New types of actuators specific to space applications
Acronim ACTOSPACE
Contract no. 88/29.11.2013

Programme of Research, Development and Innovation for Space Technology and Advanced Research - STAR

Contracting Authority: Romanian Space Agency (**ROSA**)

Subprogramme *S1 Research*

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Project duration: 29.11.2013 – 29.11.2015
Total costs 925000 lei
Public Budget 900000 lei
Private co-financing 25000 lei

Buton 1 Abstract

The project "*New types of actuators specific to space applications",* proposes as main objective to achieve two functional models as follows: magnetostrictive linear micromor and piezoelectric rotating micromotor, each with its own specific driving equipment. The target application is to fabricate driving system in the field of aero space technology. Altough, some similar devices are already developed worldwide, but the development of new active materials, electronic components and new ideas regarding the conception and design of the micromotors could lead to significant technological improvements. From the main objective, four other objectives can be drawn: fabrication of a new linear micromotor using magnetostrictive principles; design and fabrication of the specific driver for the magnetostrictive linear micromotor; fabrication of a new rotating micromotor working on piezeoelectric principles; design and fabrication of the specific driver of the piezoelectric

rotating micromotor. We have proposed a new concept of the linear magnetostrictive micromotor, whose pre-magnetization magnetic field is produced by an auxiliary coil powered by direct current. The auxiliary coil together with a new smaller permanent magnet, replaces the permanent magnet with coaxial cylindrical geometry and is capable of producing a pre-magnetization magnetic field, directed longitudinally. The activation coil of the linear magnetostrictive micromotor is supplied with a voltage PWM waveform (Pulse Width Modulation) via the new drive that was designed for this application. Also, from the constructive point of view, the new piezeoelectric rotative micromotor presents several novelty elements: the manufacture of a piezeoelectric rotative micromotor which uses a cylindrical piezoceramic converter with multi-phase; the producing of progressive ultrasonic waves is intended by applying four cvasisinusoidal voltages with the phase shift of 45 electric degrees, applied on 8 sectors bounded on the piezoceramic cylinder converter. The purpose of this method is to obtain a torque increase, as well as achieving the increase of the positioning precision. In order to make a comparison between conventional electromagnetic motors and rotary piezoelectric micromotor will briefly present the advantages and disadvantages of the latter. As disadvantages may be mentioned the need a ultrasonic frequencies power supply and voltages above 50 V-100 V, which implies significant demands on the various electronic components.. From the advantages of the electric drive for rotary piezoelectric micromotor we can include high resolution positioning, fast response, excellent controllability, rapidly braking without inertia, quiet operation (ultrasonic frequency), compact shape and reduced size, ability to withstand high forces and torques compared to the weight and its size, simplicity of structure and manufacturing technology, allowing continuous miniaturization. The behavior of *the rotary piezoelectric micromotor in space is much better than electromagnetic motors, does not generate electromagnetic energy and are not influenced by this external electromagnetic fields.* This project could generate a product family for the magnetostrictive linear micromotors as well as a product family for the piezoelectric rotating micromotors with similar working principles. Thus, a various range of applications is covered by the specific electric drivers with application in aero space technology. **ICPE-CA** through ECCE Department has the necessary logistics to produce micro-coils and perform micro-processing and micro-assembly. Also, within the Advanced Material Department, permanent magnets as well as cylindrical piezoceramic converters could pe produced. **UPB –ECEE** has a laboratory for Multiphysics Modelling, equipped with necessary infractusture for 2D and 3D modeling. **STRAERO** has an extensive experience in aero space industry and it assumes all the activities regarding the establishment of work conditions in space, as well as the demonstration of the utility of the applications resulted from the project implementation. Finally, **SMART MECHANICS** has experience in designing and fabrication of mechanical subassemblies which completes the micromotors proposed for fabrication in this project.

Buton 2 Work package

WP no.	**1**				
WP title	**Physico-mathematical and numerical models for the proposed micromotors**				
Involved partners	**CO**	**P1**	**P2**	**P3**	**Total**
Person-months	**10**	**18**	**0**	**0**	**28**
Start month	**month 1**				
End month	**month 6**				

Objectives

O 1.1 Visualisation of the magnetic field of the magnetostrictive linear micromotor required to determine the maximum amplitude of displacement for the mobile equipment;
O 1.2 Visualisation of the thermal field of the magnetostrictive linear micromotor required for framing in to acceptable limits for materials suitable for space applications;
O 1.3 Visualisation of the electric field of the rotating piezoelectric micromotor required for obtaing the surface waves which determines the displacement of the mobile equipment;
O 1.4 Visualisation of the thermal field of the rotating piezoelectric micromotor, required for framing in to acceptable limits for materials suitable for space applications;
O 1.5 Determining the optimal geometric dimensions for the proposed micromotors ;

