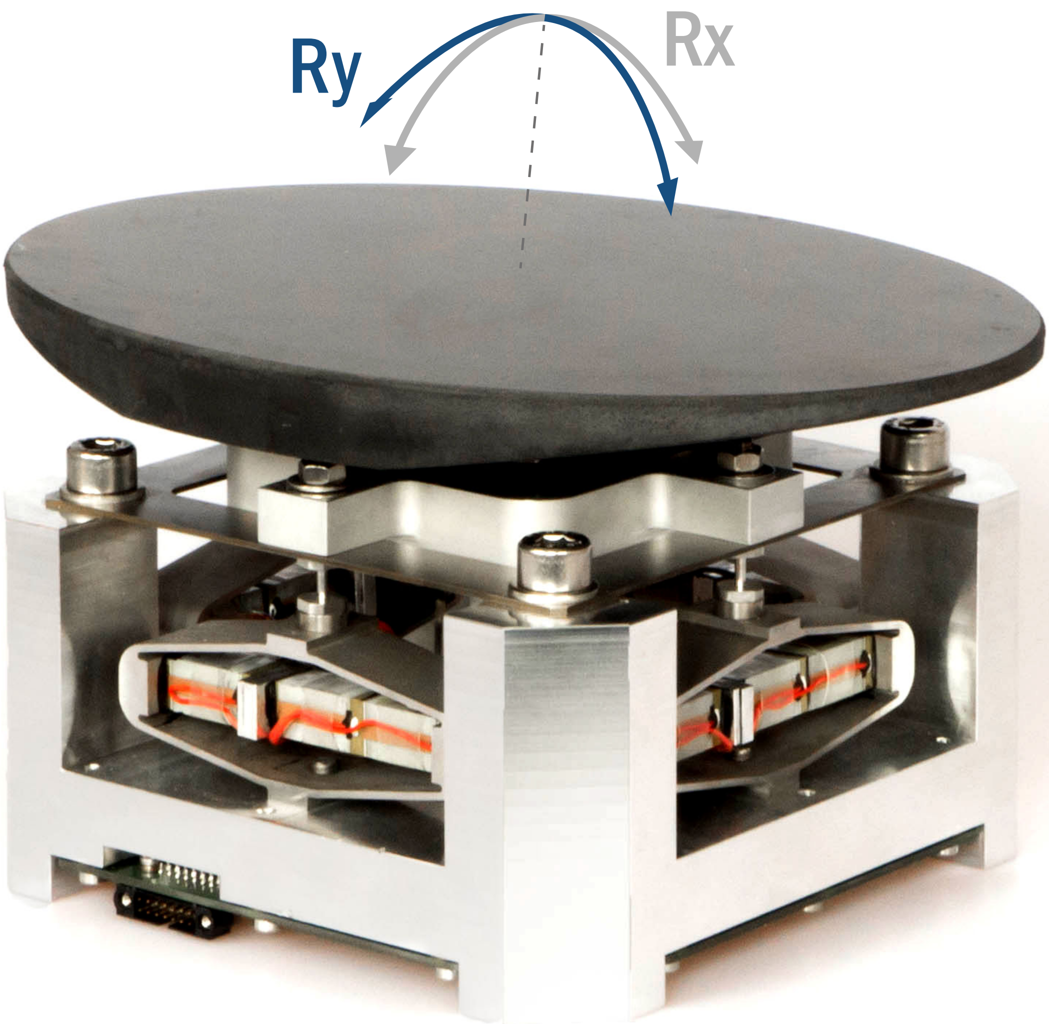
FINE & FAST STEERING MIRRORS

COMPACT - DYNAMIC - PRECISE



CEDRAT TECHNOLOGIES
Innovation in Mechatronics

TABLE OF CONTENT

(1) Peak-to-peak value. Mechanical angular stroke.

