MECHANICAL ENGINEERING – WEAK-HEARTED OR UNDERVALUED

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ABSTRACT

Serious concerns expressed by the academic community over the plight of Mechanical Engineering industry and the apparent failure of University programmes to meet the challenges posed are discussed. The question is posed whether it is the vicious cycle formed by weak industry supported by unimaginative academic programmes, which in tern are fuelled by the former. An effort is made to identify salient characteristics of performing Mechanical Engineering academic programmes and the growth drivers along with the characteristics of performing Mechanical Engineering Industries and their growth drivers through an analysis of domain leaders and to extend these for the local context. We try to discover a meaningful role for the mechanical Engineer in charting a development path for Sri Lanka. Bold steps for an aggressive programme to force a reverse flow of high value-added industrial products is proposed with details from a topical sector. Inability/inflexibility of policy makers to respond positively to turns of events in the country's socio-economic context is seen as a major obstacle to rapid industrial growth. We try to demonstrate how these constitute more important preoccupations for us than for industrialised countries. In this context [Fletcher, 2000] describes the constant pressure on course developers of the West thus, "the significant involvement of mechanical engineers in the development of new technologies, and in turn, the impact of these technologies on the world economy suggests that mechanical engineering education programs must be modernised to reflect the needs of the future. ... Mechanical engineering education programs must accommodate the changing technological and industrial environment and continue to provide a forum for intellectual growth in the next century." "The traditional science-based theory courses, which are likely to be a part of engineering for the coming decade, give us engineering analysts. However, practice-based, well-implemented design and manufacture courses, give us the additionally important "professional component" of mechanical engineering [Henderson, 2000]."

1. INTRODUCTION

Serious concerns expressed by the academic community over the plight of Mechanical Engineering industry and the apparent failure of University programmes to meet the challenges posed are discussed. The question is posed whether it is the vicious cycle formed by weak industry supported by unimaginative academic programmes, which in tern are fuelled by the former. An effort is made to identify salient characteristics of performing Mechanical Engineering academic programmes and the growth drivers along with the characteristics of performing Mechanical Engineering Industries and their growth drivers through an analysis of domain leaders and to extend these for the local context. We try to discover a meaningful role for the mechanical Engineer in charting a development path for Sri Lanka. Bold steps for an aggressive programme to force a reverse flow of high value-added industrial products is proposed with details from a topical sector.

2. WEAK MECHANICAL ENGINEERING INDUSTRY

Here we are, in particular, interested in local industry that could be supportive of Mechanical Engineering education. At a first level of analysis, sectoral composition of industrial product in the GDP can be attempted (table 1).

In 1998, the services sector, which accounts for 52.8 percent of GDP, increased by 5.2 percent. The manufacturing sector grew by 6.3, compared with growth of 9.1 percent in 1997. The manufacturing sector's share of GDP was 16.5 percent, about 44 percent of which is textiles, apparel and leather products.

Strong performance of domestic market oriented industries contributed heavily to growth in 1998. Performance in the export oriented manufacturing industries was mixed.

Manufacturing

The textile, apparel, and leather products sector is the largest industrial sector and accounted for 44 percent of industrial output. This sector grew by 4.5 percent in 1998, a significant slowing down from the 18.7 percent growth in 1997. Garments, mainly exported to the U.S. and Western European markets, account for about 32 percent of manufacturing employment and 46 percent of total exports. There are 860 garment factories in operation. The exporters faced a shortage of U.S. quotas towards the end of the year. The unexpectedly high utilization of certain fast moving categories of U.S. textile quotas prompted the Sri Lankan Government to temporarily stop issuing textile visas for the affected categories of exports. The U.S. is the main export market for Sri Lanka's apparel exports, taking 60 percent of all apparel exports. Data indicate an increase in higher value added items to the U.S. About 77 percent of exports to the U.S. are under quotas. Sri Lanka's textile and apparel industry will need to invest heavily in technology and skills to face increased competition when quotas are fully phased out in 2005.