Description of work (possibility broken down into tasks) and role of participants

The objectives of this work package will be achieved through the cooperation of work teams by performing tasks associated to each partner as follows:
A 1.1 Development of physical, mathematical and numerical model for magnetostrictive linear micromotor
UPB-ECEE will establish physical and mathematical model for the magnetostrictive linear micromotor
UPB-ECEE will model the magnetic field and temperature field for magnetostrictive linear micromotor using COMSOL software package, taking input data from ICPE-CA
ICPE-CA establishes and calculates the equivalent magnetic circuit of magnetostrictive linear micromotor and obtain the input data (elastic constant of the mechanical bias spring, current waveforms through the drive coil and the magnetic bias coil, magnetic hysteresis loop of the permanent magnet used, etc..) for numerical modeling
A 1.2 Development of physical, mathematical and numerical model for rotating piezoelectric micromotor
UPB-ECEE will establish physical mathematical model for rotating piezoelectric micromotor ;
UPB-ECEE will model using the software package COMSOL electric field and temperature field for rotating piezoelectric micromotor, taking input data from ICPE-CA
ICPE-CA sets and calculates parameters for the rotating piezoelectric micromotor based on electromechanical equivalent scheme and deduct input for numerical modeling

Deliverables (brief description and month of delivery)

D 1.1 Numerical model of the linear magnetostrictive micromotor ; month of delivery - 3
D 1.2 Numerical model of the rotating piezoelectric micromotor ; month of delivery - 6

WP no.	**2**				
WP title	**Implementation of unconventional electrical drive: magnetostrictive linear micromotor - specific driver**				
Involved partners	**CO**	**P1**	**P2**	**P3**	**Total**
Person-months	**14**	**8**	**12**	**6**	**40**
Start month	**month 3**				
End month	**month 11**				
Objectives					
O 2.1 Functional model of the electric drive: magnetostrictive linear micromotor –specific electronic driver suitable for space applications					
Description of work (possibility broken down into tasks) and role of participants					
The objectives of this work package will be achieved through the cooperation of work teams by performing tasks associated to each partner as follows: **A 1.3 Study of a specific electronic driver for driving magnetostrictive linear micromotor** **ICPE -CA will study different topologies of electronic component from the electronic scheme of the specific driver of the magnetostrictive linear micromotor and indicate the optimum solution.** **A 1.4 Electronic circuit diagram design of the specific driver for driving magnetostrictive linear micromotor** **ICPE -CA will design based on previous studies specific electronic driver circuit diagram for driving magnetostrictive linear micromotor** **A 1.5 Design magnetostrictive linear micromotor** **UPB- ECEE will provide numerical model based on the following data: geometric arrangement and dimensions of the main components of the magnetic circuit , magnetic flux of the permanent magnet , the number of turns , wire diameter and winding filling factor of the coil windings and magnetic bias, as well as for the drive coil .** **STRAERO will establish specific working conditions for the magnetostrictive linear micromotor operation in space applications** **ICPE -CA will design magnetostrictive linear micromotor based on data obtained from UPB- ECEE and STRAERO .** **A 1.6 Realisation of a functional model of the electric drive : magnetostrictive linear micromotor - specific electronic driver** **ICPE -CA acquires the electronic components necessary to build the specific electronic driver , makes the specific electronic driver and the driving and magnetic bias coils and also connects the electronic driver to the magnetostrictive linear micromotor . ICPE-CA performes preliminary operation tests of the electric drive .** **SMART MECHANICS performs the mechanical parts of the magnetostrictive linear micromotor and its general assembly . Participate in preliminary operation tests of the electric drive .** **A 1.7 Experimenting on the functional model of electric drive : magnetostrictive linear micromotor - specific electronic driver** **ICPE - CA organizes the experiments on the functional model consisting of: determining the variation limits of the mobile equipment with laser interferometer , recording the temperature fields with thermal camera, determination of the waveforms of the voltages across the driving coils and magnetic bias coils, using digital oscilloscope , determining the RMS currents through the two coils, etc.** **All partners (ICPE -CA , UPB- ECEE , STRAERO , SMART MECHANICS) will participate in this activity with their expertise for the appropriate action.** **A 1.8 Demonstration of the utility of the functional model of electric drive : magnetostrictive linear micromotor - electronic driver specifically for space applications** **STRAERO will identify possible applications of electric drive functional model : magnetostrictive linear micromotor - specific electronic driver in the use condition of space and proposes a strategy for the**					

