LEAFLET 4

THE IMPORTANCE OF MAINTAINABILITY IN ACHIEVING OPERATIONAL AVAILABILITY

CONTENT

1. INTRODUCTION

Acquiring military capability is little different in many respects than providing transport for the family in the purchase of a family car. It is unlikely and would be inappropriate to tell your preferred automobile manufacturer how to service and maintain their products and the same applies to military equipment. Therefore when developing and specifying the R&M requirement for a solution the User and Project Team need to recognise *'Maintenance'* as an unfortunate but necessary overhead and burden and specify 'Maintainability' in a manner to enable the Service to tolerate that maintenance with the minimum of interruption.

2. SPECIFYING MAINTAINABILITY

2.1 When specifying Maintainability the following needs to be considered:

a) <u>The loss in capability during maintenance:</u> consideration needs to be given to filling the capability gap during in preventative and corrective maintenance activities. To return a vehicle every time it had a puncture would be feasible but not practical, to change the engine of a vehicle or aircraft in theatre is a regular occurrence but to replace a warships engine becomes a major overhaul.

b) <u>Is the solution maintainable:</u> if it is not then the issue is one of disposal and resupply not one of maintenance.

c) <u>The current maintenance philosophy for the solution type:</u> there may already be established maintenance policies for some types of equipment or the way in which maintenance is carried out i.e. levels and lines of repair. A warship has to be maintenance sufficient whereas little can be maintained on an aircraft in flight and the maintenance has to be delayed until it lands.

d) <u>The acquisition philosophy:</u> whether the capability is purchased outright, leased and self operated, provided by a contractor, PFI, PPP, white fleet and so forth can influence the maintenance option. CLS may be inappropriate in a war-zone or on-board a warship but ideal for home bases and shore establishments.

e) <u>The operational scenario:</u> few solutions can be maintained during use and even less when within the sights of an enemy. Harsh environmental conditions can make the simplest of maintenance extremely difficult or impossible, and even desirable conditions can render maintenance impractical for delicate and intricate solutions

f) <u>The projected availability of appropriate maintenance:</u> maintenance is more than the skill set of the technicians and engineers; it includes the facilities, test equipment, tools, manuals, spares etc. While some maintenance may take little more than a screwdriver other maintenance may require dedicated facilities costing many thousands of pounds. At times the maintenance can go to the equipment but on other occasions it is necessary for the equipment to go to the maintenance.

g) <u>Technology employed (particularly new and novel):</u> too often new and novel technology requires maintenance which is either more novel of technically more advanced. Often these requirements escalates costs and the skill set and training of those required to complete the maintenance, in turn creating an additional maintenance overhead.

2.2 Examples:

2.2.1 For an equipment such a vehicle, generator, weapon, etc. which would be maintainable by the Services during peacetime and military operations the following requirements may be appropriate.

The following maintainability requirements shall be applied to all variants of the equipment:

- Scheduled (preventative) maintenance must not exceed 30 minutes per duty cycle
- The Active Corrective Maintenance Time (ACMT) at Level 1, using the tools and spares carried with the equipment must not exceed 30 minutes.
- The Mean Active Corrective Maintenance Time (MACMT) for Level 2 unscheduled maintenance is to be no greater than 2 hours, with 95% of all maintenance taking no more than 4 hours.
- The MACMT for Level 3 unscheduled maintenance is to be no greater than 4 hours with 95% of all maintenance taking less than 8 hours.
- Levels 2 and 3 maintenance tasks are to be limited to no more than two, Class 2, trained maintenance tradespersons (or three if a Material Handling Equipment (MHE) operator is needed) requiring no special tools and test equipment, other than those agreed by the Support Analysis process, and will be to no greater depth than sub-assembly exchange.

2.2.2 The maintenance of electronic, optical or other equipment comprising one or a number of self contained assemblies which requires dedicated maintenance facilities will usually be specified in the following manner.

The following maintainability requirements shall be applied to the complete equipment including all of its accessories:

- Scheduled (preventative) maintenance shall be no greater than ensuring the equipment is kept clean and free from damage.
- The Active Corrective Maintenance Time (ACMT) at Level 1 shall be no greater than 10 minutes and shall comprise the replacement of faulty assemblies and accessories.
- Faulty assemblies and accessories shall be returned to the Contractor for maintenance.

Note: This maintainability requirement should ideally be supported in other parts of the requirement for the need for Testability and the capability to self-test.