Growth in other major industrial sectors was mixed. The second largest industrial sector, food, beverages and tobacco, contributed 24 percent of industrial output and grew by 9.6 percent, compared with 3.4 percent growth in 1997.

Two other major industrial sectors, chemicals, petroleum and rubber products sector and the nonmetallic mineral sector, grew by 13.1 percent and 5.1 percent, respectively.

The smaller fabricated metal products and machinery industry grew substantially, by 10.7 percent following a growth of 19 percent in 1997. This sector contributes 4 percent of GDP.

The Government is encouraging production of selected goods for which the country is believed to have a comparative advantage. A range of special incentives is now given for investments in these selected "thrust" industries:

--electronics and components for electronic assembling
--ceramics and glassware
--rubber-based industries
--light and heavy engineering
--cutting and polishing gems, diamonds and manufacture of jewellery.

Manufacturing sector growth had slowed to 3.3 percent in the first quarter of 1999 from 7.7 in 1998 due to a decline in demand for a range of Sri Lanka's exports including processed rubber, coconut, fiber and ceramic, leather and food and beverage exports. Textile and garment exports, which have grown rapidly in the past, had increased by just one percent in the first four months of 1999.

Services

Services, which account for 53 percent of GDP, grew by 5.3 percent in 1998.

The communications sector, boosted by increased private sector participation, continued to grow strongly by 46 percent following a 33 percent growth in 1997.

Electricity sub sector also grew sharply by about 10 percent in 1998. Increased thermal capacity following the addition of 51 megawatts of new thermal capacity to the national grid and increased hydropower generation were the main factors contributing to increased electric power generation.

Growth slowed in banking and the insurance sector to 6.4 percent from 10.3 percent in 1997. The decline in external trade constrained the profitability of the banking sector. The stock market downturn also caused portfolio losses in the banking sector and eroded the profitability of stock brokering firms.

The communications and power sectors were buoyant in 1999, contributing markedly to service sector growth as a result of increased private sector participation.

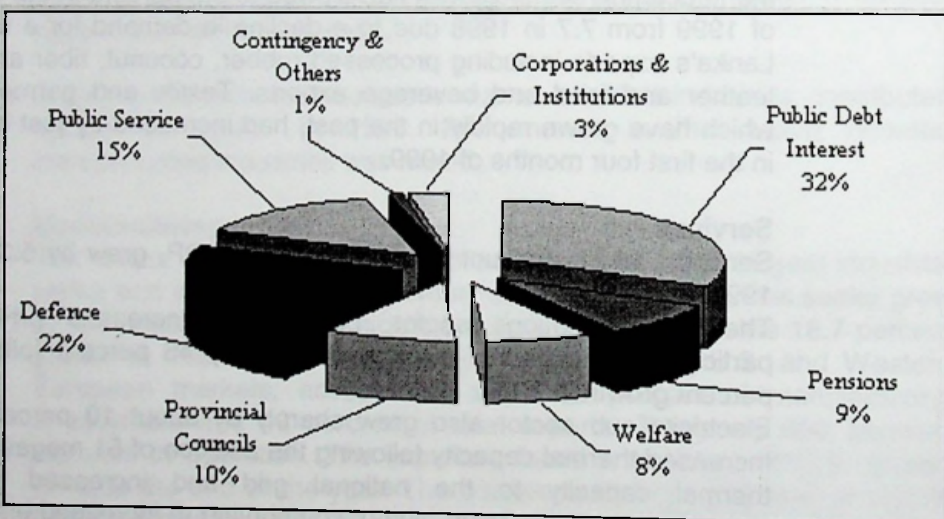
Port services declined in 1998 and the trend has continued into 1999 due to increased competition from regional and Middle Eastern ports. The recent transfer of transshipment traffic from Colombo to Port Raysut in Salalah, Oman by two of the main users of the port, Sea Land and Maersk Shipping Lines, is a major cause for concern.