development of this device.
Deliverables (brief description and month of delivery)
D 2.1 Project of the electronic design of the electronic driver specific for driving the magnetostrictive linear micromotor ; month of delivery - 4 **D 2.2 Project of the magnetostrictive linear micromotor; month of delivery - 6** **D 2.3 Functional model of the electric drive: magnetostrictive linear micromotor – specific electronic driver; month of delivery - 9** **D 2.4 Experimentation and utility demonstration report for the functional model; month of delivery -11**

WP no.	**3**				
WP title	**Implementation of unconventional electrical drive: piezoelectric rotary micromotor - specific driver**				
Involved partners	**CO**	**P1**	**P2**	**P3**	**Total**
Person-months	**14**	**8**	**12**	**6**	**40**
Start month	**month 13**				
End month	**month 24**				
Objectives					
O 3.1 Functional model of the electric drive: piezoelectric rotating micromotor – specific electronic driver suitable for space applications					
Description of work (possibility broken down into tasks) and role of participants					
The objectives of this work package will be achieved through the cooperation of work teams by performing tasks associated to each partner as follows: **A 2.1 Study of a specific electronic driver for driving piezoelectric rotating micromotor** **ICPE -CA will study different topologies of electronic component from the electronic scheme of the specific driver of the piezoelectric rotating micromotor and indicate the optimum solution.** **A 2.2 Electronic design diagram design of the specific driver for driving piezoelectric rotating micromotor** **ICPE-CA will desing based on the previous study the electronic scheme of the electronic specific driver for driving the piezoelectric rotating motor** **A 2.3 Designing the rotating piezoelectric micromotor** **UPB- ECEE will provide based on the numerical model the following data: geometric arrangement and dimensions of the main components (piezoelectric cylinder , housing , mobile equipment, etc .)** **Required electric field required for the polarization of the piezoelectric cylinder , four waveform characteristization (frequency , amplitude, phase shift) applied to the piezoelectric cylinder** **STRAERO will establish the specific working conditions of the rotating piezoelectric micromotor operation in the space applications** **ICPE -CA will design the rotating piezoelectric micromotor based on data obtained from UPB- ECEE and STRAERO .** **A 2.4 Realization of a functional model of electric drive : rotating piezoelectric micromotor - specific electronic driver** **ICPE -CA acquires electronic components necessary to achieve specific electronic driver ,** **realisation of the specific electronic driver and rotating piezoelectric micromotor . ICPE -CA performs preliminary tests of the electric drive .** **SMART MECHANICS performs mechanical parts of the rotating piezoelectric micromotor and its general assembly . Participate in preliminary tests of the electric drive .** **A 2.5 Experienting of a functional model of electric drive : rotating piezoelectric micromotor - specific electronic driver** **ICPE - CA organizes the experiments on the functional model consisting of: determining the variation**					

limits of the mobile equipment with laser interferometer , recording the temperature fields with thermal camera, determination of the waveforms of the voltages across the driving coils and magnetic bias coils, using digital oscilloscope , determining the RMS currents through the two coils, etc. **All partners (ICPE -CA , UPB- ECEE , STRAERO , SMART MECHANICS) will participate in this activity with their expertise for the appropriate action.** **A 2.6 Demonstration of the utility of the functional model of electric drive : rotating piezoelectric micromotor - electronic driver specifically for space applications** **STRAERO will identify applications for functional model of electric operation : rotating piezoelectric micromotor - specific electronic driver for conditions in outer space and proposes a strategy for the development of this device.**
Deliverables (brief description and month of delivery)
D 3.1 Project for the electronic scheme of the electronic specific driver for driving the piezoelectric rotating micromotor ; month of delivery - 15 **D 3.2 Project of the piezoelectric rotating micromotor; month of delivery - 17** **D 3.3 Functional model of the electric drive: piezoelectric rotating micromotor –specific electronic driver; month of delivery - 21** **D 3.4 Experimentation and utility demonstration report for the functional model; month of delivery – 23**

