Inflatable Marine Safety Equipment

Low Weight and Cost System using Microcontroller Technology

Polymarine Ltd

Associated TTN: UGCS Ltd
AE Abstract

Polymarine Ltd have manufactured and supplied inflatable products for the marine safety and survival applications for over 20 years. The company now employs 9 people and has sales of 1.1 MEURO. The company’s product range includes complete inflatable craft as well as specialised components for these systems. The company’s products are based on the use of a variety of mechanical manufacturing processes, and the company had no experience in the area of microelectronics.

The company markets mechanically activated inflation system for inflating marine safety and survival products such as Liferafts, Lifejackets, Inflatable Marine Escape Systems and Emergency Buoyancy Systems. The inflation systems for these products traditionally have used compressed gas for inflation. The gas is released in an emergency by a mechanical actuator and valve system. The weight and size of these gas cylinders is a major disadvantage when used in weight sensitive applications such as commercial and military aircraft.

Polymarine have developed a new patented, inflation system which uses a chemical gas generator to advantageously replace the traditional compressed gas supply systems. The objectives of the Application Experiment was to produce a low cost and low weight inflation system for survival applications. The microcontroller incorporates in the improved product performed the following functions:

- to actuate these gas generators in response to several sensor inputs.
- to operate several gas generators in a predetermined sequence to maximise the buoyancy of the inflatable.

The development of the microcontroller-based gas generator will result in an unique and class-leading patent protected product. The use of the gas-generator will have a significant impact on the survivability, and offer a lower cost and weight solution. These advantages will lead to increasing sales and profits for the company.

The cost of the development work supported under FUSE funding was 34 KEUR. The development of the prototype required 8 months to complete. The payback period for these prototype development costs is 27 months.

The return on investment on the costs of prototype development is estimated at over 1,290 % over the product’s 10-year patent protected lifetime.
AE Signature and Keywords

AE Signature:

2 0121 555 0320 2 2513 1 35 UK

Keywords:

Marine Safety
Liferafts
Lifejackets
Gas-generators
Microcontroller
1. Company name and address

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2. Company size

Polymarine Ltd achieves sales of typically 1.1 MEUR per annum and employs 9 people in total. The company is owned by the Directors and is not part of a larger group.

3. Company business description

Polymarine design, manufacture and assemble, and sell products and services to the inflatables industry for over 20 years. During this time the company has been a major manufacturer and supplier of raw materials, components and associated equipment required by the inflatables industry. The company’s product range includes complete inflatable craft as well as specialised components for these systems, including products such as Liferafts, Lifejackets, Inflatable Marine Escape Systems and Emergency Buoyancy Systems.

Industrial Sector: Marine Equipment (Prodcom Code 35)

4. Company markets and competitive position at the start of the AE

Polymarine, is a supplier of specialised equipment for marine safety and leisure inflatable craft. It has traditionally operated within the UK and Europe, and has more recently expanded its operation to include export to the rest of the world. The company has a very well respected position within the marine safety and survival industry despite its relatively small size in comparison to the overall industry size.

The global market for marine safety products is valued at approximately 400 MEUR per annum. This market is a very mature market with products based on mechanical solutions that have been well established for many years.

Within this total marine market, the market for marine safety inflatables using compressed gas inflation systems is made up approximately as follows:-
## Lifejackets

<table>
<thead>
<tr>
<th>Description</th>
<th>MEUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflatable lifejackets general/leisure</td>
<td>15</td>
</tr>
<tr>
<td>Inflatable lifejackets offshore and shipping etc (SOLAS)</td>
<td>7.5</td>
</tr>
<tr>
<td>Inflatable lifejackets aviation</td>
<td>12</td>
</tr>
<tr>
<td>Inflatable lifejackets military</td>
<td>22.5</td>
</tr>
</tbody>
</table>

## Liferafts

<table>
<thead>
<tr>
<th>Description</th>
<th>MEUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflatable liferafts general/leisure etc</td>
<td>15</td>
</tr>
<tr>
<td>Inflatable liferafts SOLAS</td>
<td>120</td>
</tr>
<tr>
<td>Inflatable liferafts military</td>
<td>75</td>
</tr>
</tbody>
</table>

## Marine Offshore Aviation escape systems

(including special platforms and inflatable escape systems etc.) 120

## Inflatable boats and other special applications using gas inflation (and also would include gas inflated buoyancy and capsize/self-righting equipment etc) 15

The company’s main competitors all currently supply mechanical valve inflation systems to the marine safety industry. The following list identifies these competitor organisations.