KEY ECONOMIC INDICATORS

	1990	1995	1996	1997	1998	1999(a)
REAL OUTPUT (percentage change)						
GNP	6.2	6.0	3.2	6.8	4.6	3.8
GDP	6.4	5.5	3.8	6.3	4.7	4.3
Agriculture, Forestry and Fishing	8.8	3.3	-4.6	3.0	2.5	4.5
Mining and Quarrying	9.1	3.4	8.9	3.8	-5.4	4.1
Manufacturing	9.4	9.2	6.5	9.1	6.3	4.4

GDP (PPP): $16.6 billion (2000)
GDP growth rate: 5.6% (2000)
Defence spending: $1.05 billion (2000)

COMPOSITION OF RECURRENT EXPENDITURE – 2001



It is worth noting that the total Manufacturing sector's share of GDP was at 16.6% in 1998 whereas the Defence expenditure for the same year was at 5.6% of GDP. By 2000 defence expenditure had risen to 6.3% of GDP and it is ever rising. This provides some indication of the potential contribution that a viable defence industry could make to the manufacturing sector. Again the impact of such thinking becomes evident when we consider that the total public investment in 1998 amounted to just 6.7% of GDP. Public investment is concentrated on vital economic infrastructure such as power, ports, telecommunications, water supplies and roads development.

An estimate of the relative strength of our manufacturing sector could be obtained through a comparison of the total Dollar value of manufacturing sectors, country-wise: $ 1.0 billion for Sri Lanka (2000) as compared to S$ 23 billion for Singapore (1999). This, without doubt, leaves much to be desired in the manufacturing sector. The mechanical/manufacturing sub-sector of this industry has proven to be lacking in direction during the whole of 53 year post-independence period: a period long enough to cripple the industry for a long time to come, unless well founded strategies are formulated without delay, which appear to us to need some very bold thinking. The fact that defence expenditure has become a fact of life seems to provide some latitude for the development of manufacturing sector.

3. CHARACTERISTICS OF A PERFORMING MECHANICAL/ MANUFACTURING INDUSTRY

A performing Mechanical/Manufacturing&Service (M/M&S, for short in the suite) industry will find support in the economic and policy framework of the country. A sustained and reliable commitment by policy makers is imperative. The cases of Israel, Korea, Taiwan, Singapore provide ample testimony (some relevant aspects of their industries will be discussed in the following). High degree of market assurance and control have always been the dream of any industry and a performing industry often has the characteristic of having a natural customer base. In the context of Sri Lanka there are several major M/M&S industries at the virtual grip of external entities (at times, absurdly enough, monsters created by these very same industries) which have total control over their markets. This is an aspect which needs greater and in depth analysis, however, for the purpose of the current paper a mere statement of these issues is considered adequate.

3.1 Growth Drivers

Ready access to competitive technology, trained personnel, capital availability, infra-structural support and growing markets are important growth drivers for M/M&S industry for the current discussion. Of course there are others related to fiscal, taxation, legal and political environment. Their interplay is complex and merit in depth analysis, which is best left for later work. The approach taken in the current study is the historical analysis of a carefully selected example. The example is considered appropriate since it provides a case of building a formidable industry starting from rags, under exceptionally difficult circumstances, within fifty years. The facts are presented in their chronological order without any attempt for interpretation or value judgement. The objective is to present them in unadulterated form to permit the reader to form the necessary linkages: this approach is adequate for the current study.

When the state under consideration, Israel, was formed in 1948 it had a few small, underground workshops manufacturing and repairing various types of small arms, ammunition, armoured vehicles, and other types of military hardware (known as Israeli Military Industries). These were founded around 1933. The principal reason for their decision to build a domestic military industry was survival [NAAZ, 2001].
In the early 1950s, these independent and often overlapping workshops were brought under a single management and incorporated into military concerns. Among these new entities were the Israel Aircraft Industries (IAI) originally known as Bedek or the Institute for the Reconditioning of Planes, and the National Armaments Development Authority (RAFAEL). Hence, during the decade, the effort was concentrated inside the armed forces and in the state owned establishments. (IMI, Rafael,and IAI.) Israel slowly acquired a greater degree of self sufficiency in small arms and mortars and showed an ability to modify and overhaul tanks, aircrafts and even electronic systems.

