PC-I

for

Establishment of Complete Facility for Design, Fabrication, Testing and Packaging of Micro Electro-Mechanical Systems (MEMS)

PHASE-I

(Education, Research and Training)

Submitted By:

ADVANCED ENGINEERING RESEARCH ORGANIZATION

National Engineering & Scientific Commission

ISLAMABAD

PART 'A'

PROJECT DIGEST

1. Name of Project:
2.

***Establishment of complete facility for design, fabrication, testing and packaging of Micro Electro-Mechanical Systems (MEMS),* (PHASE-I)**

2. Authorities responsible for:

i)	Sponsoring	***Ministry of Science and Technology, Government of Pakistan.***
ii)	Execution	***Advanced Engineering Research Organization (AERO), NESCOM***
iii)	Operation and maintenance	***Advanced Engineering Research Organization (AERO), NESCOM***

3. Time required for completion of project (in months) ***12 months for Phase-I***

4. (a) Plan Provision

(i) If the project is included in the current five year Plan, specify actual allocation.

a) This project is not included in the current five years plan. It will form part of the development path for the establishment of world class R & D facility in the field of electronics and MEMS as decided by Ministry of Science and Technology on 15th July, 2003.

b) The project will enable the development of new and modern technologies in the country through establishment of facilities and training of highly skilled manpower.

(ii) If not included in the current plan, how is it now proposed to be accommodated (inter/intra-Sectoral adjustments in allocation or other resources may be indicated)

The project is included in the overall vision of the plan and would be accommodated through inter-sectoral adjustments.

(iii) If the project is proposed to be financed out of block provision for a program, indicate:

N.A.

(iv) For each project a statement showing Plan allocation and impact of the project being submitted for approval on the sectoral portfolio should be given.

Total Block Provision	Amount already committed	Amount Proposed for this project	Balance available
		Rs. 35.5 Million	

(b) If the project is not in the Plan, what warrants its inclusion in the Plan

The field of MEMS is the study of small mechanical devices and systems. They range in size from a few microns to a few millimeters. The field is called by a wide variety of names in different parts of the world: Micro Electro Mechanical Systems, MEMS, Micromechanics, Micro System Technology (MST), Micro Machines, Micro, and is called Nano Technology by some people (Nano technology usually refers to devices ranging in size from a nanometer to a micron). This field, which encompasses all aspects of science and technology, is involved with things on a smaller scale.

Things behave substantially differently in the micro domain. Forces related to volume, like weight and inertia, tend to decrease in significance. Forces related to surface area, such as friction and electrostatics, tend to become large. And forces like surface tension that depend upon an edge become enormous. It takes a while to get one's micro intuition sorted out. An ant carrying many times its weight or a water bug walking on the surface of a pond are just two manifestations of this different micro world.

MEMS include micro fabrication techniques for making mechanical parts. Motors, pivots, linkages, and other mechanical devices can be made to fit inside this circle O. These devices are also potentially quite inexpensive. For example, using silicon surface

micromachining, a gear captivated on a pivot can be made for less than a dollar.

There are a number of MEMS micro fabrication technologies. These technologies make devices ranging in size from a dozen millimeters to a dozen microns. Silicon surface micromachining inexpensively makes completely assembled mechanical systems. Silicon bulk micromachining uses either etches that stop on the crystallographic planes of a silicon wafer or etches that act isotropically to generate mechanical parts. These techniques combined with wafer bonding and boron diffusion allows complex mechanical devices to be fabricated.Electro Discharge Machining (EDM) extends conventional machine shop technology to make sub-millimeter sized parts.

Micromechanical parts tend to be rugged, respond rapidly, use little power, occupy a small volume, and are often much less expensive than conventional macro parts.

5. Relationship of the project with the objectives of the Sector indicate contribution of the project, quantified if possible to the targets in the Five Year Plan, and the names of other projects (whether sanctioned or under preparation) which would form part of an integrated programme within the sector.