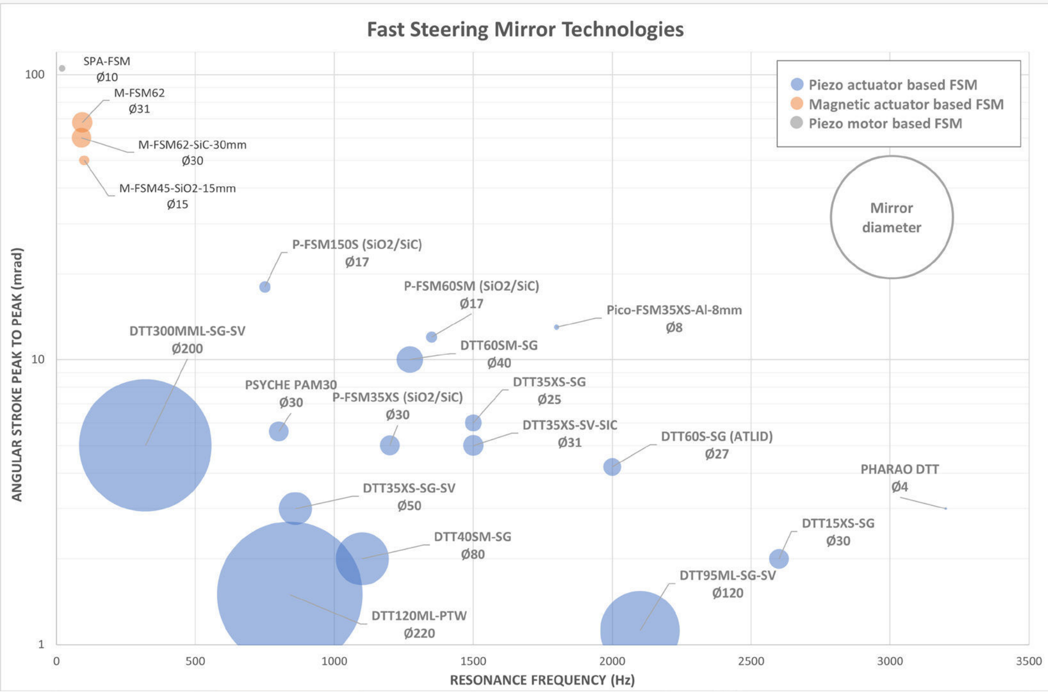
HERITAGE IN AEROSPACE & DEFENCE

CEDRAT TECHNOLOGIES (CTEC) piezo mechanisms and their associated electronics are widely used in Air, Space & Defence (ASD) applications. They can be found in optical instruments, cameras, telescopes and electro optic systems embedded on airplanes, helicopters, unmanned aerial vehicles (UAV), satellites, spacecrafts, etc... Their excellent dynamic performance, reliability and compactness make them ideal for the following mechatronic functions & applications:

- Image resolution enhancement (micro-scanning, pixel shift, dithering)
- Image & line of sight stabilisation
- Field of view increase
- Fillet compensation
- Fine pointing ahead
- Tracking

The DTT is the most common mechanism (steering platform) that constitutes a fast steering mirror (FSM), it means Double Tip Tilt i.e. tilt along two perpendicular axis. In the graph below, we show a list of FSM stroke vs resonance frequency vs mirror size.

In the previous table you will see a recap of the products realizing the steering function.



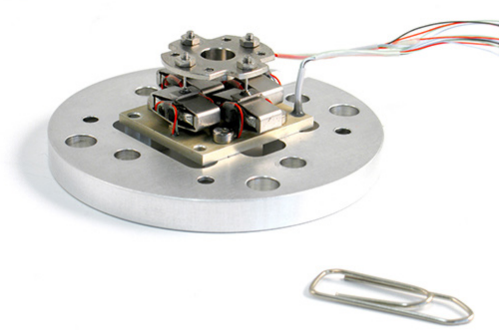


Fig. 1 : DTT35XS-space

1. PHARAO DOUBLE TIP TILT (DTT)

1.1. DESCRIPTION

The Double Tip Tilt mechanism DTT35 XS-space delivered to SODERN (AIRBUS) is a very light piezoelectric mechanism (25 grams) designed according to space rules for the PHARAO ACES mission. The mechanism uses Strain Gauges (SG) as positioning sensor and allows to reach a 1:4000 stability (1 µrad rms). It controls the incidence of a laser beam flux towards an optical fiber

1.2. APPLICATION

Space, fine pointing

1.3. ENVIRONMENTAL CONDITIONS

The DTT35 XS-space has followed a space qualification program according to ECSS standards (European Space Agency Standards)

- **Operating temperature in vacuum:** -20°C / +75°C
- **Random vibration:** 41 Grms
- **Lifetime:** 2 e8 cycles full stroke

PARAMETER	UNIT	PHARAO DOUBLE TIP TILT (DTT)
Max. angular stroke	mrad	3
Dimensions	mm	ø 30×22
Total mass	g	25
Mirror mass	g	1
Mirror dimensions	mm	ø 40 x 5
Loaded resonance frequency	Hz	3200
Position stability	µrad	<1
Capacitance per axis	µF	0.5

Table a : Performances of Pharao double tip tilt (DTT)