In the early 1960s attention was directed to building up the electronic industry and by 1965, the country had reached defence production capability not only in small arms but in aircraft and electronics as well. Thus the main emphasis in the first two decades of the new was on the establishment of modern military production lines.

Besides the manufacture of arms, mainly ammunition, mortars and small arms, Israel was also assembling French planes and other weapons systems, on a limited basis and was itself producing certain parts for these systems.

Activities upto the 1967 war included maintenance and upgrading of existing platforms, production of Second World War style conventional armaments and the development of some advanced systems.

After 1967 due French arms embargo they embarked on an all out policy of self-sufficiency trying to develop and produce all its defence needs. This sense of urgency to achieve independence from foreign suppliers led the country into an unprecedented industrial revolution, the main thrust of which was directed towards the manufacture of military equipment.

Money previously invested in France and other foreign countries was diverted to local munitions firms. And by the time France declared its second arms embargo in January 1969, Israel was domestically producing most of the items that were withheld. In the first three years after 1967, the military industry quadrupled its output. Research and Development intensified and the independent design and manufacture of major subsystems came to be favoured over licensing or co-production arrangements involving foreign companies. The period of major investment in the defence industrial sector also took place between 1968 and 1972. The number of persons employed by it rose by about 20,000 during that time. In those years the purchase of weapons system from local industry underwent a real growth of approximately 86 per cent. Metals and electronics were the chief beneficiaries and they absorbed about 1/3 of industrial investments.

By 1972, Israel was producing a domestically designed combat jet with a speed of Mach 1.2 as well as its own armoured fighting vehicle. Three years later, it introduced what is now commonly known as the Kfir C-2, fighter jet, the most sophisticated fighter ever manufactured in any developing country. As marketing began for its own air-to-air missile and sea- skimming infrared missiles, work was being done on a new generation of supersonic cruise missiles. Then in 1981, the new Barak anti-missile, missile defence system was unveiled. Israel also designed and developed its own battle tank, 'Merkava', which has an armour so advanced that shells fired by a World War II tank would simply bounce off it. Highly computerised and carrying twice the amount of ammunition as other tanks , the Merkava also has an explosion suppression system, developed by the Israeli firm Spectronnix. The Merkava uses an inert agent to stop an explosion within 60 milli seconds before burns are caused.

In fact the list continues into an impressive array of advanced defence systems. By 1981, Israel had unlimited potential in the military, industrial and security fields and was able to produce everything it needed to protect itself.

Now, this illustrates how an industry could grow in extreme adversity. Without making any value judgements on the political aspects, we try to explore the best course of action available under the constraints set by larger social issues. In a way it is an effort to see how adversity could be turned into an opportunity to develop a key sector of the economy.

4. UNIMAGINATIVE ACADEMIC PROGRAMMES IN MECHANICAL ENGINEERING

The current needs stemming from Mechanical/Manufacturing & Service industry, which is not in a particularly developed or strong position, do not seem to warrant much imagination from the part of curriculum developers in mechanical engineering. The singular cry from M/M&S industry, over the past couple of decades have been the need for skilled technicians capable of putting their set of equipment/machinery to better use. Though a cry worthy of being heard and acted upon (already being attempted with varying degrees of success), the dynamic created does not seem to be strong enough to prompt mechanical engineering educational establishment to develop strong research programmes/laboratories or disciplines that could give a kick-start to a crippled industry.

Also, the lack of sufficiently rich industry-university interaction in M/M&S has a retarding influence on the development process of this discipline in universities. The much-needed industrial training in the formation of a mechanical engineer cannot be assured at an acceptable level.