- ***MEMS is a relatively new technology that is expected to revolutionize our lives in a similar way as semiconductor technology did in 80s and 90s. If MEMS design, development and fabrication facilities are established in country today; it will be of tremendous advantage in the years to come and will enable us to compete with the developed countries in this new and emerging technology.***

- ***The project involves system engineering, MEMS design, ASIC design, wafer processing, testing and device packaging. These activities will extensively enhance the overall capability of the electronics sector.***

- ***Inertial sensors are a very important component in automotive, environmental testing, oil drilling applications and navigation systems.***

? ***Establishment of an in-country facility to develop and fabricate these sensors will also make Pakistan more independent in terms of commercial and defense needs.***

? ***The MEMS facilities so established can also be used to design and fabricate pressure sensors, acoustic transducers, micro-scale bio-chemical sensors, micro-pumps, RF switches, optoelectronic devices, micro-turbines and even ultra light UAVs.***

6. Capital Cost of Project

(In Million Rupees)

Local:

(i)	***Computers Software/Hardware***	***02.000***
(ii)	***Building***	***10.000***

Foreign exchange cost:

(i)	***Equipment for Fabrication***	***06.000***
(ii)	***Computers Software/Hardware***	***16.500***
(iii)	***Training***	***01.000***
	Total	***35.500***

7. Annual recurring expenditure after completion:

(In Million Rupees)

Local	***to be met by AERO***
Foreign exchange cost	
Total	***NIL***

8. Objectives of the project preferably in quantitative terms:

MEMS (Micro Electro-Mechanical Systems) are tiny electromechanical devices of the size of micrometers (1000th part of a millimeter) capable of performing various tasks with an

effectiveness that cannot be achieved by ordinary devices. MEMS are used in diverse fields of life like medicine, automobile, aviation, space, military, Information technology, communication etc. Development and Production of MEMS can be achieved at an IC fabrication plant with a few additional processes.

Following are the main objectives of the proposed MEMS project

- ***The main purpose of this activity is to develop a facility to design, fabricate and produce micro-scale linear acceleration sensors i.e., accelerometers using Micro Electro-Mechanical Systems technology.***
- ***Accelerometers of varying specifications are used for a wide range of applications. A market size of USD 500M addresses applications in tilt measurement and navigation. Another market of USD 200M addresses applications like crash sensing in automobiles.***
- ***The facility hence established will then be used to design, develop and produce other MEMS devices like pressure sensors, acoustic transducers, micro-scale bio-chemical sensors, micro-pumps, RF switches, optoelectronic devices, micro-turbines and even ultra light UAVs which have a huge potential market in the years to come.***
- ***Presently the overall MEMS market is about 3 billion USD and is estimated to exceed 12 billion USD by the end of 2004. Having a MEMS capability will allow us to enter into this rapidly growing market and subsequently recover any investment that we make today.***

In the first phase, building, Computer hardware/software support necessary for MEMS and some equipment for fabrication will be required. The equipment for Fabrication will cost around Rs. 6 million and the cost on Training will be around Rs. 1.0 million. The cost involved on computers software/hardware will be Rs. 18.5 million. The extension of building & HVAC cost will be around 10 million.

The estimated capital cost of the project is Rs. 35.500 Million for phase-I including a foreign exchange component of Rs.23.500 Million.

PREPARED BY **(Dr. Asif Raza, Director Electronics, AERO)**

&

(AVM Raja Tariq Mahmood, DG AWC)

CHECKED BY **(Mr. Z. H. Bukhari, Member Finance NESCOM)**

REVIEWED BY **(Dr. Samar Mubarakmand, N.I., H.I., S.I.,Chairman NESCOM)**

APPROVED BY **(Dr. Atta-ur-Rehman, N.I., H.I., S.I., T.I.**
Minister Incharge Science & Technology & Chairman HEC)

PART 'B'

PROJECT'S DESCRIPTION AND FINANCING

9. Location of Project: (attach map) give name of place and administrative districts in which the Research Institute/Center will be selected.

(a) give name of place and administrative district in which the service center will be located.