- Life Support Systems Inc.
- Halkey Roberts Corporation
- Henco Corporation
- Nippon Tansan Gas
- Thanner
- Kiddie Gravener Ltd

Most of these companies are located in either the USA or Japan, and the main supply of the associated technology is dominated by these Japanese and US manufacturers.

Most of these products use very similar technology, and competitive position is linked to cost and delivery performance. Polymarine occupy a very small share of its markets (<1%).

The typical cost of a 4 to 8 man raft, which uses the existing mechanical inflation system, ranges from 1.5K to 3.0 KEuro. The percentage of the company’s turnover, which uses the existing inflation mechanism, is approximately 5%.

The particular strengths of Polymarine’s products, which contain the existing inflation mechanism, are as follows:

- Proven reliability over many years of experience
- Certified to international marine safety standards
- Highly regarded by marine operators and emergency services
- Competitively priced.
The sales history of products containing the existing inflation system is shown in the following graph as percentage levels of 1996 sales revenue:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>100</td>
<td>112</td>
<td>125</td>
</tr>
</tbody>
</table>

Table 1: Sales History of products containing existing gas inflation mechanism
(revenue relative to 1996 expressed in %)

The objective of the application experiment is to produce an improved inflation system that meets a number of market trends including:

- ‘Fit and forget’ systems requiring longer inspection intervals and reduced maintenance costs.
- Systems that automatically maintain a defined inflation pressure. This is difficult to achieve using mechanical systems, which are subject to freezing temperatures as the gas is released.
- Inflation systems that avoid the use of cooling gasses.
- Reduced space and weight requirements. A lightweight, compact system is required for items such as pilot lifejests that are stored under the seat.

5. **Product to be improved and the reasons to innovate**

The company supplies a range of inflation control and delivery systems for a range of inflatables which can extend from a lifejacket with a volume of some 10 litres, to an inflatable rapid escape system with a volume in excess of 10,000 litres. Currently all of these systems use stored compressed gas cylinders to inflate these structures.

Polymarine designs, manufactures and markets and distributes a range of such marine safety and survival equipment, including buoyancy aids, safety harnesses, life jackets and liferafts. These systems require the application of a Gas Inflation Cylinder Valve Operating Head Assembly, which controls the flow of gas from the gas cylinder into the inflation chamber.

Photo 1 - Illustration of Typical Life Raft and Inflation System
In common with industry wide products, the use of compressed gas systems controlled by the Gas Inflation Cylinder Valve Operating Head Assembly with its mechanical actuators suffer from the following problems and shortcomings in marine safety and survival products:-

- They are relatively very heavy. For example on a High Speed Vessel the cylinders and mechanical actuation systems for a marine escape system can weigh as much as 6 tonnes per system.
- They are bulky and large in stowed volume.
- Their performance is very badly affected by cold, with freezing of the mechanical operating systems and valves. Inflation performance can often be very slow or inflation can be totally obstructed.
- In cold climates they reduce survival potential through accelerating hypothermia. Typically the Carbon Dioxide gas filling the inflatable structure is at -70°C which worsens the effect of cold on the survivors and will accelerate death through hypothermia.
- They require frequent servicing because of the danger of gas leakage from the compressed gas systems and because of the potential deterioration of the mechanical activation systems and valves etc, in the hostile marine environment.
- They only operate on mechanical activation, often using multiple valves and extensive piping to fill the various chambers and parts of the inflation system. Large inflatable structures have to inflate in sequence in order to function correctly. This leads to additional expense, a bulky system and considerable danger of human error in assembly.
- There is very limited potential for introducing a range of different sensors to initiate the inflation and this restricts the potential application of such inflatable structures.

The objective of the application experiment is to replace the gas cylinder and Gas Inflation Cylinder Operating Head Assembly by a gas generation system. This will allow the company to meet a number of market trends that provides the opportunity to innovate a new product that meets customer needs for:

- ‘Fit and forget’ systems requiring longer inspection intervals and reduced maintenance costs.
- Systems that automatically maintain a defined inflation pressure. This is difficult to achieve using mechanical systems, which are subject to freezing temperatures as the gas is released.
- Inflation systems that avoid the use of cooling gasses.
- Reduced space and weight requirements. A lightweight, compact system is required for items such as pilot lifevests that are stored under the seat.

