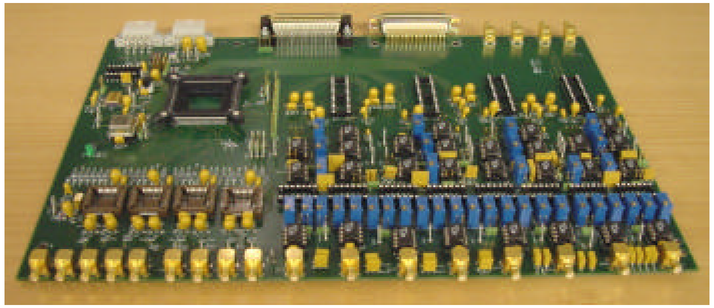
# MCE : Bread Board

- MCE equipment are of Bread-board level In this study
  - Electronic components are of space types
  - ERC32 based control computer
  - Use FPGA-component in logical functions

  - Commercial level High Voltage amplifiers

MCE Control Module :

- an ERC32 based computer



MCE Electronics Module

- Capacitance measurement circuits

- Logical functions

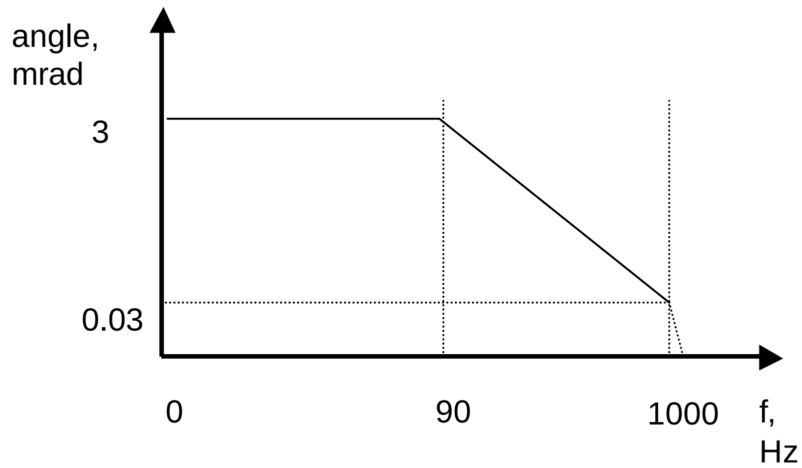
MCE HV-amplifiers

# SMMS System Requirements

Patria

- Mechanical Angular Range : ± 3 mrad (0.17 degrees), both axis.
  - Note : Optical beam deflection ± 6mrad
  - Positioning accuracy ± 20 μrad
- Control Frequency : 0 - 1000 Hz
  - defined as the response of angular acceleration to system control signal
  - at 1000 Hz ± 26 μrad movement is obtained
- Mirror surface flatness better than 20 nm (rms)
  - Design for λ/50 at 1064 nm (YAG wavelength)
  - To be maintained between -40 - +50 C°
  - Reflectivity better than 0.99 at 1064 nm
  - Mirror diameter more than 23 mm
- Vibrational load capacity : 50 g (rms)
- Power consumption 1 - 4 watts
- Low mass : MMP is 95 grams

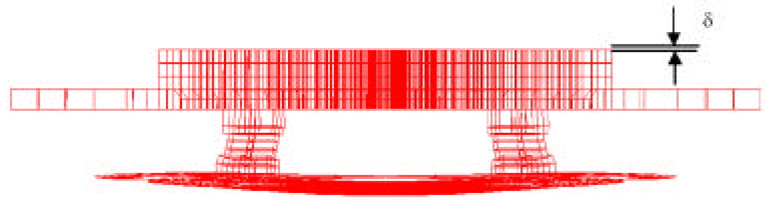
- Realistic requirements for a fine pointing module in a Free Space Laser Link system (SILEX type)




Angular amplitude vs. operation frequency

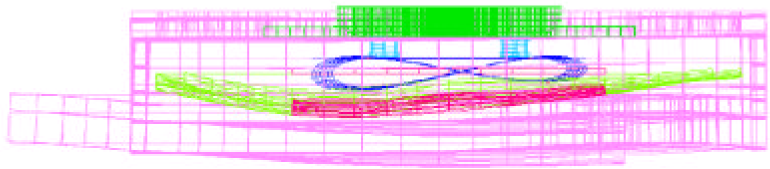
# Performance estimates

- Mirror surface flatness
  - SiC (Silicon Carbide) material selected for thermal and mechanical properties
  - Analysis of thermal deformations
  - Analysis of dynamic deformations



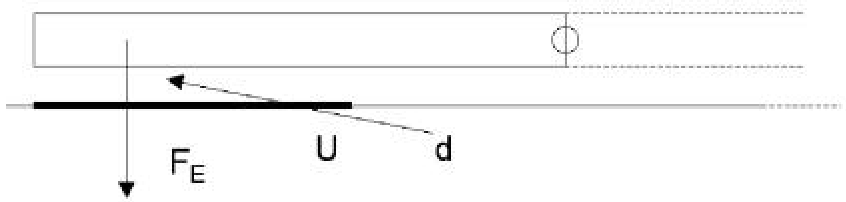

Add-on mirror thermal deformation analysis

- Control frequency performance and angular stability
  - The defined angular acceleration is obtained by high voltage actuation (600 - 800 volts)
  - A dedicated control algorithm is required to stabilize the mirror position
  - Positional instability of the MEMS actuator due to electrostatic attraction force behaviour