The project will be located at Advanced Engineering and Research Organization (AERO), Hasanabdal and managed by the Navigation Systems Department of AERO. Existing space will be used for offices and design facility. Fabrication and packaging will be partially done at the IC fabrication facility being established at LTE, Hasanabdal. Some new labs shall be constructed at the premises of Advanced Engineering and Research Organization.

(b) Indicate total area which will be served

National level facility.

(c) Environmental Aspects: A detailed sector-wise list of impacts be attached with these proforma and agency in relevant sector should furnished information in the PC-I on related aspects.

None

10. Existing facilities:

Give information about public and private sector in institutions in the areas, their staff and equipment, actual enrolment in various classes and enrolment capacity of the institution. The information about public and private sectors institutions should be given both for the level of the educational programmed proposed by the project as well as for the lower level institutions which will serve as feeder institutions for the project.

MEMS is a fairly new technology and currently there is no MEMS fabrication facility in the entire country. Most of the processes used for MEMS fabrication are same as IC fabrication process. Ultimately a high-tech IC fabrication

facility is being established at LTE, which will be utilized. The Navigation System Department at AERO can also be utilized. Utilization of

existing space and facilities will allow the accomplishment of the first phase of the project within the estimated budget.

11. Description of project

a. give brief history, proposed facilities and justification of project.

Why MEMS

MEMS is an enabling technology. It uses the tools originally developed for the silicon integrated circuit industry. MEMS technology is used to fabricate miniaturized transducers and actuators. In most cases, these new devices are smaller and offer newer functions. Using batch fabrication as in the IC industry, economies of scale can be realized. A large number of sensors or actuators can be packaged together in the form of arrays. As the IC industry goes from small wafer sizes to bigger ones, MEMS industry also gains the advantage of lower per unit cost. Fabrication of devices on silicon substrate allows incorporation of the sensing and drive electronics on the same chip. This not only makes the overall system smaller but also gives better signal to noise ratio in sensing applications. This technology has grown in the past two decades and has enabled applications like air bag actuation that were previously not economically possible.

In 1981 and 1982, the first start-up companies were founded in USA. During 1982 and 1983, the first mass-produced MEMS products were released into high volume production; these being the micro machined Manifold Absolute Pressure (MAP) sensor and the micro machined disposable medical blood pressure sensor. By 1983, every major university in USA had a research program in MEMS. Today over 50 companies are contributing to the technology, and DARPA and other US agencies spend more than $100 million a year for specific militarily and commercially strategic MEMS applications. The number and type of commercial products has grown over the years. Now accelerometers, micro-valves, projection-displays chips, biosensors, ink jet nozzle

arrays, and other products are all manufactured and shipped in large volumes.

Commercial Applications of MEMS Technology

Micro electromechanical systems (MEMS) has numerous and diverse applications ranging from aerospace technology to biotechnology. MEMS are forecasted to have a commercial market growth similar to its present IC technology. MEMS approach is to implement miniaturized, micro and nano systems, resulting in evolutionally small systems which are equivalent in terms of functions to the current systems much bigger in size. Typical applications of MEMS are as follows:

Automotive	Electronic	Medical	Communications	Defense
Inertial Navigation Sensors	Disk drive heads	pressure sensor	Fiber optic network components	Munitions guidance
Air Conditioning Compressor sensor	Ink jet printer heads	Muscle simulators & drug delivery systems	RF relays, Switches and filters	Surveillance
Brake force sensor & suspension control accelerometer	Projection screen television	Implanted pressure sensors	Projection displays in portable communication devices and instrumentation	Arming systems
Fuel level and vapor pressure sensors	Earth quake sensors	Prosthetics	Voltage controlled oscillators	Embedded sensors
Air bag sensors	Avionics sensors	Miniature analytical instrument	Splitter and couplers	Data storage
Intelligent tyres	Mass data storage	Pacemakers	Tune able lasers	Aircraft control

	systems			

Automotive ***applications include pressure sensors for engine manifolds, fuel lines, exhaust gases, tires, seats ant other uses, accelerometers for automobiles airbags, micro-heat exchanges for electronic cooling and micro mirrors used for light-beam steering and fuel sensors.***