WP no.	**4**				
WP title	**Dissemination and industrial property rights**				
Involved partners	**CO**	**P1**	**P2**	**P3**	**Total**
Person-months	**6**	**6**	**6**	**0**	**18**
Start month	**month 7**				
End month	**month 23**				
Objectives					
O 4.1 Preparing documentation for patenting the electric drive: magnetostrictive linear micromotor - specific electronic driver ; **O 4.2 Preparing documentation for patenting the electric drive: piezoelectric rotating micromotor;** **O 4.3 Publication in ISI journals and attending to international conferences;**					
Description of work (possibility broken down into tasks) and role of participants					
A 1.9 Protection of industrial property rights, patenting of the electric drive: magnetostrictive linear micromotor - specific electronic driver **ICPE-CA, UPB-ECEE and STRAERO will work together in order to prepare the documentation for certification of the electric drive: magnetostrictive linear micromotor - specific electronic driver** **A 1.10 Dissemination of the results** **ICPE-CA, UPB-ECEE and STRAERO will disseminate the results obtained in the first phase of the project by submission of papers to ISI internationally recognized publications.** **A 2.7 Protection of industrial property rights, patenting of rotating piezoelectric micromotor electric drive - specific electronic driver** **ICPE-CA, UPB-ECEE and STRAERO will work together in order to prepare the documentation for certification of the electric drive: rotating piezoelectric micromotor - specific electronic driver** **A 2.8 Dissemination of results** **ICPE-CA, UPB-ECEE and STRAERO will disseminate the results in the second phase of the project by submission of papers to ISI internationally recognized publications**					

Deliverables (brief description and month of delivery)
D 4.1 Patent Application for the electric drive: magnetostrictive linear micromotor - specific electronic driver, month of delivery - 11 D 4.2 Patent Application for the electric drive: piezoelectric rotating micromotor - specific electronic driver, month of delivery - 22 D 4.3 Participation and communication of research results from the first stage, at specialized international conferences and accept for publishing of an ISI scientific paper; month of delivery - 12 D 4.4 Participation and communication of research results from the second stage, at specialized international conferences and accept for publishing of an ISI scientific paper; month of delivery - 23

WP no.	5				
WP title	Project mangement				
Involved partners	CO	P1	P2	P3	Total
Person-months	2	0	0	0	2
Start month	month 1				
End month	month 24				
Objectives					
This work package will be carried out throughout the project and includes all activities related to the coordination of the project both in terms of administration and management. O 5.1 Administrative and financial coordination of the project; O 5.2 The overall coordination of the project; O 5.3 Risk management.					
Description of work (possibility broken down into tasks) and role of participants					
This stage is carried out throughout the project life cycle and includes all activities related to project coordination, both administrative and management. Project coordination involves responsibilities regarding the task completion according to the contract and detailed work plan, deliverables and all official documentation control provided by the consortium for the Contracting Authority. This phase includes the following activities: T 5.1 Technical coordination of the project - At the beginning of each stage, a plan of action to meet the targets will be prepared; - Ensure quality control for the partner activity reports; - Prepares technical and financial documentation requested by the Contracting Authority for the reimbursement. T 5.2 Administrative and financial coordination of the project - Takes care of all administrative aspects of the project, collecting and providing all documents requested by the Contracting Authority, checks the payment requests of each partner - Ensure that the payments are made to the partners of the consortium in time , respecting the rules of financing; - The interface between partners and contractors T 5.3 The overall coordination of the project The aim of this activity is to facilitate interactions between partners, management meetings, exchange of know-how and dissemination activities. In order to coordinate the project will be set two meetings: - Mid-term meeting in month 6; - Mid-term meeting in month 14; - Virtual meetings and phone will be taken according to the needs of the project. T 5.4 Risk of management Coordinates project risks definition at consortium level, monitors and manages the appropriate actions, ensuring that necessary measures are taken in time.					

Deliverables (brief description and month of delivery)
D 5.1 Free web site implementation. Delivery: month 6; **D 5.2 Intermediate scientific report for the Contracting Authority; month of delivery - 12;** **D 5.3 Final scientific report for the Contracting Authority; month of delivery - 24.**