2. DTT60S-SG FOR ATLID

2.1. DESCRIPTION

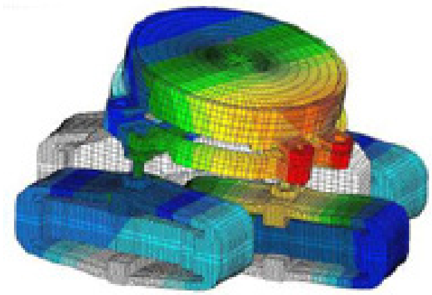


Fig. 2 : BSM CAD model

Thanks to the heritage from the PHARAO DTT, CTEC has developed the ATLID Beam Steering Mechanism (BSM) for SODERN (see publication). ATLID is a Lidar instrument for the EarthCARE mission. The BSM is a Tip-Tilt piezo mechanism based on 4 APAs including Strain Gauges. The requirements were particularly severe regarding the long term stability and the cleanliness. CTEC has successfully delivered the Flight Models in 2015

The BSA (Beam Steering Assembly), included in the emission path, aims at deviating a pulsed high energy UV laser beam to compensate the pointing misalignment between the emission and reception paths of ATLID. It requires a very high stability and high resolution

2.2. APPLICATION

Space

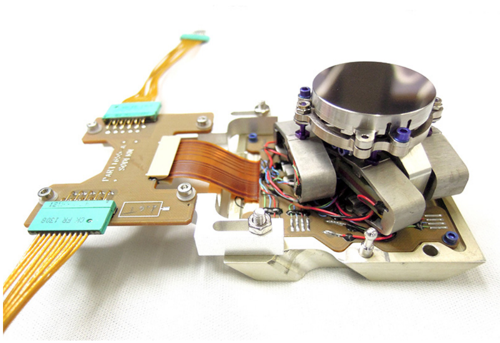


Fig. 3 : Complete BSM mechanism

2.3. ENVIRONMENTAL CONDITIONS

- Non magnetic
- **Shock level:** 100 G
- **Random Vibration level:** 15.5 Grms
- **Quasi Static:** 26 g
- **Cleanliness:**
    - **Particular:** 50 ppm
    - **Molecular:** 5.10 e-8 g/cm²

PARAMETER	UNIT	DTT60S-SG FOR ATLID
Max. angular stroke Rx	mrad	4.2
Max. angular stroke Ry	mrad	3
Dimensions	mm	63×62×40
Total mass	g	130
Mirror mass	g	2.9
Mirror dimensions	mm	ø 27×5
Loaded resonance frequency	Hz	2000
Resolution	nrad	400
Repeatability	µrad	70
Capacitance per axis	µF	3

Table b : Performances of DTT60S-SG for ATLID

3. POINT AHEAD MECHANISM (PAM30)

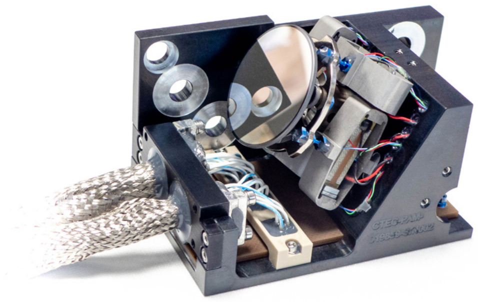


Fig. 4 : PAM30

3.1. DESCRIPTION

The Point Ahead Mechanism (PAM30) consists in a SiC mirror mounted on a 2-rotation axis (“Tip Tilt”), small range and pointing mechanism with Strain Gages positioning sensors, mounted on a bracket including a thermal sensor.

3.2. APPLICATION

The PAM30 aims at accurately pointing the optical downlink signal (communication laser beam) towards Earth position from the Psyche Asteroid beyond Mars Planet.

The Psyche mission, led by NASA JPL, will be the opportunity to test the first deep-space optical communication made from a satellite to earth.

3.3. ENVIRONMENTAL CONDITIONS

- **Operating temperature:** -40/+65°C
- **Vacuum compatible**
- **Random vibration:** up to 42 Grms
- **Lifetime:** > 7 years

PARAMETER	UNIT	PAM30
Max. angular stroke	mrad	8
Total mass	g	< 500
Mirror dimensions	mm	ø 32
Loaded resonance frequency	Hz	> 1200
Reflective Wavefront Error PV	nm	40

Table c : Performances of PAM30

4. DTT15XS-SG

4.1. DESCRIPTION

Compact FSM with its controller box for embedded electro optic systems

Fig. 7 : DTT15XS-SG

4.2. APPLICATION

Image stabilisation and micro-scan combined in a single unit (5th and 6th axis of gyro stabilised platform).