Electronics ***applications are related to monitoring the manufacturing process, manufacturing of miniaturized robots (micro-robot), micro-grippers, micro-conveyers, micro-flow sensors earth quake and pressure sensors, microphones, strain gauges, electric motors, humidity sensor, disk drive read/write heads, scanners and micro pumps used for ink -jet printing***

Medical ***A combination of micro-fabrication techniques and molecular biology procedures has a potential to produce powerful, miniature analytical devices called Lab chips which are capable of processing minute volumes of genetic sample in order to pursue on-chip reactions and detect reaction outcomes. Typical devices under this category include implantable devices for measuring ocular, cranial or bowel pressure and devices built into catheters that can assist in procedures such as angioplasty. Also reactors for separating biological cells, controlled delivery and measurement of minute amount of medication and DNA on a chip.***

Communication ***micromechanical communication circuits fabricated via IC-compatible MEMS technologies which are capable of low-loss filtering; mixing, switching and frequency generation results in miniaturize wireless transceivers. Typical MEMS devices for communication circuits are micro mirrors for display applications (projection displays, virtual reality glasses, hands free computing), optical switches, RF switches and RF filters.***

Defence ***main MEMS devices used in Defence sector are accelerometers and gyroscopes.***

State of the art/background

Accelerometers:

Accelerometers are manufactured using a number of technologies. Traditionally accelerometers have been based on a spring-mass construction where the specific force acting on the mass is measured as a function of the displacement of the mass from a reference position. The displacement measurement methodologies have been differential transformers, synchros and capacitive plates. A modified construction has been one that uses a quartz pendulous flexible membrane. This provides long-term stability and eliminates hysteresis and fatigue, which exists even in the best metal alloy suspensions. These accelerometers offer good performance but at a relatively high cost. Another construction that has gained good market share is that of a vibrating beam. In this an elastic beam is used as a resonating element in a piezoelectrically or electromagnetically excited electromechanical oscillator. The resonant frequency of the beam varies as a function of the applied acceleration by attaching one end of the rigid beam to the seismic mass and the other end to the body-mounted casing. Crystalline quartz is the most common material for the resonating beam element. However, silicon is rapidly gaining importance with the advent of silicon micro fabrication technology.

In the last decade, silicon micro-fabrication technology has allowed cheaper realization of accelerometers based on the various constructions mentioned earlier. The performance of these accelerometers has improved over the years. The designs have also benefited from the advantage of combining the sensor and its processing circuitry together on the same silicon chip. This has led to the availability of accelerometers that occupy lesser space and are much easier to interface with the systems that they reside in. In terms of size, silicon accelerometers are generally ten times smaller than their mechanical equivalents. Cost of manufacture has probably been the most significant advantage of silicon accelerometers. This alone has been responsible for the wide spread use of silicon accelerometers as accident sensors for air bag activation in cars. Had these not come along, we might still not be using air bags in cars. In addition to being small and cheap, these sensors are very light. This has

allowed their use as embedded sensors in aircraft structures for fatigue and flutter characterization.

Analog Devices Inc USA is one of the leading companies in the US that manufacture accelerometers for various applications. Its ADXL series of accelerometers are available in different performance and package configurations. The performance of these accelerometers has shown a steady improvement over the years. Single-axis and three-axis accelerometer clusters are presently being marketed. The company is working to develop better performance accelerometers under a project funded by the US government. Latest publications indicate research into manufacturing accelerometers and gyroscopes on the same substrate.

Silicon accelerometers of around 2mg performance (with temperature control) are presently available in the market (even though difficult to procure for Pakistan). Research groups in USA and Europe have demonstrated performances as good as 0.001 mg in the laboratory. Efforts are being put in by various groups and companies to field devices with this accuracy. In Asia too, Japan, China, India and South Korea are working in MEMS technology for industrial military ends. In India, the research group have already been able to fabricate the first prototype using wet etching techniques and is now into the second iteration. The Tata Institute of Technology is also investing into MEMS devices.

