# Ruggedising Off-the-Shelf Computers for Military Applications

## ABSTRACT

The computing performance and technology of commercial consumer computers are typically more advanced than military computers. Increasingly, military computers need to achieve higher performance due to the use of modern command and control systems in a network-centric battlefield. While there is a desire to enable the quick adoption of leading-edge computer technologies, it is also essential to ruggedise computers for military applications to ensure that they survive harsh operating environments. These computers must allow ease of upgrades to remain operational and technologically relevant throughout their expected life cycle.

This article examines the traditional approach to devise technologically advanced but cost-effective ruggedised computer solutions. It proposes a 'cocoon' approach to facilitate the use of the latest commercial computers as an alternative for the military operating environment.

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## INTRODUCTION

Tactical command and control systems such as the Battlefield Management System operate on military computers under demanding environmental conditions in the land theatre of operations. The computer hardware has to be ruggedised and specifically designed with protection measures to withstand external environmental effects and rough handling.

During the selection of suitable computers, there are competing requirements (e.g. high processing speed versus low heat dissipation) to manage. System trade-off analysis is often conducted to ensure a cost-effective solution. Military-grade computer systems generally lag behind commercial off-the-shelf (COTS) systems in terms of the level of technology and computing performance. On the other hand, most COTS systems are not designed to withstand the typical military operating conditions. Thus, it is a challenge to adopt leading COTS computer technology with adequate ruggedisation for military applications.

It is an increasing trend to deploy COTS computers in military environments to reduce cost, improve performance, and accelerate system development cycles (Keller, 1997). In the use of military computers, there are other important requirements such as the ability to deploy the system quickly, as well as the ease of managing obsolescence and implementing upgrades. All these requirements drive the review of traditional ruggedisation solutions, for a new approach to develop ruggedised computers that are more cost-effective and technologically competent.

This article proposes a ruggedisation development framework as well as a 'cocoon' approach. The framework leverages and adapts from a repository of known ruggedisation solutions to reduce lead time in development of a new solution. The key concepts and 'solution patterns' (i.e. the optimal approach to address common problems) in the repository are explained in this article. The 'cocoon' approach advocates the quick insertion of COTS computers with higher computing performance in keeping with technology advancement. An illustration of the development of a ruggedised system solution for a land platform highlights several considerations (e.g. communication medium and applications) in the development process.

## REQUIREMENTS AND CHALLENGES OF MILITARY COMPUTERS

Most military computers have to comply with a series of environmental qualification tests (see Figures 1 and 2) before they can operate in the targeted land platform. It is crucial to understand the operating environment to ensure that suitable protection measures are in place for the military computer. A generic solution may not be effective as each military platform may have unique characteristics to be considered.