<table>
<thead>
<tr>
<th>Parameter to be Improved</th>
<th>Current Product</th>
<th>Improved Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>-</td>
<td>50% reduction</td>
</tr>
<tr>
<td>Volume</td>
<td>-</td>
<td>50% reduction</td>
</tr>
<tr>
<td>Inflation Sequences</td>
<td>Manual</td>
<td>Automatic</td>
</tr>
<tr>
<td>Activation</td>
<td>Mechanical</td>
<td>Mechanical and Electrical Sensors</td>
</tr>
<tr>
<td>Multi-chamber capability</td>
<td>Centralised</td>
<td>Distributed _ with electrical synchronisation</td>
</tr>
</tbody>
</table>

Table 2: Parameter Improvements Realised by Gas Generator System

The cost of a current gas inflation system, comprising a gas cylinder and a Gas Inflation Cylinder Operating Head Assembly, is typically 375 Euro. The application experiment’s objective is to replace both of these items by a gas generation system at a cost reduction of at least 70%.
6. **Description of the technical product improvements**

The aim of this Application Experiment was to design and develop an improved gas inflation system using a microcontroller device in order to actuate gas discharges from the ignition of gas generators. The gas inflation system is similar in principle to that used in current automotive air bag systems. However, the gas generants utilised for this marine safety system differ from that used in automotive applications because of the chemical and thermal characteristics of the gasses generated.

The microcontroller assembly in the improved gas inflation system replaces the traditional mechanical actuation and valve system used in marine and aero safety and survival equipment to control the rate of gas generation and the gas flow. The electronic controller has been designed to satisfy the following requirements:

- To actuate a gas generator in response to several possible sensor stimuli (such as a water sensor, accelerometer, or manual trigger).
- To operate several gas generators in a predetermined sequence to maximise the buoyancy of the inflatable.

Typically, a gas generator is made up of a number of gas emitting sections, each one being controlled in sequence. The sequencing of the gas emitting sections is required to ensure that the initial inflation of the folded rubber materials in the inflatable lifevest or raft is controlled so as to allow the unfolding of the unit during the inflation process, and thereafter to maintain the inflation pressure of the system.

The microcontroller controls the activation of these individual gas emitting sections when used in multiple gas generator systems. For example in a lifejacket there may be two gas generators filling a double chamber lifejacket, whereas in a marine evacuation system there could be as many as 50 or more gas generators.

The gas generators are electrically initiated by discharging a capacitor to provide a peak current of 8 amps. The capacitor will only be charged as part of the arming sequence in order to ensure that the gas generators are fired only when required. The system is operated from a 3V battery supply.

The functions performed by the microcontroller device include:

- Monitoring of the sensor inputs. The microcontroller is configured to normally operate in a low power mode, but the activation of any sensor input ‘wakes’ the microcontroller and starts the inflation timing sequences.
- Generate the internal timing signals, and when the pre-programmed timing intervals are reached to actuate the gas generator firing signals. The firing pulses are controlled via logic driven MOSFET devices.
- The control of the arming signal only when a manual override or sensor activation signal is detected.
The removal of the existing mechanical activation and valve system will reduce the size and weight of the final product, and allowed the company to target new markets such as the aviation market where these benefits will be highly valued by customers.

The improved inflation system incorporates re-programmability to allow the firing sequences to be adapted for the particular requirements of life vest, life raft, and escape slide applications.

**Figure 4: Simplified Block Diagram**

**Photograph 2: Illustration of the Prototype Circuit Board**
A typical firing sequence is defined in the following table.

<table>
<thead>
<tr>
<th>Sequence Step</th>
<th>Input / Sensor</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manual Over-ride or Acceleration</td>
<td>ARM SYSTEM</td>
</tr>
<tr>
<td>2</td>
<td>Water Activation Or Manual Over-ride</td>
<td>Fire Primary Charge</td>
</tr>
<tr>
<td>3</td>
<td>Internal Gas Pressure Or Temperature</td>
<td>Fire Top Up Charges</td>
</tr>
</tbody>
</table>

Table 3: Typical Gas Generant Firing Sequence

7. **Choice and rationale for the selected technologies, tools and methodologies**

Since the arming of the controller and sequencing of the gas generators is specific to a particular marine safety and survival application (life jacket, life raft, escape chute etc.) then it was necessary for the selected technology to offer a modular, programmable solution.

The attributes required were identified as follows:

- Ability to interface to a range of analogue and digital ‘triggering’ sensors
- Simple reprogammability to enable a common module to be used for different inflation products
- Extremely low power consumption required for battery operation, over an ‘in service’ life of several years before the module is replaced.
- Immunity to false triggering from RF coupling or other electromagnetic radiation.
- Simple, low cost solution to promote high reliability.
- The ability to be able to build ‘intelligence’ into the device to control timing functions and make decisions based on the status and combination of trigger inputs.