MEMS Gyroscopes:

MEMS gyroscope is another tremendous invention of MEMS. Its size is very small as compared to mechanical gyroscope and is low cost. It is used for munitions guidance and navigation.

Such gyros operate in accordance with the dynamic theory that when an angular rate is applied to the translating body, a coriolis force is generated. When this angular rate is applied to the axis of resonating tuning fork its tines experience a coriolis force, which then produces torsional forces about the sensor axis. These forces which are proportional to the applied angular rate cause displacements that can be measured capacitively in silicon instrument. The output is then demodulated, amplified and digitized to form the device output.

Inertial Navigation on a Chip: For munitions guidance and independent personal navigation

Distributed Unattended Sensors: For asset tracking, border control, environmental monitoring, security surveillance, and process control.

Integrated Fluidic Systems: For miniature analytical instruments, hydraulic Pneumatic system, propellant and combustion control.

Weapons Safing, Arming and Fusing: To replace current warhead and weapons Systems, to improve safety, reliability and long term stability.

Embedded Sensors and Actuators: For condition based maintenance of machines and vehicles, on-demand amplified structural strength in lower weight weapons systems & platforms and disaster resistance buildings.

Integrated Micro Opto-mechanical components: For identifying friend- or- foe (IFF) Systems, displays, fiber optic switches and modulators.

Active and Conformable Surfaces: For distributed aerodynamic control of aircraft, adaptive optic systems, precision parts and material handling.

Biomedical:

The most widespread use of MEMS technology is the blood pressure sensor. This device measures blood pressure without using the standard air pump that suffocates the patient’s arm. This less-evasive method works faster and causes less discomfort, making it ideal for emergency situations and for times when the blood pressure must be constantly monitored.

MEMS-based devices also analyze the content of blood. I-STAT Corporation developed a device that analyzes 60?L of blood for sodium, potassium, chlorides, urea, and glucose.

This hand-held "blood-lab-on-a-chip" paves the way for future chips with many times the capabilities.
Automotive:
The automotive industry has put MEMS acceleration sensors to use. Vehicles use micro machined accelerometers to sense a crash and deploy the airbag immediately. Air-bag systems formerly used mercury switches to detect the sudden acceleration caused by a crash. They worked well, but required air bags to deploy almost instantaneously, creating a force sometimes fatal to small children. The MEMS-based accelerometer senses the crash much more quickly than the mercury switches, allowing the air-bag to deploy with a much lower force. These devices add reliability in addition to decreased detection time.
MEMS-based devices currently make other parts of the automobile work more effectively. Tiny sensors measure the pressure on the manifold and in the fuel lines. These sensors supply information used to regulate the engine, increasing fuel efficiency and decreasing harmful emissions.

b. Give details of administrative structure for implementing the project.

The project would be implemented by AERO in the existing and proposed new building to be built. A Director or Project Director to be nominated by Chairman NESCOM along with a team consisting of technical persons will assist in the implementation of the project.

c. Give population of the area to be served, age groups and income levels.

(NIL)

d. Relationship with other programmes in the same sector and in other sectors. Indicate whether coordination with other sectors has been ensured.

The aspect of human resource & technology development in the proposed fields has a direct relationship with other sectors such as research. These sectors will automatically get the required benefits such as trained manpower & self-reliance.

e. Give student-teacher ratio for the project and the national average for the proposed level of education. - Give also the extent of library and laboratories facilities per student and how it compares with the national average.

NIL

f. The employment prospects of the persons to be trained in terms of the present and future demand.

The project will have about five phases of completion. After the completion of the project, a complete design, development and production facility for several types of MEMS devices will be ready for the industry which in turn will produce employment opportunities for the persons to be employed for manufacturing of new products using MEMS.

g. Employment to be created by gender.

Equal employment opportunity on merit.

h. Detailed analysis of estimation of the likely employment.

i. Give details of the type of training or education to be imparted. The syllabus and the subjects in which emphasis will be placed. Indicate availability of teaching staff.

Research & Development will have direct relevance to national high technology goals. Manpower will be arranged by AERO.