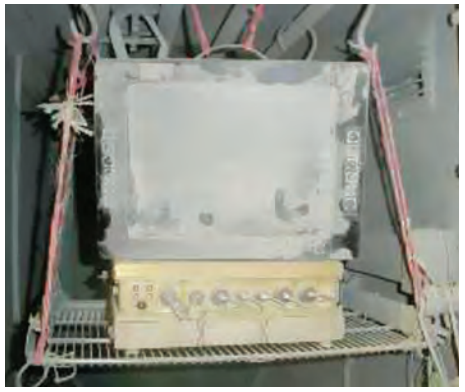

*Figure 1. Sand and dust test*

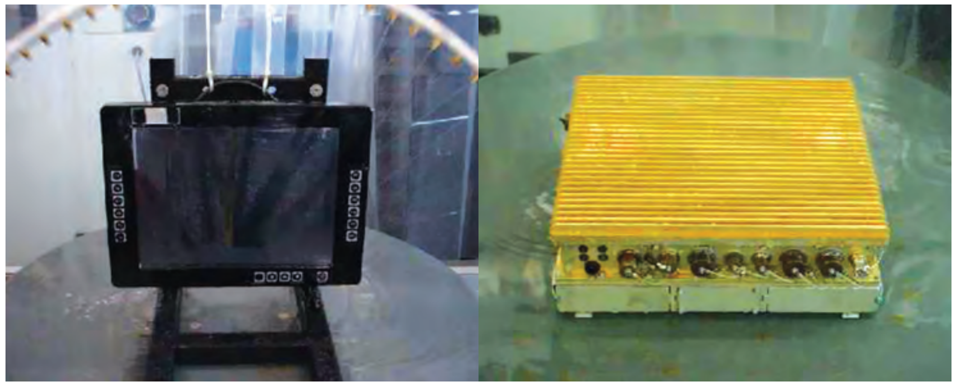

*Figure 2. Spraying water test*

To ensure that military equipment survives during operational use, transportation and storage, there are stringent standards (e.g. MIL-STD-810E and IP54 standard) to comply with and tests to be conducted (MIL-STD-810E, 1989; American National Standards Institute, 2004). It is prudent to examine applicable military standards in relation to actual operating requirements. Military standards may require the system to operate under extreme temperatures ranging from –40 to 85 degrees Celsius, but this temperature range may not be relevant to the expected actual operating conditions which typically range from 0 to 50 degrees Celsius.

### Shock and Vibration

Shock tests, vibrations tests and drop tests may be conducted to ensure that the equipment can survive harsh treatment and remain operational, without incurring mechanical damage. In shock tests, the equipment typically receives up to 40g of shock for a duration of 11 milliseconds in both directions and in the three axes i.e. transverse, vertical and longitudinal. These parameters for shock tests are also applicable to vibration tests, where devices are used to excite the structure of the equipment. Finally, during drop tests, the equipment is made to drop from a specified height to the ground.

### Temperature

The equipment has to operate within the temperature range of 0 to 50 degrees Celsius and be stored within the temperature range of 0 to 65 degrees Celsius. Thermal management takes into consideration the effects of computer heat and condensation caused by sudden changes in temperature. The requirement for sealed enclosures to shield the equipment from the elements, such as electromagnetic interference, dust and water ingress, is another challenging aspect of thermal management.

### Electromagnetic Compatibility

The targeted equipment is in the vicinity of other computing or communications equipment in a typical land platform. Thus, to ensure that there is no interference between the equipment and other devices, electromagnetic compatibility (EMC) effects need to be measured at various test points. It may be necessary to subject the equipment to electromagnetic effects, in order to observe if there are undesirable effects such as malfunction or damage to the equipment.

### Other External Environmental Factors

The equipment must be able to withstand other external environmental factors such as sand, dust, humidity and water. For example, the equipment has to be protected from the ingress of dust and harmful deposits. To guard against equipment malfunction, the equipment has to be insulated against water seepage.

Other than the harsh environmental elements and operating conditions (such as vehicle vibration and shocks from weapon firing), other key considerations in ruggedising a military computer include:

a) Space constraints in a land vehicle

b) Obsolescence management – parts need to be designed for easy replacement and upgrade when obsolete

c) Evolving requirements for better hardware specifications in view of new commercial computing products

## COMMERCIAL OFF-THE-SHELF COMPUTERS

Desktop and mobile COTS computers offer faster Time-to-Market (TTM) with new product releases. Besides being lighter in weight and lower in cost, COTS computers are also widely available in the market (McKinney, 2001). Additionally, they have better performance specifications with faster Central Processing Units (CPU) at lower prices compared to military-grade computers. However, COTS computers are not designed for military field usage.

Military-grade computers are well protected to endure outdoor deployment and harsh environmental conditions. The protective measures and customisation for the development of military-grade computers incur high costs and may result in dependency on proprietary parts for maintenance and future upgrades. Figure 3 summarises the characteristics of the three categories of computing devices.