5. CHARACTERISTICS OF A STRONG MECHANICAL ENGINEERING ACADEMIC PROGRAMME

Cross-breeding between university and M/M&S industry is without doubt the most important of these characteristics. Others are related to the availability of specialist faculty, active linkage programmes with similar programmes elsewhere and strong research programmes.
In this context, we can gain some insight from some related work reported in [HENDERSON, 2000] where they list skill sets for engineers in various phases of their careers from engineering student to a point of leadership 10 years after graduation. Although this table was created in 1997, it is largely still current.

CAREER PHASE	FUNCTION	TECHNICAL COMPETENCE	LEARNING & CURIOSITY	PRACTICE
ESTABLISHED PROFESSIONAL 10 + YEARS OUT	* Marketing & sales * Product engrg. * Specialist * Project engineer * Educator * Interdisciplinary * ***Knowledge mgr*** * ***Systems integrator*** * ***Process design mgr***	DEPTH * Solves analytical probs. * Project specific appl. * Specific tools * Expert in communications ***plus company experience and "best practices"***	* Personal contributions * Deep & broad investigations * Serendipitous discoveries * ***International contacts*** * ***Understands cultural issues and international business methods***	* Understands what's possible * Drives to results * Anticipates problems & opportunities * ***Serves on diverse international teams*** * ***Effectively uses info. technology***
ENTRY LEVEL BS DEG.	* Design engineer * Analyst * Field engineer * Process engineer * Mfg. engineer * Grad student * ***Systems analyst*** * ***Info. Manager***	BREADTH * Classical physical laws * Design application * Tools competent * Effective communicator * ***Info technologies, knowledge bases and simulation technologies***	* Extra curr. activities * Exposure to diversity * Street smart * Self initiated discovery * ***Interna'l experience*** * ***Cultural awareness*** * ***Entrepreneurial exposure***	* Sound assumptions * Gets linearized results to real problems * Not intimidated by engineering problems * ***Uses diverse sources of info.*** * ***Balances theory & empirical info***
ENGINEERING STUDENT	* Self motivated learner * Team member * Citizen of university community * ***Manages own education process***	* Strong aptitude and interest in math & sciences * Some exposure to real products * ***Computer strength*** * ***Aware of physical systems***	* Extra curricular activities * Seeks cultural diversity * Self initiated discovery and exposure to physical phenomena * ***Participates in service opportunities***	* Problem solver * Familiarity with fundamental principles * Makes things * ***Participates in product development and international education experiences***

NOTE: This abbreviated table is from a report of the ECGREE Workshop at November 10-11, 1997 at The Boeing Company, Mesa, Arizona and Jordan Cox of Brigham Young University is credited with drafting the original version of it.

Table 1: VISION OF ENGINEERING IN 2010 (Attributes of the 90's in regular font, *attributes of the early 21st Century in bold italics*)[7]

Their final recommendations for a mechanical engineering department are as follows (to be considered as a good starting point in the development):

§ Competition requires mechanical engineering departments of the future, like industry, to be flexible and responsive to opportunities and needs of the changing world market for graduates.

§ Use the process suggested by ABET and involve all of your stakeholders to create a vision for your department. This vision should enable your students to excel at the product realization process once they enter industry.

§ Once the department vision has been created, work at getting the reward system for existing faculty and the hiring decisions for new faculty in line with fostering the realization of the desired vision.

§ Students must have some hands-on practical experience in at least one complete product realization process.

§ "Virtual factory" concepts must be made more typical in the curriculum.

§ More practice-oriented experiences can and must be included within the curriculum and the learning environment.

§ Effectively use modeling tools for dynamics, thermal, mechanics, material and behavior systems shared in a networked and collaborative environment toward better products.

§ Develop scenarios such as model laboratories, design immersion, teaching factories and virtual manufacturing which support an integrated vision of the product development process.

§ Exercise every opportunity for student learning to take place in ways that reflect the variety of learning styles and that combine the brain, body, and emotion.