12. Give date when capital expenditure estimates were prepared: if prepared more than one year ago, confirm if they are still valid.

The capital expenditure estimates had been prepared in Jan. 2004

13. Give summary of capital cost, covering the whole of fee investment period as indicated below:

#	Item	GOP		F.Aid		Total
		L.C(Million Rs.)	F.E.C	L.C	F.E.C	
1)	Cost of Building Extension & HVAC	***10.000***				
2)	Computers Software	***02.000***	***16.500***			
3)	Books and Journals	***to be arranged by AERO***				
4)	Other Costs *Equipment for Fabrication Training, etc.*		***07.000***			
Total		***12.000***	***23.500***			***35.500***

14. Basis of cost estimates: (Give Full Details)

The building is estimated at the basis of covered area. The technical equipment is based on international quotation attached at Flag-A.

15. Financial Plan:

i) Give complete sources of financing of the project. Clarify sources of financing such as federal/provinces, foreign/local grant/loan

Federal Government

ii) Provide details of recurrent expenditure on the basis of fixed and variable costs also specify the items such as establishment charges, interest payments, depreciation and non salary items, maintenance charges, etc. indicate the operational arrangements of implementation and the agency responsible for meeting the recurrent cost.

Nil for specified period

16. Beneficiary Participation:

Execution agencies to confirm whether prospects for beneficiary participation have been considered and if so, provide a detailed mechanism for involving beneficiary.

All research institutes & industries in the country will be benefited from this facility and will also add value to the Human Resource development of the country.

17. Risk Analysis:

Give detailed list of assumptions and the basis of changes therein. Also indicate likely events, which may delay the projects and means of addressing these delays.

Following are the risk areas in the project

New Technology

MEMS is an emerging technology that has a lot of room for improvement. Even the most advanced countries are still putting a lot of effort to take this technology to the levels of maturity where MEMS devices become part of our daily lives. Hence, risk is always there in the development of a new technology.

Manpower

Currently, there are very few people in the country who are trained specifically on MEMS. Therefore, the project requires training of existing manpower.

18. Estimates of annual recurring expenditure after completion of each phase of project: (Also indicate the source of financing recurring expenditure)

(Million Rs)

Item	Local	F.E.C	Total
a) Research staff			
b) Ancillary staff			
c) Supervisory and administrative staff			
d) Consumable stores and supplies (Please specify)			
e) Books and journals			
f) Contingent Staff			

g) Other contingencies - e.g services like electricity, water postage and operation & Maintenance etc.

h) Rent and rates

Nil

19. Authority responsible to meet the recurring expenditure after completion of the project
AERO, NESCOM Islamabad.

20. Unit cost for each category of service or output: Indicate number of technical personnel and man years, number of studies, cost per study, cost per man-year

This will be determined towards the end of development and is expected to be lower than international prices. Important is the fact that the output will be services and devices that are not otherwise directly accessible by the local industry, academia and scientific community.

21. Comparative unit cost of similar project under implementation and completed.

No such programme exists in the above capabilities in these fields. This is a special programme to be customized as per requirements of the cutting edge technologies required for the specific field.

22. Give statement showing phasing of repayment of loans indicate debt servicing capacity (i) of project, (ii)of loan receiving organization.

N.A.

23. In case of industrial research, if the processes developed are to be leased to commercial firms, give cash flow statement (inflow and outflow) for the next five years.

N.A.

24. Annual phasing of physical work and financial requirements for the project (Attach Bar diagram)

Sr. No.	Heads		1st year (Millions Rs.) Local	F.E.C	
1.	Equipment for Fabrication	Critical point drying		4.000	
		Supplies		2.000	
2.	Computers Software/ Hardware	MEMSCAP/ COVENTOR/ INTELLISENSE		8.000	
		Workstations	2.000		
		Tsupreme/ Mentor Graphics/ Cadence mixed signal		8.500	
3.	Training	Design Training abroad (3x3 months)		0.500	
		Fab. Training abroad (3x3 months)		0.250	
		Packaging Training abroad (3x3 months)		0.250	
4.	Building	Extension of existing building for MEMS	5.000		
		HVAC for MEMS facilities	5.000		
Total (Million Rs.)			12.000	23.500	35.500