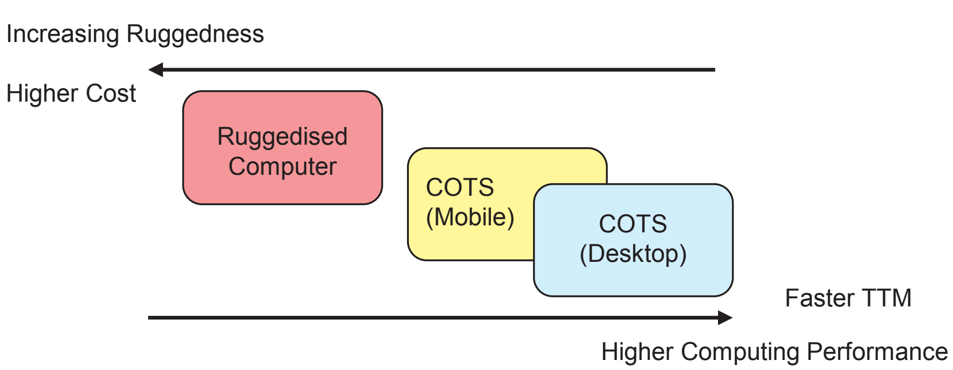


*Figure 3. Characteristics of different computing devices*

While some COTS products are certified to certain military standards, it does not necessarily mean that the products are suitable for use in military environments. To establish a product's level of ruggedness according to military standards, comprehensive tests which are often not included in the specifications of COTS products (see Table 1) have to be conducted.

The operating environment has a huge impact on the choice of computing system and the level of ruggedisation required. To leverage rapid technological advances in COTS products, a realistic operating environment must be carefully defined for the adoption of a COTS product with specifications that match the military-grade systems.

## TRADITIONAL RUGGEDISATION APPROACH

The traditional ruggedisation approach was re-examined based on ongoing projects. Feedback from key industry players was collated through a survey on selected projects. Solutions implemented in the projects can range from fully ruggedised solutions, to semi-ruggedised solutions which combine ruggedised chassis and internal COTS computing components. The findings from the survey provided insights and perspectives with respect to the considerations and challenges faced in typical ruggedisation efforts.

| STANDARD | EQUIPMENT THAT IS FULLY RUGGEDISED FOR MILITARY USE | EQUIPMENT THAT IS SEMI-RUGGEDISED FOR INDUSTRIAL USE | COTS PRODUCTS |
|---|---|---|---|
| MIL STD* 810G certified | Yes<br><br>Meets the most stringent profile of MIL-STD 810G standards<br><br>Usually for moving operations on tracked vehicles | Yes<br><br>Meets the low ruggedisation profile of MIL-STD 810G standards<br><br>Usually for transportation or wheeled vehicle operations | No |
| MIL STD 461 certified | Meets the MIL-STD 'Ground Army' (Electronic Warfare) EMC performance levels | Meets the MIL-STD or slightly enhanced EMC performance levels | No, usually meets Federal Communications Commission standard |
| Dust and moisture resistance | 'Good' to 'higher' levels of dust and moisture resistance (IP65-IP67) | 'Good' to 'higher' levels of dust and moisture resistance (IP54-IP67) | Usually not a requirement |

**MIL STD: MIL-STD 810G is a Military Standard that describes specifies broad range of environmental tests. MIL-STD 810G is a revision of MIL-STD 810E. MIL-STD 461 is a Military Standard that describes how to test equipment for electromagnetic compatibility.*

*Table 1. Comparison of different levels of computer ruggedness*

The relevant military standards and specifications serve as benchmarks in assessing system operability and performance in the targeted operating environment. Similar ruggedisation practices can also be observed from the production lines and road maps of foreign militaries and key industry players.

Many projects are focused on meeting the current known requirements. The usual ruggedisation approach is to come up with a cost-effective solution with obsolescence management. This involves leveraging COTS products as much as possible, while meeting military standards for survivability in the operating environment and ensuring in-country capability for subsequent serviceability and replacement. It is a practical and systematic approach to derive an optimal ruggedised solution, taking into consideration factors such as system performance and cost-effectiveness. The approach is also in line with practices of key industry players to leverage COTS products to develop ruggedised chassis with customisable internal components.

While the traditional approach is adequate for meeting current requirements, it does not make provision for future growth and upgrades. It also does not leverage past solutions and know-how to reduce the lead time required in deriving new ruggedisation solutions.

## PROPOSED RUGGEDISATION DEVELOPMENT FRAMEWORK

In seeking alternatives to military computers, the ruggedisation development framework is proposed to reduce lead time in acquiring solutions and meet the long-term consideration of ensuring ease of system upgrades.

It is important to project system growth to cater for future requirements adequately. Taking into account the expected life cycle of the system, future requirements are anticipated and managed alongside obsolescence issues.