Fig. 5 : Batch of DTT15XS-SG with mirror

4.3. ENVIRONMENTAL CONDITIONS

- **Operating temperature:** -40°C/+70°C
- **Storage temperature:** -55°C/+85°C
- **High altitude operation:** 55 000 ft
- **High altitude storage:** 70 000 ft
- **Half sine Shock level :** >20 G
- **Vibration level (CBO):** 0.025 g^2/Hz up to 1 kHz

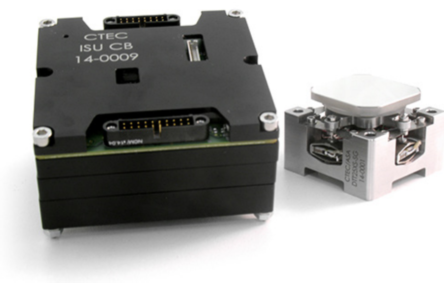


Fig. 6 : DTT15XS-SG with CCBu20 controller

PARAMETER	UNIT	DTT15XS-SG
Max. angular stroke	mrad	2
Dimensions	mm	40×40×24
Total mass	g	< 110
Mirror mass	g	10
Mirror dimensions	mm	30×30×4.85
Loaded resonance frequency	Hz	2600
Resolution	nrad	50
Settling time within 5%	ms	1
Position stability	µrad	<25
Capacitance per axis	µF	0.6
Power consumption with CCBu20 50 Hz @ +/- 700 µrad	W	9
Power consumption with CCBu20 480 Hz @ +/- 200 µrad	W	13.5
Controller	Driven by custom embedded CTEC electronic and controller board call CCBu20-PROX	
Embedded electronics board	SG conditioning, EEPROM memory, temperature monitoring and compensation	

Table d : Performances of DTT15XS-SG

5. DTT35XS-SG-SV

Fig. 8 : DTT35XS-SG-SV with CCBu20 electronics

5.1. DESCRIPTION

FSM for 50 mm diameter mirror with CCBu20 controller box

5.2. APPLICATION

Line of sight stabilisation

5.3. ENVIRONMENTAL CONDITIONS

- **Operating temperature range:** -40°C to +70°C
- **Shocks :** 30 G

PARAMETER	UNIT	DTT35XS-SG-SV
Max. angular stroke	mrad	3
Dimensions	mm	ø 48×27
Total mass	g	164
Mirror mass	g	25
Mirror dimensions	mm	ø 50×6
Loaded resonance frequency	Hz	860
Resolution	µrad	< 1
Settling time within 5%	ms	<2
Linearity	%	0.2
Control bandwidth	Hz	200
Capacitance per axis	µF	0.5
Controller	CTEC standard CCBu20	
Embedded electronics board	SG conditioning, EEPROM memory, temperature monitoring and compensation	

Table e : Performances of DTT35XS-SG-SV

6. DTT35XS-SV-SIC

6.1. DESCRIPTION

FSM for 31 mm diameter mirror with CCBu20 controller box

6.2. APPLICATION

Line of sight stabilisation, Laser Pointing Ahead

This version of DTT35XS is especially designed for vacuum space application

Fig. 9 : DTT35XS-SV-SiC

6.3. ENVIRONMENTAL CONDITIONS

- **Operating temperature range:** -40 °C to +70 °C
- **Shocks :** 30 G
- **Vacuum compatible**

PARAMETER	UNIT	DTT35XS-SV-SIC
Max. angular stroke	mrad	5
Dimensions	mm	ø 45×22
Total mass	g	65
Mirror mass	g	5
Mirror dimensions	mm	ø 31×6
Loaded resonance frequency	Hz	2400
Resolution	µrad	< 1
Settling time within 5%	ms	5 at full stroke
Linearity	%	0.2
Control bandwidth	Hz	>600
Capacitance per axis	µF	0.5
Controller	CTEC standard CCBu20	

Table f : Performances of DTT35XS-SV-SiC

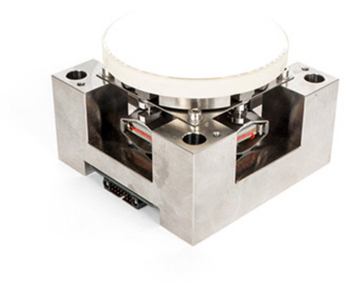


Fig. 10 : DTT40SM-SG

7. DTT40SM-SG

7.1. DESCRIPTION

FSM for 80 mm diameter mirror

7.2. APPLICATION

High power laser, atmospheric disturbance compensation

7.3. ENVIRONMENTAL CONDITIONS

- CTEC commits on mirror flatness in operations
- **Operation temperature:** -10/+50°C
- **Storage temperature:** -20/+70°C
- **Vibrations:** random 4 Grms up to 500 Hz
- **Shocks:** 20 G/11 ms half sine