PART 'C'

PROJECT REQUIREMENTS

26. (a) Manpower:

		For Execution	For Operation
I.	Regular project staff	**Man Month (Over one years)**	**Number**
(i)	Professional and technical	One P.D.	**20(Pool)**
(ii)	Admin, Executive .	01	**04**
(iii)	Clerical	01	**03**
(iv)	Service	01	**04**
(v)	Skilled	01	**03**
(vi)	Unskilled	01	**03**
	Others	**Nil**	**01**

All the above staff will be provided by AERO from its own manpower

II Consultants

(i) Local

(ii) Foreign **1-2**

The manpower will partially be paid by AERO, Islamabad.

c) Give list of employment to be generated by gender

Equal opportunities on merit

d) Give manpower required during the first year of the implementation of the project. Give details of specific skills required (scientist, lab/field workers, technician etc) separately for male and female and their grades.

Not being asked for

d) Likely shortage of manpower by occupation

? ***Experts in MEMS and ASIC Design***
? ***Experts in MEMS and IC Fabrication***
? ***Experts in MEMS Packaging***

e) Steps to be taken to assure availability of manpower

Manpower to train new personnel is available in NESCOM. Scientists or Professors within NESCOM and from other research institutes or national universities will be hired if exists a requirement and will be paid by AERO.

f) Approximate number of persons required to be trained per year (locally and abroad) and the kind of skills to be learnt.

10-15

27. Civil works:

a) Total covered area of the building (basic for determining the space requirements) along with Line-plans, number of stories, etc.
6,400 Sq. Ft.

b) If houses provided, their number and categories along with covered area and Line-plans
N.A.

c) Size of the plot on which a building/houses are to be constructed viz the percentage of open and constructed area.
80 Ft. X 100 Ft.

d) Give description of already completed or under construction building/houses viz the new proposed construction.
N.A.

e) Existing water supply and sewerage arrangement in the area as well as for the present project

Project will use already existing water supply and sewerage arrangement in the area

f) Unit-cost supported by item-wise detailed estimates of the building/houses, separately for civil-works, water supply, sewerage other utilities including HAVAC(if present), external development, etc**.**
Attached at Annex "B" & "B-1" respectively.

g) Percentage of contingencies, departmental charges and escalation based on based-cost.

Covered in estimate

28. Physical and other facilities required for Project:

Items from	Total	To be provided from the itself	To be provided the public utility

(a) Power Supply
(b) Water and other utilities
(c) Education facilities by type
(d) Others

The Sector is already developed by AERO, NESCOM. Infrastructure exists. The cost of the above works is included in the estimates.

29. Materials, supplies and Equipment Requirement:

A-1 Minimum total requirements during execution:

To be completed only for major items costing more than10% of the total cost.

Item	**Units**	**Local**			**Foreign**			**Already available with the Agency**
		Quantity	Unit rate	Cost	Quantity	Unit rate	Cost	

1. Material
   (a)
   (b)
   (c)
   (d)

The above materials are covered in capital cost at Para 13

2. Supplies and spares
   (a)
   (b)
   (c)

3. Equipment and machinery
   (a) Attached at Annexure "A" with "Appendix-1"
   (a) Computer Software/Hardware Prices are attached at "Appendix-2"
   (c)

A-II Materials, spares and supplies and equipment for operation of project

Item	Units	Local			Foreign		
		Quantity	Unit rate	Cost	Quantity	Unit rate	Cost

1. Materials
   (a)
   (b)
2. Supplies and spares
   (a)
   (b)

30. In the case of imported material and equipment for execution, indicate:
   (a) Justification for imports

   The equipment indicated in Para 25 is a highly sophisticated technology that is not available in the country. No vendor within the country can provide equipment for any process for MEMS fabrication. There are very few countries in the world which provide these processes. Hence the only way to set up a MEMS fabrication facility inside the country is to import this equipment.