As shown in Figure 4, the framework is developed from a repository of proven ruggedisation solutions. These ruggedisation solutions address various aspects, such as suitable hardware and software which can be implemented for different operating environments. This repository could be organised in categories to facilitate the reuse of known solutions. For example, the ruggedisation solution for an existing land vehicle may be applicable to a new land vehicle which is of a similar type. A solution specific to the project can be adapted quickly from the ruggedisation solution which was applied previously, providing a timely solution for this new land vehicle.

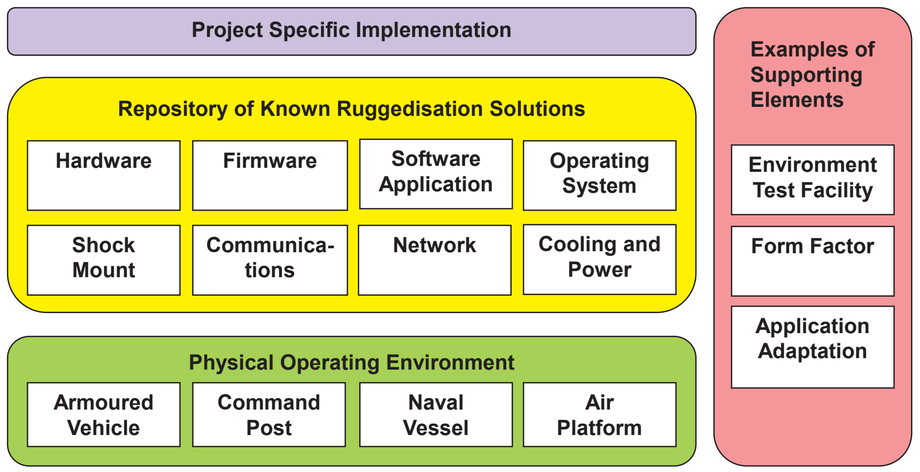


*Figure 4. Proposed ruggedisation framework*

From a repository of ruggedisation solutions, the architecture design and specifications for solution patterns can be established. The solution patterns serve as standard guidelines for the various classifications of military platforms and profiles of typical operating environments. Common interfaces can be identified and defined as recommended standards.

The system development methodology applies in verifying the ruggedisation solution in the following phases, namely, design, simulation, analysis, prototyping, qualification testing and production. In addition, the solution patterns must go beyond the hardware ruggedisation aspects and address factors such as the communications medium, command and control (C2) applications and operating system (OS) software, so as to develop a total system solution.

The supporting elements will facilitate the build-up of the ruggedisation solutions. These supporting elements include the provision of local test facilities for environment testing, form factor protection (i.e. the housing of the computer), as well as the development and adaptation of C2 applications for specific OS. For example, if Windows OS cannot be implemented fully for some ruggedised or handheld devices, other lightweight or embedded OS will be explored. The possible impact to the required C2 applications also needs to be assessed.

Three key ideas that tap COTS-based ruggedisation practices were conceptualised with the objective of achieving a shorter lead time. These concepts have the potential to form the baseline solution patterns in the repository.

### Generic Housing or 'Cocoon' Concept

A generic housing concept can be set up based on the use of a controlled box to shield and protect the COTS products from the harsh operating environment. The 'cocoon' concept allows the COTS system to work reliably beyond its originally designated environment, while providing a solution that can be deployed quickly. Ruggedisation parameters controlled by such a protective housing may include shielding against temperature, humidity, EMC, solar radiation, vibration and shock. These parameters are further elaborated in the next section.

### Qualify by Similarity

The concept which is based on 'Qualify by Similarity' aims to leverage and adapt proven ruggedisation solutions. This is accomplished by reading available test data from previously qualified systems, where possible. The concept can be applied to new target systems and environments where operating limits and critical ruggedisation parameters are less demanding than those of the previously qualified system. Through this concept, significant time and cost savings can be achieved with less environmental qualified testing required.

By using proven ruggedisation solutions as reference, the design and development time frame for new solutions is shortened effectively. Figure 5 shows the proposed methodology and process flowchart.