PARAMETER	UNIT	DTT40SM-SG
Max. angular stroke	mrad	2
Dimensions	mm	110×110×63
Total mass	g	1600
Mirror mass	g	100
Mirror dimensions	mm	ø80×8
Loaded resonance frequency	Hz	1100
Settling time within 5%	ms	2.6
Accuracy	µrad	<1
Linearity	%	<0.25
Rising time 90%	µs	780
Capacitance per axis	µF	3
	INVAR components to reduce the mechanism CTE and mismatch with the optical component	

Table g : Performances of DTT40SM-SG

8. DTT60SM-SG

8.1. DESCRIPTION

The DTT60SM-SG is a piezo Tip Tilt Platform for Fast Steering Mirror (FSM) for electro-optics systems

Fig. 11 : DTT60SM-SG

8.2. APPLICATION

Line of sight stabilisation inside electro-optic systems

8.3. ENVIRONMENTAL CONDITIONS

- **Operation temperature:** --40°C/+70°C

Fig. 12 : Rack RK42F3U

PARAMETER	UNIT	DTT60SM-SG
Max. angular stroke	mrad	10
Dimensions	mm	ø 65x40
Total mass	g	310
Mirror mass	g	16
Mirror dimensions	mm	ø 40x5
Unloaded resonance frequency	Hz	1746
Loaded resonance frequency (Blocked- free with 26mm x 6mm BK7 mirror)	Hz	1 272
Loaded resonance frequency (Blocked- free with 40mm x 5mm BK7 mirror)	Hz	806
Capacitance per axis	µF	3
Resolution	µrad	1
Settling time	ms	2
Controller	LA75B amplifier into a desktop rack RK42F-3U	

Table h : Performances of DTT60SM-SG

9. DTT10M-SG-SV

Fig. 13 : DTT10M-SG-SV and electronic rack

9.1. DESCRIPTION

FSM for 50 mm diameter mirror with its controller rack

9.2. APPLICATION

High power Laser, atmospheric disturbance compensation

9.3. ENVIRONMENTAL CONDITIONS

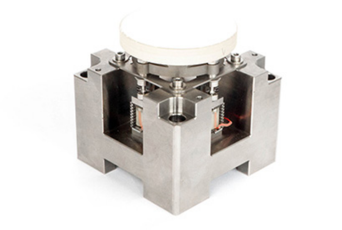


Fig. 14 : DTT10M-SG-SV

- CTEC commits on mirror flatness in operations
- **Operation temperature:** -10°C/+50°C
- **Storage temperature:** -20°C/+70°C
- **Vibrations:** Random 4 Grms up to 500 Hz
- **Shock:** Half Sine 20 G 11 ms

PARAMETER	UNIT	DTT10M-SG-SV
Max. angular stroke	mrad	0.5
Dimensions	mm	65×65×65
Total mass	g	860
Mirror mass	g	30.25
Mirror dimensions	mm	ø50×7
Mirror flatness		L/10 (632 nm) over CA 90 %
Loaded resonance frequency	Hz	5100
Settling time within 5%	ms	0.7
Accuracy	µrad	<1
Linearity	%	<0.25
Control bandwidth	Hz	1000
Capacitance per axis	µF	1
	INVAR material to reduce the mechanism CTE and mismatch with the optical components	

Table i : Performances of DTT10M-SG-SV

10. DTT95ML-SG-SV

10.1. DESCRIPTION

FSM with 120 mm diameter SiC mirror

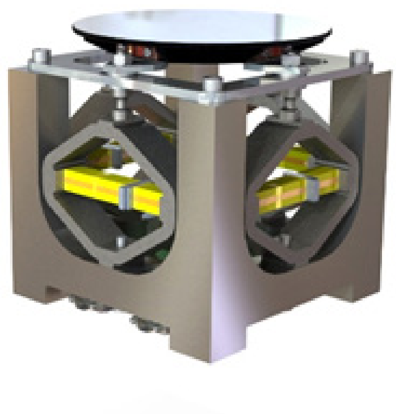


Fig. 15 : CAD view of DTT95ML-SG-SV

10.2. APPLICATION

Space, point-ahead mechanism for infrared telescope

10.3. ENVIRONMENTAL CONDITIONS

- SRS 800 G
- Random 8 Grms

PARAMETER	UNIT	DTT95ML-SG-SV
Max. angular stroke	mrad	1.12
Dimensions	mm	127×127×128
Mirror dimensions	mm	>130
Loaded resonance frequency	Hz	2100
Control bandwidth	Hz	700
Capacitance per axis	µF	40
Embedded electronics board	Embedded electronics board to secure the wires	
	Driven with 0-80V reduced voltage	