§ Change the department into an effective organization where the new requirements are an integrated part of the way teaching, research and industrial collaboration are performed and that reflects strategies to recognize the changing needs and expectations of your customers (students, research funding organizations and industry).

Again, this aspect needs closer scrutiny, but left for a later study. Our emphasis here is on discovering means by which these academic programmes could be brought back to life. The current level of analysis permits us to conjecture the urgency of discovering alternate means of establishing a facilitating environment, which will be relevant in the current developmental/policy context of the country. Given the key role that the development of M/M&S industry plays in this issue and given the present circumstances of the country, there seems to be a very strong case for exploring the possibility of a defence industry which, mostly is a mechanical engineering affair. In this context we need emphasise that we should not be so weak-hearted as to fail to see the emerging potential for mechanical engineering. These possibilities may be of still greater importance and interest to national policy makers, considering other national issues.

6. JUSTIFICATION FROM A NATIONAL POINT OF VIEW

Quite apart from the benefits to M/M&S industry and Mechanical Engineering education, the prospect of a strong defence industry can have far reaching National implications. To enable a country to follow an independent foreign policy, and make its own decisions, it needs, among other capabilities, a relatively strong and sophisticated defence force. A strong local defence industry deployed in support of the National defence force is a considerable advantage. Defence forces which have to buy their equipment from foreign suppliers have significant disadvantages, while those which are supported by their own local defence industry have significant advantages, which include the following:

Maintenance of equipment and systems can be carried out locally by the supplier. This decreases downtime and improves operational availability with commensurate cost savings. In times of urgent need, the supplier is available to carry out required maintenance and repairs.
Modifications and developments to improve availability and performance can be effected when necessary, creating more cost-savings.
Surprise in battle can be achieved, as capability is unknown to the enemy. The technological capabilities and systems, e.g. mine protection technology, are not known by a potential enemy, which makes it much more difficult for such a potential enemy to develop countermeasures and tactics.

With a local defence industry, it is possible to keep systems in service much longer than the normal life expectancy of such systems, due to effective maintenance programmes and life extension developments. These have achieved enormous reductions in cost, as many systems would have had to be replaced, if this capability had not been available.
Defence forces can never achieve the same in-depth technical knowledge and skills that are available in an experienced industry, due to promotions and service conditions. The average experience of Air Force mechanic, for example, is less than three years, compared to about fifteen years in industry. The technological strength of any defence force lies in its supporting defence industry.
With a properly structured local defence industry, it is strategically easier and more efficient to gear the National defence force to counter a heightened threat.

The National defence force would become sophisticated clients as a result of their exposure to the local industry. Because of their technical and operational expertise and experience acquired through this exposure, they would have learned what and how to specify, what can possibly be expected, and how to evaluate offers. This ensures that cost-effective purchases are made. [Hatty, 96]

7. SOME NEW TOPICS FOR MECHANICAL ENGINEERING CURRICULUM

Based on the above discussion and a short survey the author conducted, a few typical subjects relevant to arms industry could be listed. This is done purely for illustrative purposes and is not to be considered as a complete list. Detailed curriculum development in these lines needs careful consideration of the constraints particular to the country.

Armament Engineering track

This technology track would provide an interdisciplinary graduate education in Armament Engineering. The program would emphasise systems engineering of military weapons from concept through development and field use. Technical disciplines in the design and manufacture of explosives, modelling and simulation of the interior and exterior ballistics, rocket and missile design, guidance and control, modern research instrumentation, and testing procedures are to be emphasised.

ME 01 Ballistics, Theory and Practice

The ballistic regimes, simple piezo ballistics, Corner's analysis, Frankle-Baer simulation, interior ballistics interactive simulation, comparison of models, projectile design practice, cannon design practice, exterior intermediate ballistic regimes, flight trajectories, terminal ballistics, numerical simulation of impact and fragmentation.