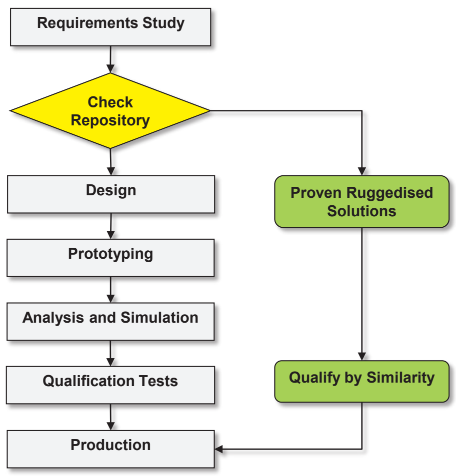


*Figure 5. Ruggedisation process leveraging proven solutions*

### Anticipation of Ruggedisation Needs

The continual emergence of new computing devices allows ruggedisation requirements to be anticipated and prepared for in a more proactive manner. Potential ruggedised solutions can be identified and pre-qualified in advance by sourcing available solutions or developing new ones. An example would be a COTS casing for iPads which enables the device to operate in harsh environments. Collaboration or engagement with potential industry partners to develop new solutions can also be explored. However, there may be cost implications if the new computing devices are required within a shorter lead time.

## THE 'COCOON' APPROACH

An ideal military computer is one that is fully ruggedised and affordable, and offers high computing performance with a fast TTM. However, a more practical approach to develop military computers is to strike an effective balance to meet ruggedisation requirements (e.g. protection against temperature and environmental effects) and performance specifications.

To develop a ruggedised computer with higher computing performance, the new two-pronged 'cocoon' approach can be adopted. This approach involves leveraging COTS products to deliver high performance computing while achieving a short production lead time. COTS products are priced more competitively, leading to lower acquisition and upgrading costs. This approach can be implemented effectively for static headquarters or command post set-ups, where the operating environments are generally less demanding.

Leveraging the generic protective housing of the COTS product, the 'cocoon' approach works by insulating the COTS product from the harsher external environment. By sheltering it against the external environment, the protective housing allows the device to function within its normal operating conditions, while meeting stringent environmental requirements and facilitating the ease of future system upgrades.

The proposed 'cocoon' approach attempts to look beyond the ruggedised chassis and seek new ruggedisation solutions. Instead of ruggedising the chassis to create a protective environment just for internal COTS components, the 'cocoon' approach extends the ruggedisation solution to the entire operating platform i.e. the COTS computer system. The 'cocoon' shields the device from environmental effects with respect to temperature, humidity, EMC, vibration and shock.

As outlined in Figure 6, the approach aims to enable plug-and-play for a wide range of COTS computers in the protective housing. This means that the range of COTS computers will be able to operate in the housing with ease of integration, replacement or upgrading. It is therefore essential to factor in the protective housing's growth potential in the planning phase so that it will be able to house different combinations of COTS computing devices. As changes to the device will incur high costs, the interface panel is meant to retain the external platform cabling in its original condition while providing the option to adapt the internal COTS cabling. This facilitates timely upgrades of computing hardware, while avoiding costly platform modifications and reducing the time required for requalification.

The main trade-off in implementing the cocoon enclosure is the larger form factor (i.e. the size and fit of the enclosure structure) of the complete package. While the cocoon enclosure may optimise space for vehicles equipped with several computers, it may not be suitable for vehicles that are equipped with just one computer. Moreover, the cocoon enclosure is likely to be larger than the customised computers developed specifically to meet military requirements.

While the 'cocoon' approach serves as a viable alternative to fully ruggedised military computers, the latter is still relevant for operations today. Fully ruggedised military computers are suitable for set-ups where space is limited and there is no air conditioning system on board to regulate the ambient temperature.