Table j : Performances of DTT95ML-SG-SV

11. DTT120ML-PTW FOR MEFISTO

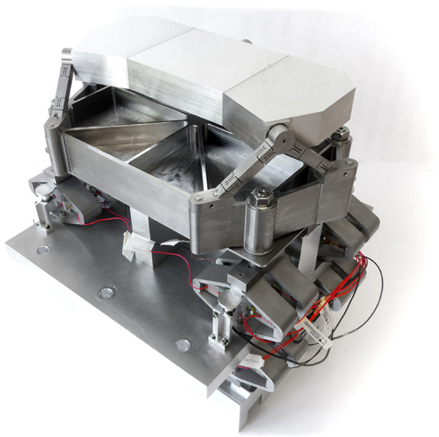


Fig. 16 : View of MEFISTO mechanism

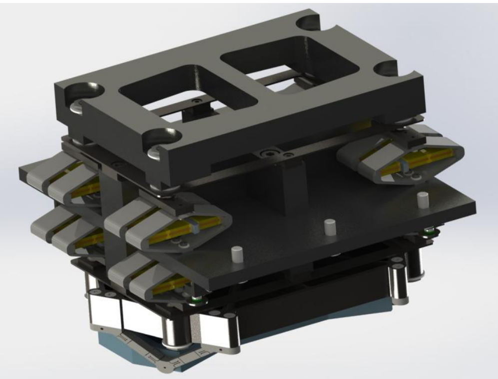


Fig. 17 : CAD of MEFISTO mechanism

11.1. DESCRIPTION

In the context of CNES future observation satellite and DGA funding, and in collaboration with CNES and SODERN, CTEC designed a large space mechanism that allows to tilt a 2 kg payload by 0.5 mrad in 2 ms with a tracking error of less than 1%, while the Loaded resonance frequency is in the 500 Hz range. The vibrations created by the payload are compensated by moving another mass in the opposite direction. It uses 8 APA120 ML with strain gauges

This project allowed CTEC to create software to compensate the vibrations with reduced additional masses

11.2. APPLICATION

The MEFISTO mechanism is dedicated to fillet compensation for space telescopes

PARAMETER	UNIT	DTT120ML-PTW FOR MEFISTO
Max. angular stroke	mrad	1.5
Dimensions	mm	279×250×293
Total mass	g	12 700
Mirror mass	g	730
Mirror dimensions	mm	220×96×23
Loaded resonance frequency	Hz	840
Speed		0.5 mrad in 2 ms
Maximum error	µm	2
Capacitance per axis	µF	40
	Capacitive sensors	

Table k : Performances of DTT120ML-PTW for Mefisto

12. DTT300ML-SG-SV

12.1. DESCRIPTION

FSM for SiC large aperture mirror with its controller rack

Fig. 18 : FSM with non-coated SiC mirror

12.2. APPLICATION

High power laser, line of sight stabilisation for atmospheric disturbance compensation

12.3. ENVIRONMENTAL CONDITIONS

- -20°C to +55°C

Fig. 19 : Customised controller

PARAMETER	UNIT	DTT300ML-SG-SV
Max. angular stroke	mrad	5
Dimensions	mm	145×145×100
Total mass	g	1800
Mirror mass	g	900
Mirror dimensions	mm	200×140×36
Loaded resonance frequency	Hz	320
Resolution	nrad	200
Accuracy	µrad	3
Accuracy	%	2
Control bandwidth	Hz	>100
Capacitance per axis	µF	40
Embedded electronics board	Embedded electronics board for Strain Gauges conditioning	