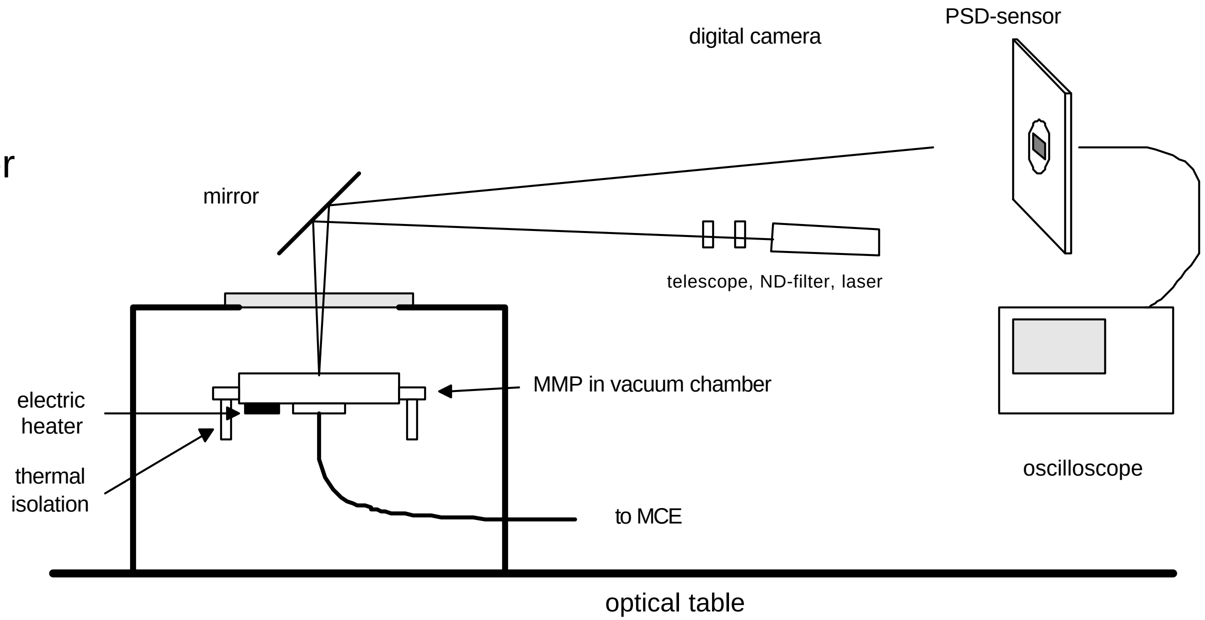
MMP vibrational modes, f>1400 Hz

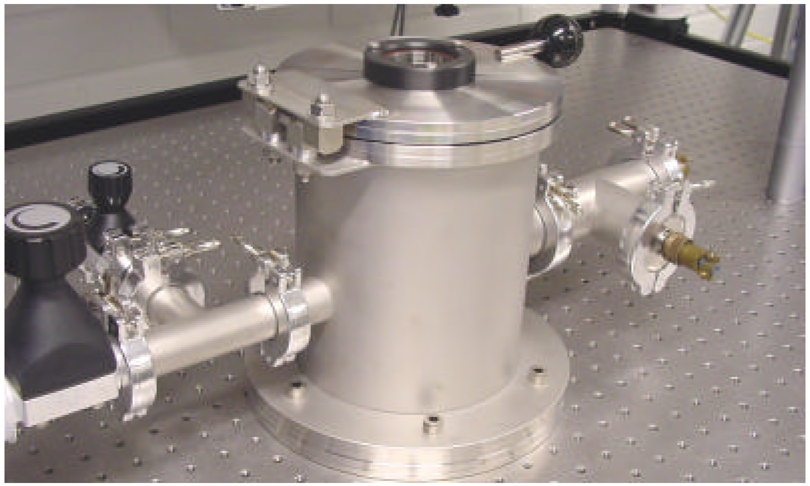
$$F_E \cong U^2 / d^2$$



# SMMS testing

- Performance tests
  - A dedicated vacuum chamber used
  - Control frequency, angular stability
  - Mirror optical reflection
- MMP vibration&shock tests
- MMP thermal cycling
  - Remeasurements of performance and optical axis orientation
- Mirror flatness measurement
  - Interferometer
  - Performed later for a high quality mirror



# Project status

- Test phase started
  - All the necessary equipment (SMMS and test) available
- SMMS equipment developed in two phases
  - Present design and equipment  with low-quality mirror and manually operated launch locks as shown in this presentation
  - Next near-term activity planned to upgrade to a high quality mirror and electrically operated launch locks -> upgrade of tests also
- Preliminary Conclusions
  - A MEMS based equipment developed in compliancy with main performance requirements
  - Critical tests performed soon (performance, vibration)
  - A lot of lessons learned what the application of a MEMS-component requires
  - Commercial potential still to be identified (space products, spin-off products...)

# SMMS contacts

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