ME 02 Theory of Performance of Propellants and Explosives I-II (first and second semesters)

These two courses would deal with the theory, performance, and life-cycle applications of propellants, explosives, pyrotechnics and advanced warhead and propulsion systems. Topics could include:

Physical and chemical principles which govern the characteristics, performance, and design for use of energetics and advanced warhead and propulsion systems;

Current theory to explain stability, sensitivity, combustion, detonation, initiation, power, shaped charge effect, and flash and smoke formations;

calculation procedures to estimate performance of energetics and warhead and propulsion systems;

modern instrumentation and test procedures for material and system evaluation.

ME 03 Ordnance Engineering I

Program could be designed to treat system engineering of military weapons from concept through development and field use;

technical disciplines in explosives, chemical and atomic;

propellants, interior ballistics and stresses, closed breech, recoilless and rocket weapons are studied and integrated for application to entire systems;

system philosophy and application of subjects such as statistics and probability and research and development of commodity could be developed.

ME 04 Ordnance Engineering II

Program to be designed to treat system engineering of military weapons from concept through development; exterior and terminal ballistics including drag and trajectory criteria in air, water and dense media; projectile, bomb, rocket and missile design including criteria and fundamentals of stress computations; penetration and fragmentation theory; fundamentals of design of fuses; artillery, nonrotated, time, VT and barometric fuses.

ME 05 Principles of Naval Architecture
Basic principles and design calculations in naval architecture; terminology, delineation of hull form, loading and stability, trim and effects of flooding; freeboard and tonnage regulations; introduction to design of hull structure; nature of resistance and its variation with hull form and proportions; introduction to propellers and propulsion. Basic theories in maneuvering and sea-keeping characteristics, computer application in naval architecture and ship design.

ME 06 Computer-Aided Aspect of Naval Architecture
Basic principles and design calculations in naval architecture as an extension of ME05 PNA course with emphasis placed on the application of computers. Computer-aided studies of hull-forms, intact stability, damaged stability, resistance and propulsion characteristics, course-keeping analysis, ship motion predictions. Problems in the area of naval architecture to be considered on computers through time-sharing systems.

ME07 Laboratory in Naval Architecture
Solution of problems in naval architecture through model testing, actual conduct of a wide variety of model tests, prediction of prototype performance.

As to qualified personnel for developing these subjects, the relevant institutions will have to draw up appropriate strategies.

8. TYPICAL ARMAMENT COMPANY

Again, for illustrative purposes we give the profiles of two developed (hypothetical) armament manufacturing companies.

Armament Manufacturing Company X (AMCX)
AMCX would be a technical engineering and management services firm. It would provide services in acquisition support, computer aided design, environmental safety & health, HSMS, information technology, ordnance engineering, system safety and training.
Gun/projectile design, cartridge actuated devices, propellant actuated devices, warhead development, energetic propellant processing, solid rocket motors, gun propellants, explosive handling, insensitive munitions testing/analysis, weapon system safety.

Armament Manufacturing Company Y (AMCY)
AMCY could be a privately owned corporation specialising in the design, development and testing of complex mechanical and hydro-mechanical systems: design, development and testing of weapon systems ranging from 20mm rapid fire rotary barrels and ammunition handling systems to

203mm howitzers. This includes both towed and self-propelled weapons and all their associated subsystems including complete vehicle and turret designs, recoil energy recovery, traversing, elevation, equilibration, loading and handling mechanisms as well as the design of the ammunition. Energy recovery systems, which harness some of the recoil energy to power selected hydraulic devices, have been successfully designed and employed on both 155mm and 203mm weapons; state-of-the-art weapon systems design and development specialising in providing fast reaction and a rapid turnaround whilst developing innovative solutions to solve design problems.

CONCLUSION

We refrain from drawing any particular conclusion. The facts seem to speak for themselves. There seems to be a great opportunity and to turn it to something more concrete we certainly would need bold thinking and proper valuation of the potential of Mechanical Engineering in the development of this country.

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