Table I : Performances of DTT300ML-SG-SV

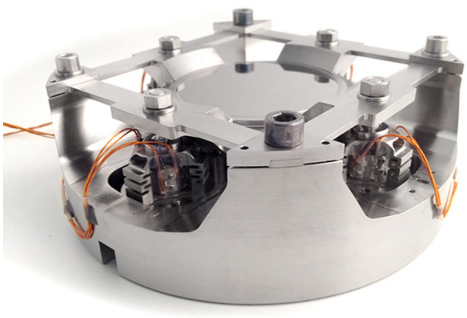


Fig. 20 : DTT10H cryogenic mechanism

13. CRYOGENIC DTT10H FOR ESA CFSM PROJECT

13.1. DESCRIPTION

For the ESA EChO mission, the use of a fine steering tip and tilt mechanism ensures the stability of the line of sight for a telescope operating in cryogenic conditions. The main efforts were focused on the management of thermo-mechanical behaviour and performances of the actuator over a wide temperature range. Its capabilities to sustain stresses due to thermal cycles between room and cryogenic temperatures have been demonstrated through the development and test of an Engineering Model

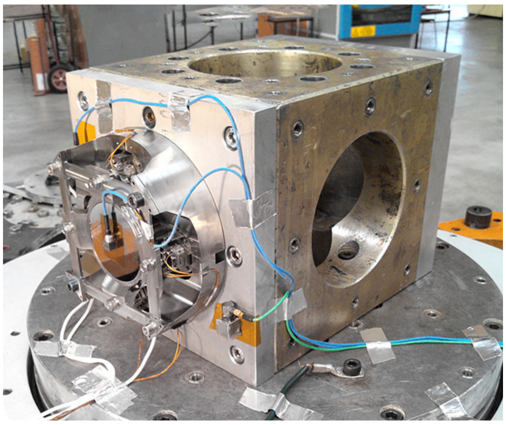


Fig. 21 : Shocks and vibrations test bench

13.2. APPLICATION

Space, pointing

13.3. ENVIRONMENTAL CONDITIONS

- Cryogenic stability 30 K
- Non-magnetic mechanism
- **Successful life time @30 K:** 2.2 M cycles
- **Successful vibration tests:**
  - **Shocks:** 700 G
  - **Random:** 18 Grms

PARAMETER	UNIT	CRYOGENIC DTT10H FOR ESA CFSM PROJECT
Max. angular stroke @300 K	mRad	0.2
Max. angular stroke @30 K	mRad	0.06
Dimensions	mm	ø 145×55
Total mass	g	1650
Mirror mass	g	72
Mirror dimensions	mm	ø 60×6
Loaded resonance frequency	Hz	3300
Resolution	nrad	0.13
Power consumption	mWatt	2
Piston drift along qualification	µm	<50

Table m : Performances of cryogenic DTT10H for ESA CFSM project

14. MAGNETIC FAST STEERING MIRROR (M-FSM62)

14.1. DESCRIPTION

Magnetic FSM for optical pointing with larger motion than piezo FSM while keeping high resolution and large bandwidth.

The M-FSM62 mechanism volume contains the mirror, the actuators, the flexure bearings and the Eddy Current positioning Sensors (ECP).

High performance Moving Iron Control Actuator (MICA™) allows to perform the dynamic strokes with low Joule heating.

Frictionless flexure bearings allow to achieve both high resolution and infinite life time.

Dedicated electronics for sensing, driving and controlling are respectively the ECS45 and MCSA480.

Fig. 22 : Magnetic Fast Steering Mirror M-FSM62 (with Ø31 mm mirror)

14.2. APPLICATION

Typical applications are Free Space Optic (FSO) communication links, applications, optical imaging.

PARAMETER	UNIT	MAGNETIC FAST STEERING MIRROR (M-FSM62)
Max. angular stroke	mrad	140
Dimensions	mm	Ø 62 × 60
Standard SiC mirror size	mm	Ø 31
Mirror full stroke open loop bandwidth	Hz	200
(with heating)	Hz	93
Resolution	µrad	20
Loaded resonance frequency	Hz	100
Power @20Hz	W	0.5
See more detailed perfomances		

Table n : Performances of Magnetic Fast Steering Mirror (M-FSM62)

Fig. 23 : M-FSM45

15. M-FSM45

15.1. DESCRIPTION

The MFSM45 is a Magnetic based Fast Steering Mirror of +15 mm diameter clear aperture (in SiC, metallic or glass substrate) with 100 mrad angular stroke (peak-to-peak). The MFSM45 can be equipped with Eddy Current positioning sensor (ECS) for accurate positioning control.

15.2. APPLICATION

Fast steering mirror, Point ahead mechanism, Line of sight stabilisation, Microscanning, Tracking, Fine pointing.