Year	Phases/Activities	Involved partner	Activity type	Phase duration: *from: month/year to: month/year*	Financial resources necesarry (lei) from which :		
					Total		
0	1	2	3	4	5	6	7
2013 - 2014	**Phase I – Elaboration and realization of the functional model for electric drive system: magnetostrictive linear motor – specific electronic driver**			**29.11.2013 - 29.11.2014**	**549000**	**536700**	**12300**
	Activity I.1. Development of mathematical, physical and numerical model for magnetostrictive linear micromotor	UPB-ECEE	A.1.2		45000	45000	0
		ICPE-CA	A.1.2		25000	25000	0
	Activity I.2. Development of mathematical, physical and numerical model for the piezoelectric rotating micromotor	UPB-ECEE	A.1.2		40000	40000	0
		ICPE-CA	A.1.2		25000	25000	0
	Activity I.3. Study of a specific electronic driver for driving the magnetostrictive linear micromotor	ICPE-CA	A.2.1		35000	35000	0
	Activity I.4. Designing the electronic scheme of the specific driver for driving the magnetostrictive linear micromotor	ICPE-CA	A.2.4		30000	30000	0
	Activity I.5. Designing the magnetostrictive linear micromotor	ICPE-CA	A.2.4		35000	35000	0
		UPB-ECEE	A.2.4		40000	40000	0
		STRAERO	A.2.4		20000	20000	0
	Activity I.6. Designing the functional model of the electric drive: magnetostrictive linear micromotor – specific electronic driver	ICPE-CA	A.2.5		70000	70000	0
		SMART MECHANICS	A.2.5		33500	26000	7500

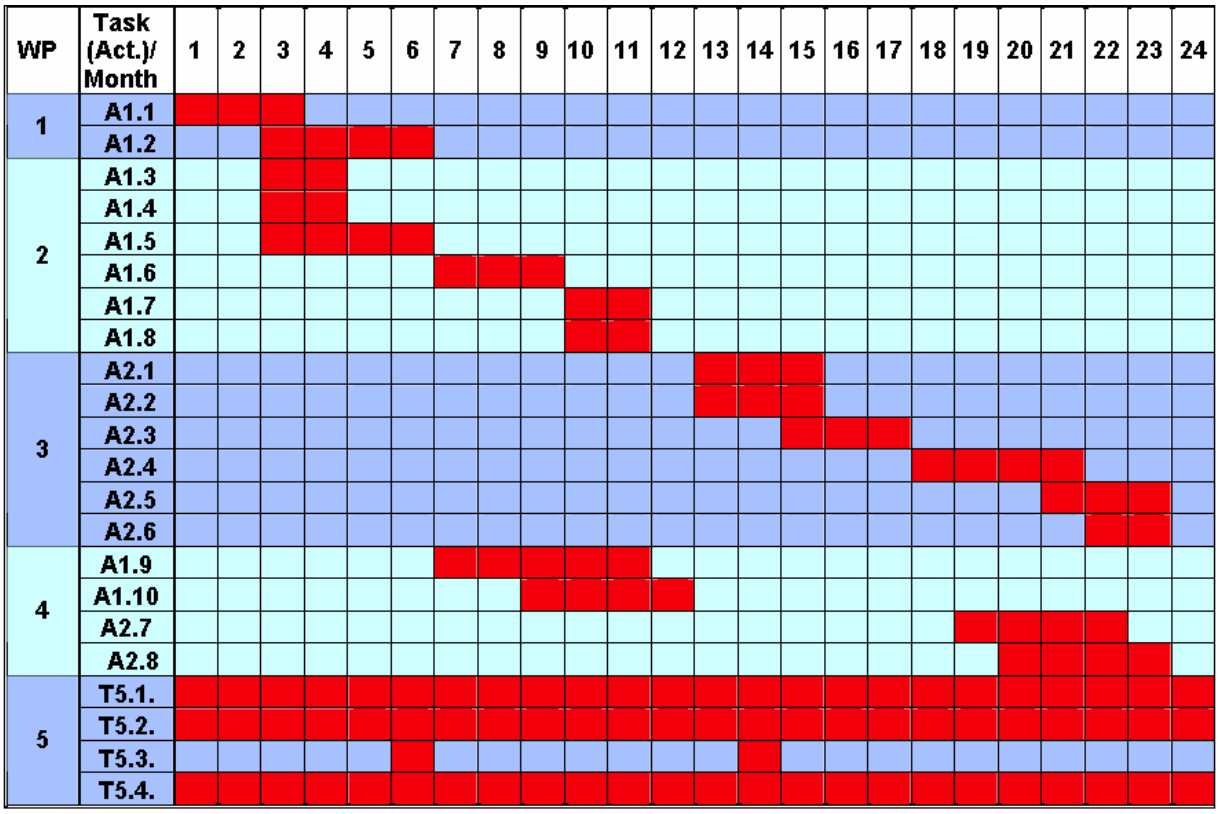
	Activity I.7. Experimentation on the functional model of the electric drive: magnetostrictive linear micromotor – specific electronic driver	ICPE-CA	A.2.6		34000	34000	0
		UPB-ECEE	A.2.6		14000	14000	0
		STRAERO	A.2.6		35000	35000	0
		SMART MECHANICS	A.2.6		15500	10700	4800
	Activity I.8. Demonstration of the utility for the functional model of the electric drive system: magnetostrictive linear micromotor – specific electronic driver , for space applications	STRAERO	A.2.7		40000	40000	0
	Activity I.9. Industrial property rights protection , patent for the electric drive: magnetostrictive linear micromotor – specific electronic driver	ICPE-CA	C.2		6000	6000	0
		UPB-ECEE	C.2		1000	1000	0
		STRAERO	C.2		5000	5000	0
2014 - 2015	**Phase II - Elaboration and realization of the functional model of the electric drive system: rotating piezoelectric micromotor - specific electronic driver**			**29.11.2014 - 29.11.2015**	**376000**	**363300**	**12700**
	Activity II.1. Study of a specific electronic driver for driving the rotating piezoelectric micromotor	ICPE-CA	A.2.1		25000	25000	0
	Activity II.2.Designing the electronic scheme of the specific electronic driver for driving the rotating piezoelectric micromotor	ICPE-CA	A.2.4		25000	25000	0
	Activity II.3. Designing the rotating	ICPE-CA	A.2.4		25000	25000	0