The selection of a modular, programmable solution using a microcontroller had several advantages and was therefore selected for this application. The functional design of the improved Gas Inflation system relied upon the use of control modules comprising one microcontroller device initiating the actuation of four gas generators. The use of several interconnected modules to realise more complex products has been selected as the preferred system architecture because:

- The single unit can meet the low cost demands for lifejacket systems.
- The modular structure with its built in redundancy improves the system availability performance for complex systems such as life rafts and emergency escape chutes.
- The use of standard modules allows rapid configuration of gas generators for new applications, and reduces unit cost through higher volume procurement.

The implementation of the improved Gas Inflation system using discrete digital and analogue devices did not allow this design philosophy to be accommodated. The need for several timing intervals to be programmed, and for sequences to be logically altered to meet each specific application area would inevitably have lead to a dedicated solution or the use of a high number of on board switches which would have increased the size and cost of the unit. The size limitation for the controller module was determined by the need to fit the unit conveniently into a life jacket. Discrete solutions did not allow the implementation of a controller in this volume, and therefore discrete solutions were unacceptable on the grounds of cost, size and flexibility.

FPGA or CPLD design solutions would potentially reduce the number of packages required for the implementation of a ‘hard wired’ logic controller. However, these devices tend to have many more I/O pins than were required for this application, and are relatively large in terms of package size compared to the lower pin count microcontrollers. Design flexibility was also less achievable with this technical solution when compared to microcontroller device solutions. FPGA / CPLD solutions were therefore rejected. ASIC design solutions were also rejected for similar reasons, and because of the higher Non Recurring Engineering (NRE) costs associated with the development of this technology.

Microprocessor and microcontroller device technology solutions were identified as clearly representing the best technical solution for this application. Since the control sequences required in the improved Gas Inflation Cylinder Valve Operating Head Assembly system were relatively simple, the demands on the control processors were minimal, and this low level processing requirements meant that the optimum device required in this application was a low cost, 8 bit single chip One Time Programmable (OTP) microcontroller device.
The factors influencing the selection of the microcontroller were therefore low cost and small package size. The microcontroller has to operate through an operational temperature range from -40°C to +60°C. The industrial version of the selected microcontroller met these environmental requirements adequately.

The packaging limitations for the electronic assembly are limited by the size requirements imposed to meet needs of the life jacket application. Initial assessments indicated that the use of a double sided surface mount assembly configuration allowed the electronics assembly to be accommodated within the available space envelope. *Multi chip module (MCM) packaging* technology was not required for this application as the design can be accommodated using surface mount methods, and because a high proportion of the space is determined by passive components (capacitors, pull switches etc). The microcontroller is now packaged in such a way that it will withstand the hostile marine environment and a "sealed for life" disposable, encapsulated unit is envisaged.

The development of the microcontroller code used assembly language programming. The relative simplicity of the functional requirements for the device did not require the use of higher level programming.

The microcontroller code development was carried out using an EPROM version of the selected microcontroller. The software was simulated using the free assembler development tools provided by the device manufacturer, and once considered to be operational the object code was blown into the device for testing. The straightforward linkage between inputs and outputs made debugging of the code relatively simple. The code testing and development consisted of several iterations of this design process. The prototype circuit board utilised the EPROM version of the PIC 16 C 57 device. The final circuit board device will use the OTP (one time programmable) version of the device.

**8. Expertise and experience in microelectronics of the company and the staff allocated to the project**

The company’s design and manufacturing experience is limited to the areas of mechanical systems design and the development of technical solutions based on new materials. The company has no electronics design experience, and has no manufacturing or assembly experience with microelectronics.

The company does employ a senior technician with some exposure to marine electronic systems, primarily in the area of marine engine electronic systems repair and maintenance. These skills will be further developed during this application experiment. This individual does not possess any formal qualifications in microelectronics, but has over 15 years experience in marine maintenance.

**9. Workplan and rationale**

The workplan consisted of the following major activities:

**Training:**

The company’s technician engineer attended a training course in the area of microcontroller hardware and in assembly language programming provided by the training supplier. The programming training also allowed the technician to familiarise himself with the use of the software build and simulation support tools.

In addition the technician engineer was provided with some on the job training by the design subcontractor throughout the application experiment.
Technical management training was supported by the on the job advice and guidance of the TTN, and a capability to manage electronics design subcontractors was successfully developed.

**Specification:**

A brief for the prototype was prepared by the company from the information developed as part of the feasibility study. The specification outlined the basic functional requirements for the equipment.