   (b) Proposed source/sources of supply
   Quotations from National Electrostatics Corp. USA through email

   Open/Limited/Single source tendering from Europe, USA, Asia

Materials and Supplies **(See Appendix-I for Details & Cost)**

Annex-A

- ? **Gases**
- ? **Chemicals**
- ? **Photo masks**
- ? **Silicon Wafers**
- ? **Spares**

Equipment and Machinery

Equipment Required for Fabrication

- ? **Double sided mask aligner**
- ? **Deep Reactive ion Etcher**
- ? **Oxide Etcher**
- ? **Metal Etcher**
- ? **PECVD System**
- ? **Quartz Ware**
- ? **Critical Point Dryer**

Equipment Required for Packaging

- ? **Anodic Bonder**
- ? **Thermal Fusion Bonder**
- ? **Dicing Machine**
- ? **Wire Bonding Machine**
- ? **Encapsulation**

Equipment Required for Testing

Meteorology

- ? **Microscopes**
- ? **Profilometer**
- ? **Ellipsometer**
- ? **Nanoidenter**

Electrical Test

- ? **Electrical Characterization meter**
- ? **Hi resolution LCR meter**
- ? **Probe station/microscope**

Existing Equipment (IC Fab. being established)

- Soft bake and hard bake ovens
- Wet Chemical hoods for developing rinsing
- Wet etcher/wafer cleaner
- Wet and Dry Oxidation Equipment
- 4 Horizontal Quartz furnace tubes (700-11500C)
- Oxygen tanks, hydrogen tanks, diborane tanks, phosphine (POCl3)
- BN disks
- 2-4 horizontal tubes at 600-8000C
- CVD low temperature oxide, silane, nitrous etc
- Thermal Evaporation System
- Sputtering System

Annex 'B-1'

COST ESTIMATE FOR LOCAL HVAC WORKS

BOQ Item No	Description of code	Unit	Qty	Total supply+Installation	
				Unit(Rs)	Amount(Rs)
1	2	3	4	5	6
1.	Package type AC units	Each	4	400000	1600000
2.	Ducting and sheet metal work	SM	180	680	122400
3.	Volume Dampers	SM	2	3900	7800
4.	Flexible Duct Connections	SM	2	500	1000
5.	Piping and Fittings				
	a. Galvanized Iron	Lot	1	30000	30000
6.	Filters other than installed in Packages Units	SM	20	8000	160000
7.	Insulation	Lot	1	550000	550000
8.	Electrical components and controls				
	a. MCC & ACPS(Supplied by the contractor)	Lot	1	1200000	1200000
	b. Variable Speed Drives	Lot	1	1500000	1500000
	c. All Electrical works as per specs	Lot	1	500000	500000
9.	Temperature and Auto				
	a. Electrical and control components	Lot	1	250000	250000
10.	Air inlets and outlets	SM	7	9386	65705
11.	Instrumentation and gauges	Lot	1	100000	100000

12.	Tools	Lot	1	30000	30000
13.	Painting and Identification Services	Lot	1	500000	500000
14.	Oil and Greases	Lot	1	45000	45000
15.	Inspection, Testing and commissioning	Lot	1	75000	75000
16.	Essential Local Spare Parts	Lot	1	75000	75000

Contingencies 5% 238095

Total Rs. 5.000 million

Annex 'B'

COST ESTIMATE OF BUILDING EXTENSION FOR MEMS FACILITIES

Covered Area 6,400 sq.ft.

S/No	*Description*	*Total Years*					
		1st Year (Million Rs)		*2nd Year (Million Rs)*		*3rd Year (Million Rs)*	
		Local	*F.E.C*	*Local*	*F.E.C*	*Local*	*F.E.C*
1.	*Civil Works*	*2.90*					
2.	*Plumbing Works*	*0.70*					
3.	*Electrical Works*	*1.40*					
4.	*HVAC for local HVAC rooms*	*5.00*					
Total		*10.00*					

In words Ten millions only.