	piezoelectric micromotor	UPB-ECEE	A.2.4		29000	29000	0
		STRAERO	A.2.4		20000	20000	0
	Activity II.4. Realization of the functional model of the electric drive: rotating piezoelectric micromotor – specific electronic driver	ICPE-CA	A.2.5		63000	63000	0
		SMART MECHANICS	A.2.5		35500	27600	7900
	Activity II.5. Experimentation of the functional model for the electric drive system : rotating piezoelectric micromotor – specific electronic driver	ICPE-CA	A.2.6		21000	21000	0
		UPB-ECEE	A.2.6		30000	30000	0
		STRAERO	A.2.6		35000	35000	0
		SMART MECHANICS	A.2.6		15500	10700	4800
	Activity II.6. Demonstration of the utility for the functional model of the electric drive system: rotating piezoelectric micromotor – specific electronic driver	STRAERO	A.2.7		40000	40000	0
	Activity II.7. Industrial property rights protection , patent for the electric drive: rotating piezoelectric micromotor – specific electronic driver	ICPE-CA	C.2		6000	6000	0
		UPB-ECEE	C.2		1000	1000	0
		STRAERO	C.2		5000	5000	0

Buton 4 Deliverables

Deliverable No.	Deliverable Name	WP no.	Type of Deliverable	WP delivery date (1 ... 24)
D 1.1	Numerical model of the linear magnetostrictive micromotor	1	Numerical model	3
D 2.1	Project of the electronic scheme of the electronic driver specific for driving the magnetostrictive linear micromotor	2	Project	4
D 1.2	Numerical model of the rotating piezoelectric micromotor	1	Numerical model	6
D 2.2	Project of the magnetostrictive linear micromotor	2	Project	6
D 5.1	Free web site implementation	5	Web site	6
D 2.3	Functional model of the electric drive: magnetostrictive linear micromotor – specific electronic driver	2	Functional model	9
D 2.4	Experimentation and utility demonstration report for the functional model	2	Experimentation and demonstration report	11
D 4.1	Patent Application for the electric drive: magnetostrictive linear micromotor - specific electronic driver	4	Patent Application	11
D 4.3	Participation and communication of research results from the first stage, at specific international conferences and accept for publishing of an ISI scientific paper	4	Scientific papers	12
D 5.2	Intermediate scientific report for the Contracting Authority	5	Intermediate scientific report	12
D 3.1	Project for the electronic scheme of the electronic specific driver for driving the piezoelectric rotating micromotor	3	Project	15
D 3.2	Project of the piezoelectric rotating micromotor	3	Project	17
D 3.3	Functional model of the electric drive: piezoelectric rotating micromotor –specific electronic driver	3	Functional model	21
D 4.2	Patent Application for the electric drive: piezoelectric rotating micromotor - specific electronic driver	4	Patent Application	22
D 3.4	Experimentation and utility demonstration report for the functional model	3	Experimentation and demonstration report	23
D 4.4	Participation and communication of research results from the second stage, at specific international conferences and accept for publishing of an ISI scientific paper	4	Scientific papers	23
D 5.3	Final scientific report for the Contracting Authority	5	Final scientific report	24

Buton 5 Gantt Diagram



Buton 6 Phase 1

Buton 7 Phase 2