This brief was developed into a formal specification for the improved product by the company’s Technical Manager in conjunction with the subcontractor. The subcontractor provided reviews of the documents, and guidance as to its completion. By this process of collaboration and discussions the specification was developed to define the detailed requirements for the prototype system.

**Hardware Design:**

The hardware design was conducted in two distinct phases. The initial phase involved the systems design and initial hardware design. The design subcontractor, in conjunction with the company technical manager, developed an optimum modular system implementation for a range of inflatable product applications. This design phase led to the development of the interim hardware design solution based on the use of a low cost 8 bit microcontroller, and MOSFET switches to control the discharge arming and firing sequences.

The objective of this initial design phase was to provide a circuit board capable of demonstrating the basic functionality of the system; the power saving features and timing refinements (both of which relied upon hardware – software interactions) were demonstrated in the second phase.

The initial prototype circuit board was developed using an EPROM version of the microcontroller, and the flexibility of the re-programmability of this device resulted in its use throughout the application experiment. The OTP device will be used in the final industrialisation phase.

The subcontractor conducted the circuit board layout design, and undertook the technical lead in all aspects of the hardware and software development. The company technician engineer assisted in the construction, and test of the hardware design.

**Software Design:**

The software design task involved the development of an overall software design using simple flow charting methods, and the coding and evaluation of the software. The task was led by the company engineer, with the company technician being provided training in the development methodology applied, the development tools and simulation facilities available, and in the downloading of the code into the prototype board using the programmer, and the final debugging process thereafter.

The final software development task was the development of the “sleep mode” for the microcontroller in which the device entered a low power consumption state. This development task was left until the end to simplify the testing of the functional code, and to thereby de-couple the “wake up” procedure testing from the rest of the code testing. This final task was undertaken entirely by the subcontractor.

**Circuit Testing:**

The circuit testing comprised of an initial circuit board test, using a cut down version, of the final software in the embedded microcontroller, to prove the functionality of the microcontroller. This testing was performed using simple switch inputs to simulate the actuation of various sensor inputs to
the controller, and by the monitoring of the output signal changes and the timing of these. No igniters were used for these tests.

**Prototype Testing:**

The testing of the prototype unit utilised a development test rig, constructed to contain a series of test gas generator charges, to simulate the inflation of the inflatable chambers. The development of the test rig was conducted jointly with the subcontractor. A four chamber inflation system was conducted successfully.

The knowledge transfer process was carried out in a number of ways:

- Training in general forms of microelectronics by the TTN so that a rational decision could be made on the preferred choice of technology, in this case microcontroller. The majority of this training tool place before the FUSE application experiment was submitted.
- Formal training delivered by the subcontractor on microcontroller architecture, theory and programming techniques.
- ‘Hands on’ training in the microcontroller design process in conjunction with support from the subcontractor.
- Regular meetings with the TTN which provided alternate guidance in areas related to the Technical Management of the project.

The time schedule for these tasks is illustrated in the following chart. The work program was conducted on schedule, and largely to plan. Only minor deviations in the timing plan occurred. The time deviations in the work plan are attributed to the following factors:

- A longer than anticipated time to develop the product requirements specification was required. This enabled the company to consider other parallel activities, including the concurrent development work related to the mechanical design of the product.
- The development task was undertaken with the final power saving circuit implementations postponed to the final stages of the development, and after the basic functionality of the prototype unit was proven. This reduced the potential for problems caused by the inter-linking the functionality and power saving design considerations inherent in the original hardware development followed by software development plan originally envisaged.
- Field trials were postponed until suitable packaging solutions were available. Realistic field evaluations, involving immersion tests, required a final encapsulated and mechanically reliable design. This packaging activity was conducted in parallel with the AE, but was not available in time. Hence the field trial demonstrations were postponed.

The resources used in the application experiment are summarised in the following table:

<table>
<thead>
<tr>
<th>Description</th>
<th>Planned Company (days)</th>
<th>Actual Company (days)</th>
<th>Subcontractor Costs (kEURO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>15</td>
<td>8</td>
<td>1.64</td>
</tr>
<tr>
<td>Specification</td>
<td>28</td>
<td>23</td>
<td>2.92</td>
</tr>
<tr>
<td>Design</td>
<td>74</td>
<td>27</td>
<td>12.39</td>
</tr>
</tbody>
</table>
Table 3 Workpackage Costs

The main deviation from plan in terms of the budgeted and actual costs for the application experiment was in the area of company design costs. This was due to the fact that one of the company’s technicians left the company during the period of the application experiment. Although this person was not directly involved in the application experiment, his loss meant that the company members involved in the development were unable to entirely de-couple themselves from day to day company affairs. This is reflected in lower than planned on the job training costs, again related to reduced on the job design training. However, a significant Technical Management capability has been developed which allows future industrialisation and replication activities to be conducted.