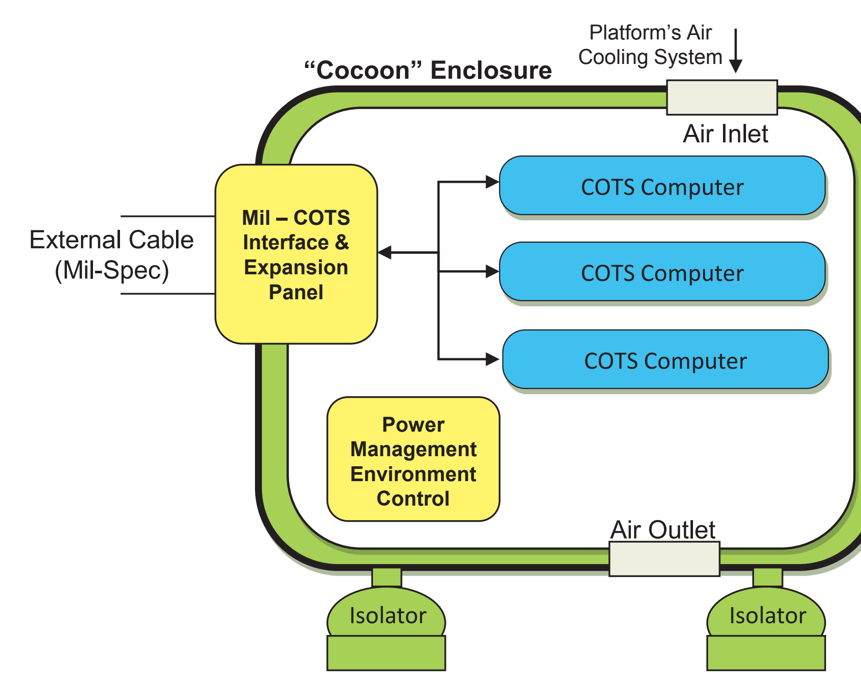


*Figure 6. Conceptual design of cocoon enclosure*

## APPLICATION

The following scenarios illustrate the application of the proposed framework to derive a ruggedisation solution:

### Ruggedisation for a Known Platform Type

If the targeted computer system ruggedisation is commonly used for a particular type of military platform, the recommended methodology is to leverage the proven ruggedisation solution pattern in the repository. This proven ruggedisation method provides a baseline solution, while project-specific requirements such as additional sensors or equipment interfaces can be implemented as add-ons. Thus, the approach enables a quick turnaround and eliminates the time and effort required to design a solution from scratch. To ascertain the feasibility of the baseline solution with project-specific add-ons, verification and environment testing are required. When proven, this solution pattern can be added to the repository.

### Operating System Upgrades

When an OS is obsolete and needs to be upgraded, an analysis of the impact of the upgrade on the overall system interoperability is required. The analysis typically includes examining the impact on supportability of hardware and the compatibility of C2 applications and communication media adaptors (used to interface C2 applications with the communication media) with the OS. Such OS upgrades may also result in the need for a corresponding upgrade of the CPU. The following are some required tasks for the successful completion of the upgrade:

a) Redevelop and test communication media adaptors and C2 applications for adaptation to the new OS

b) Test the relevant CPU and OS upgrade solution patterns in the repository for application

c) Examine the ruggedised form factor for accommodating the replacement of the CPU motherboard

d) Develop and test new OS and its relevant C2 applications for interoperability

Upon the successful completion of the upgrade, the solution pattern can be added to the repository.

### Ruggedising a New COTS Computing Device

To quickly ruggedise a COTS device such as an iPad, an external case can be installed. Alternatively, a flash disk and screen protection can be installed. These simple solutions, which require a short production lead time, can be implemented quickly for user trials and training, while full ruggedisation development and verification testing are in progress.

The form factor ruggedisation only requires prototypes to be developed for external protection. The mobile operating system has to be explored and assessed based on its adaptability to the C2 applications and its impact on them. When validated, the specifications for the new COTS computing device will be stored as a proven solution in the repository.

## CONCLUSION

It is important to hone the capability of harnessing COTS ruggedisation solutions to meet the increasing demands of the military operating environment. While current ruggedisation solutions meet today's requirements, the proposed ruggedisation approach suggests ideas that take into account desired long-term outcomes such as shortening the production lead time and enabling the ease of system upgrades. To develop a holistic ruggedisation solution, it is necessary to go beyond the hardware aspects and take into consideration both the C2 software and OS.

The ruggedisation development framework drives coherent acquisition strategies and helps to build a repository of architectural designs and solution patterns. This repository will aid system upgrades and enhance interoperability. The cost of adopting the 'cocoon' design approach on a COTS computer is usually lower than acquiring a fully ruggedised military computer, as maintenance and upgrades for military computers tend to be more costly. However, the fully ruggedised military computer is still relevant for operations where space on the military platform is limited. The application and effectiveness of the ruggedisation framework, as well as the engineering feasibility of the concepts discussed in this article require verification through a pilot project with a series of trials.

## ACKNOWLEDGEMENTS

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## BIOGRAPHY

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