PARAMETER	UNIT	MAGNETIC FAST STEERING MIRROR (M-FSM45)
Max. angular stroke	mrad	50
Dimensions	mm	Ø45 × 40
Standard SiC mirror size	mm	Ø17
Mirror full stroke open loop bandwidth	Hz	350
Resolution	µrad	<0.5
Loaded resonance frequency	Hz	100
See more detailed perfomances		

Table o : Performances of Magnetic Fast Steering Mirror (M-FSM45)

16. PIEZO FAST STEERING MIRROR (P-FSM150S-SG)

16.1. DESCRIPTION

The P-FSM150S is a piezo based Fast Steering Mirror of +15 mm diameter clear aperture (in SiC, metallic or glass substrate) with +18 mrad angular stroke. The P-FSM150S is equipped with Strain Gages positioning sensor for accurate positioning control. The P-FSM150S has been qualified for Space environmental conditions.

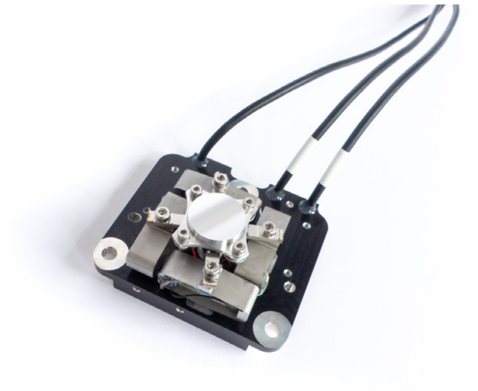


Fig. 24 : P-FSM150S-SG

16.2. APPLICATION

Fast steering mirror, Point ahead mechanism, Line of sight stabilisation, Microscanning, Tracking, Fine pointing.

PARAMETER	UNIT	PIEZO FAST STEERING MIRROR (P-FSM150S)
Max. angular stroke	mrad	18
Dimensions	mm	61 x 63 x 30
Standard SiC mirror size	mm	Ø17
Mirror full stroke open loop bandwidth	Hz	400
Resolution	µrad	<2
Loaded resonance frequency	Hz	700
See more detailed perfomances		

Table p : Performances of Magnetic Fast Steering Mirror (P-FSM150S)

17. MINI FAST STEERING MIRROR (MINI P-FSM35XS)

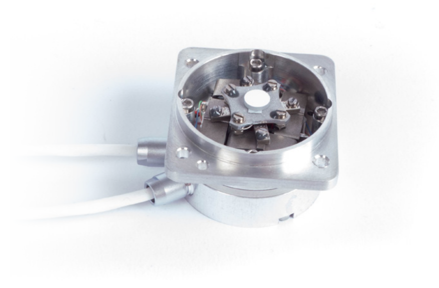


Fig. 25: View of the Mini P-FSM35XS

Fig. 26 : View of the CCBu20-SV

17.1. DESCRIPTION

Recently, CTEC has delivered a mini FSM for a 3U CubeSat, for an undisclosed constellation that will have several hundreds of satellites. This mini FSM offers a **stroke of 6 mrad and a resonant frequency of 1700 Hz, with a mass of 50 gr.**

This FSM mechanism is a good candidate for all projects involving nano satellites or cube satellites, and is a high end alternative to MEMS, which reliability and resistance to space conditions are still being questioned.

To control the Mini FSM, CTEC developed a custom 2-channel CCBu20 controller qualified for vibrations. The controller prototype will be used for a New Space mission and needs to survive the extreme vibration conditions met during launch. To ensure the resistance of the controller, CTEC designed a new reinforced housing and performed vibration tests.

17.2. APPLICATIONS

Fast steering mirror, point ahead mechanismn, line of sight stabilisation, microscanning, tracking, fine pointing

PARAMETER	UNIT	MINI P-FSM35XS
Max. angular stroke	mrad	12
Resonant frequency with1x5mm mirror (Blocked Free)	Hz	1700
Angular resolution	µrad	2.2
Operating temperature	°C	-55 to 80
Height without mirror	mm	20
Typical mass	g	50

Table q : Mini P-FSM35XS Specifications

CEDRAT TECHNOLOGIES (CTEC) offers off-the-shelf mechatronics products including piezoelectric & magnetic actuators, motors, mechanisms, transducers and sensors with corresponding drivers & controllers. These mechatronics products are used for scientific and industrial applications requiring fonctions such as: micro and nano positioning, generation of vibrations, micro-scanning, fast & precise motion control, active control of vibrations, and energy harvesting

Most of the products are available in OEM versions for low cost and high volume industrial applications. CTEC also offers services including, design, R&D under contract and training

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CTEC is a SME located in Meylan, Inovallée, the French Innovation Valley near Grenoble. CTEC is recognised as a highly innovative company and has received several awards

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