The company however, fully engaged in all other elements of the workplan. Reduced evaluation costs were related to the postponement of the field evaluation because of the need for a final packaged solution to be provided; the evaluation costs in person days were to plan when this factor is considered.
| ELAPSED WEEKS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
|---------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Microcontroller Training - plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| System Specification - plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| Systems Design - plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| Hardware Design- plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| Microcontroller S/W Design + Coding - plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| Initial Circuit board Test - plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| Prototype Testing - plan |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| actual        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | |
| Field Trials - plan | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 3: Panned and Actual Schedule of the Application Experiment.
10. Subcontractor information

Polymarine had no experience of selecting an ‘electronics design’ subcontractor, and so obtained advice from the TTN as to how to select a suitable partner. The ‘agreed’ criteria that formed the basis of the selection process included the following:

- Extensive knowledge of designing ‘safety critical’ systems which involve electronic controls or actuators.
- Experience of designing products that operate in a highly regulated framework, for example military systems, aerospace or marine safety systems.
- Knowledge and experience of designing electronic modules that are required to operate in extremely harsh environmental conditions, and are considered to be ‘fit and forget’ items.
- Extensive knowledge and practical experience of designing ‘high reliability’ modules containing microcontrollers, analogue and digital interface circuitry, and multiple sensor inputs. The ability to be able to guarantee fail-safe operation and near 100% reliability of electronic actuation modules that are generally left unattended for many years was essential.

The final choice of subcontractor was a company called Q Par Angus, a company with proven expertise in electronic designs, as well as military project experience. The company had the necessary design expertise as well as microelectronic technology knowledge to support Polymarine during the application experiment.

The subcontract agreement between Polymarine and Q Par Angus covered the following issues:
- A list of agreed deliverables and timescales.
- ‘Ownership’ of the design rights.
- Fixed-price development costs.
- Standard terms and conditions appropriate to a contract of this nature.

The sub-contract was satisfactorily concluded, and the work plan was fairly accurately adhered to.

11. Barriers perceived by the company in the first use of the AE technology

Polymarine supply inflatable products for the Marine Safety and Survival industry, and have previously developed skills in the area of mechanical systems and materials selection for inflatable products. The company had no experience in the area of microelectronics, and as such the company faced several barriers to implementing microcontroller technology for the first time.

The barriers foreseen by Polymarine included:

i. A lack of knowledge on the capabilities of electronic device technologies and the potential of these for solving specific problems, thereby limiting the ability to specify new products. The inability to translate ‘ideas’ into complete Technical Specifications produces a high level of perceived risk for a small company such as Polymarine.

ii. A lack of technical knowledge in the areas of microelectronic device selection and evaluation, circuit design processes, and microcontroller hardware and software development. This knowledge gap provides a major barrier to the company, presenting formidable obstacles in terms of the development of costed development plans and the
determination of economic success. The lack of confidence produced by this inability to forecast the results of microelectronic developments means that companies in Polymarine’s position tend to avoid investing in the technology.

iii. A lack of management skills necessary to manage the technical aspects of an electronics product development. The inexperience of the management in microelectronics reduces its confidence in its ability to manage the risk inherent in development programmes.

iv. A psychological preference to invest in well known areas. The availability of finance for new developments in a company of Polymarine’s size is always limited. This factor means that the limited resources available are normally invested in well understood technological solutions to minimise the risks involved in these investment decisions.

v. A lack of experience in dealing with electronic subcontractors exists in the company. The company was therefore concerned as to the potential for cost and delivery problems when dealing with more knowledgeable subcontractors. The financial impact should such problems occur were a significant concern to the company, and perceived as a major risk.

12. Steps taken to overcome the barriers and arrive at the improved product

The company’s non-microelectronics background meant that the original knowledge development barrier was only addressed through its initial contact with the TTN, and the preparation of technical solutions as part of the TTN’s support process provided Polymarine with the initial knowledge to develop its original concepts further. This support enabled the company to limit the level of risk through the choice of inappropriate technical solutions, and by developing an initial understanding of the capability of microcontroller device technology.

The major technical gap in the understanding of the selection and development routes for the microcontroller circuit implementation was overcome in stages. The initial stage was the preparation of the feasibility study for the application experiment, which identified the costs of both the prototype product and of the related development activities. It also provided an initial work plan for the company, which provided the basis for later sub-contract stage payments and deliverable negotiations. The later stages of knowledge development included formal training on microcontroller technology, and training provided by the sub-contractor throughout the development programme.

The risk of incorrect management approaches in this unknown technical area was greatly reduced by the presence of the TTN as a guidance source throughout the application experiment. This allowed reference to independent technical advice if required.

The financial barrier was reduced when the benefits of the application experiment were more clearly understood after the knowledge of the development costs was confirmed as part of the feasibility study. The psychological risk of undertaking a development programme in an unknown technology area was also significantly reduced by the support mechanisms offered by the TTN, and the collaborative working relationship with the subcontractor. The fact that the development programme was being monitored by a knowledgeable third party provided the reassurance that the outcome of the application experiment would be successful.

The barrier formed by the lack of experience in operating with electronics subcontractors was reduced by the presence of the initial development plan which provided guidance on the delivery time scales and costs for these prepared in the initial feasibility stage. An initial joint meeting with the TTN
and subcontractor also provided further guidance, which led to the preparation of a sub-contract document. Whilst this in itself was not guarantee of success, the initial liaison process resulted in mutual understandings which meant that relationships with the subcontractor were good.

13. **Knowledge and experience acquired**

The company expected to develop several new technical and managerial skills in conducting this application, including:

*Technical Management Skills, including:*

a) An understanding of the development programme phases for electronic design programmes, and the ability to define key deliverables during these development programmes.

b) An ability to perform cost and time estimation for microcontroller based product developments. This included the provision of contingency plans for identified risks.

c) The ability to identify and manage electronic subcontractors, including those required for prototype and full production manufacture of electronics products.

*Design and Development Skills, including:*

i. Knowledge of microcontroller devices and the design of circuits based on these devices.

ii. Knowledge of electronic system design methods, and the ability to partition design function to major electronic modules cost effectively.

iii. Skills in the area of microcontroller based product design, including the ability to design digital and analogue interfaces for these devices.

iv. Software programming skills, including the ability to undertake software systems design and conduct software amendments without subcontractor support.

v. Knowledge of microcontroller development methods and the ability to use microcontroller development support CAD tools.

vi. An ability to define appropriate test methods for microcontroller based systems, including the ability to define production test methods for these systems.

At the end of the Application Experiment, the company had acquired the Technical Management skills anticipated. The company has also acquired knowledge of the microcontroller development process, and is capable of maintaining the microcontroller system developed. However, the company has not developed a capability to independently undertake future development activities. In retrospect it is apparent that the company, which had no microelectronics expertise needs the full time allocation of staff to the project development to assimilate this knowledge; circumstances related to staff resignations prevented this from occurring. The company has however, achieved a significant technology increment and will continue to develop this capability in the future.

14. **Lessons learned**

As the application experiment has progressed the company has acquired experience covering both managerial and technical issues. Of particular note are the following:
Technology
The success of the application experiment has depended on the selection of the correct technology to implement the sequential firing that is fundamental to the whole project. It is microcontroller technology that has allowed this to happen as planned. Whilst this technology is new to the company and had not previously figured in its development plans, it is now realised at various levels just how important this technology is. It is apparent that for small companies like Polymarine Ltd this technology needs to be given a high profile as it can provide an answer to many problems. The company suggests a company contact a support or sign-posting organisation to review the potential for microelectronics technology in their products.

Planning
The initial planning exercise was greatly helped by the early meeting between representatives of Polymarine Ltd, the TTN and the sub-contractor. Because of the lack of technical knowledge within the company it would have been difficult to gauge the timescales of realistic deliverables without this pre meet.

It is advised that such meetings be held prior to the start of any new technology project with a third party support agency so as to allow a clear set of goals and a common understanding to be developed. This benefits the progress of the application experiment thereafter.

Team Working
All members of the project team as well as a key member of our technical staff, none of whom had any previous experience in microtechnology have been involved at some stage during the application experiment. This has been particularly true of the project technical manager and a one of our technical operatives. The big plus from a sales and marketing view point was the broadening of the product potential that the microtechnology brought to it.

Other potential first users of microelectronics technology are advised to conduct regular monthly review meetings involving all team members, and informal project meetings at a more regular basis be held. This has allowed all aspects of the product development to be considered, and has been a key aspect of avoiding project overruns.

Business benefits
The successful introduction of microcontroller technology into the gas inflation project has undoubtedly increased product potential and has broadened the scope of application. This has in turn increased potential market and subsequent customer base. It will increase flexibility in product design and allow the company to offer bespoke products to fit customer requirements. The introduction of microelectronics into the "psyche" of company personnel will certainly bring future rewards.

The company advises others considering microelectronics technology to seriously consider the investment. The costs have been demonstrated not to be excessive, and the return on investment is therefore reasonable.

Time Pressures
The pressure of unrelated day to day business operations on the staff allocated to new technology projects must be entirely removed. The learning curve requires full time concentration on the technology to be adopted. Scheduling of alternative staff to cover this work in this period is essential.

15. **Industrialisation and internal replication**

A prototype sequentially fired, gas generant, inflation delivery system has been produced and successfully tested. A number of successful test firings have been undertaken.

The internal replication potential for this prototype development lies largely in the application of the technology to a wide range of inflation systems for marine survival. These systems will be configured to meet each customers needs using the modular microcontroller system architecture.

The manufacture of the final production circuit board will be sub-contracted. The company’s development plans did not anticipate the in-house manufacture of the circuit boards because of the lack of manufacturing skills in this area, and the investment costs required. The prototype products produced by the sub-contractors who will be contracted in the future to produce the first production run for our anti-capsize gas inflation system.

Larger production runs for higher volume product delivery systems will need to be manufactured elsewhere. We are having preliminary discussions with a company who are already manufacturing traditional compressed gas delivery systems; they are keen to quote for new generated gas delivery systems. This company has the expertise to produce the microcontroller units.

The remaining stages to industrialisation are therefore:

- Development of layout for one time programmable circuit board using surface mount technology. (month 1)
- Confirmation testing and evaluation of code in OTP device (month 2).
- Finalisation of manufacturing sub-contractor selection and negotiations (months 1 – 5)
- Finalisation of the chemical gas generant composition and charge (months 1-4)
- Finalisation of packaging design, including preliminary trials (months 1-4)
- Full field trials and demonstration to safety standards (months 4 - 8). This will provide results required to market the product.
- The preparation of new marketing information (months 7-8).

The schedule anticipates an 8 month industrialisation period, and industrialisation costs of approximately 60 KECU. Sales are anticipated in Q2, 2000.

16. **Economic impact and improvement in competitive position**

The market for marine safety and survival equipment is expanding, due to the increasingly strict requirements placed on marine safety by such organisations as the USA Coastguard in America.

The company has identified four application areas where the company will first use the microcontroller to replace mechanically activated valve systems. These applications are chosen on the basis of positive comments and feedback from the customers, and because of possibility of gaining a competitive advantage in the shortest timescales.
In the identified applications a range of technical and commercial advantages have been gained by the application of microelectronics technology. These include:

- A considerable reduction in weight and size,
- A reduction in unit cost.
- The overcoming of functional and operational problems which exist with current cold gas inflation systems.

The basis of selling the improved Gas Inflation system will be to offer the improved system at a comparable price to the current competitor system on the basis of the several additional benefits to the final user, including advantages in performance, weight and volume savings, reduced servicing costs etc. Using the cost structure for the life jacket as the determining factor, the projections of cost savings for the improved system indicates an unit cost saving of over 10%.

The company’s sales projections for the improved system on completion of the application experiment are indicated in the following chart. The delay in large volume sales is related to the obtaining if various equipment type approvals in different markets.

The company believe that within 5 years they will have been able to secure 5% of the market share world-wide of inflation control systems. This will be aided by the company’s patent protection.
The impact on sales turnover is illustrated below.

![Chart 1: Sales Revenue Growth as a Result of Adopting Microcontroller Technology](image)

Based on the current profit margins achieved by the company, and the increased levels of sales achieved by the improved product the company projects a payback period of approximately 27 months on the prototype development costs of 34 KECU. The relatively long payback period is due to customer evaluations in the first year after launch.

The return on investment on the costs of prototype development is estimated at over 1,290% over the product’s 10-year patent protected lifetime. Industrialisation costs are estimated to be approximately 60 KECU.

17. **Best practice and target audience**

The company’s experiences in the application experiment have demonstrated best practice elements in specification, especially in developing a modular system architecture to maximise re-usability, and workplan development and management. These aspects of the application experiment will be of interest to the target audience of Managing Directors and Technical Managers of small and medium sized companies operating in the marine and safety product manufacturing sectors. In addition a large number of non-microelectronics companies will also be interested in the company’s experiences in adopting microcontroller technology for the first time.

The target industry sectors are therefore:

- Marine Vessels and Products (Prodcom code 35).
- Marine and other engine repair and maintenance services (Prodcom code 2915)
- Safety items manufactured using rubber etc. (Prodcom codes 24 and 25)