2.2.3 The maintenance of maritime, aircraft and UAV systems which all comprise an integration of hardware, electronics, weaponry etc. will be broken down by system and/or sub-system perhaps on a capability or functionality bases then subsequently maintained at equipment level. Such maintenance will be little difference than that described above.

2.2.4 The warship however must be self contained while at sea from both a maintainer and spares perspective. Much of the maintenance alongside will be completed under contract particularly that to propulsion, and power generation and distribution systems. The overhaul of large weapon systems, radar, sonar, etc will also be the responsibility of a contractor. This in many respects is little different than running the family car and your relationship with the local garage. You keep it clean, check its functionality, top up the oil and water when needed and replace the occasional flat tyre and blown bulb. Once a year planned maintenance will be carried out by the garage when your car has its annual service. The maintenance of a warship is very similar but on a grander scale, maintained by the crew when at sea and a major service by the contractor every 4-5 years. The opportunity will also be taken when the ship is in port to complete those repairs beyond the scope and capability of the crew and any other scheduled maintenance which needs to be completed at a more frequent interval.

2.2.5 The maintenance of fixed and rotary wing aircraft, and Unmanned Aerial Vehicle's (UAV's), is little different in principle than that of the family car or warship; it is the maintenance frequency which is the major consideration. Whereas the maintenance on land and maritime systems can be measured as a small percentage of their duty cycle the maintenance of military aircraft is often many times the duty cycle to the extent it is frequently expressed in terms of Maintenance Hours/Flying Hour. As with the family car the military aircraft needs to be firmly on the ground and stationary when being maintained but will be maintained as with the warship to assembly and sub-assembly level by a mix or military and contractor engineers and specialists.

2.2.6 As with all military equipment, maintenance should be influenced by the need for the capability and the constraints of safety and the resources of the Services, not visa-versa. Much of the advice will be provided by the Contractors however that advice should be tailored to satisfy the needs of the Services not adopted to make life easy for industry. Adopting what has been practiced previously without further consideration is dangerous to the extent of foolishness. As capability, technology and tomorrows equipment evolve so does the needs and the techniques of maintenance all of which can greatly influence and optimise Availability and WLC.

3. THE NEED TO OPTIMISE MAINTAINABILITY

3.1 To replace a faulty passenger side headlight bulb on a Mini-Metro there is the need to either remove the front grill and cross member before removing the headlight assembly; or disconnect and remove the battery and battery box to gain access to the rear of the headlight assembly to then replace the bulb in-situ. Without doubt faulty headlight bulbs on the Mini-Metro are maintainable, whether or not maintainability was a consideration during the design process is questionable.

3.2 Replace a damaged power cable on a Dyson DC4 upright vacuum cleaner which has fractured due to constantly coiling it for storage in the same manner there is the need to gain access to the rear of the power on/off switch. The switch is retained by a single cross-headed screw and ample cable is provided to enable the switch to be withdrawn from its housing once released. Unfortunately a special tool is required to remove the knob from the switch which itself is a push fit to the switch and retained by a small plastic tag. A special tool which is not readily available from trade is required to hold this plastic retaining tag to one side while the knob is removed. As with the Mini-Metro the vacuum cleaner can be maintain but was maintainability a consideration? Fitting the knob to the power switch during production would have been convenient being no more than a push fit; and would have helped keep production costs down. Replacing a fractured power cable, which is quite common with electrical equipment having trailing cables, in this example, is over complicated, expensive and time consuming.

3.3 These examples are two of many which at some time or other we have all encountered in a daily lives. Military equipment is no different; in many instances it is worse. Too often the hull, fuselage or chassis of the military equipment is very similar to its civilian counterpart unfortunately then packed with 50% more equipment before being covered with armour for protection. It is then deployed in the middle of no where to be maintained by engineers and technicians with limited resources often under the gaze of an enemy.

3.4 Maintainability is not an option and a nice to have; it is a necessity and a major influence on Availability. Examples of maintainability best practice are shown in Section 4.

4. MAINTAINABILITY BEST PRACTICE

Examples of maintainability best practice are shown in the table below.

	Advantage	**Example(s)**
DESIGN		
Designed to reduce or eliminate preventative maintenance.	Increased availability	Lubricated for life assemblies/bearings. Improved material technology.
Components that can only be fitted the correct way.	Reduced maintenance induced failures	Bearings, gaskets, spacers, plus and sockets.
Components that are a safe one person lift.	Improved H&S, maintainer flexibility.	Assembly design, reduced bulk and weight. Lifting handles/grabs, reduced sharp edges/surfaces.
Components that cannot be confused with others.	Reduced maintenance induced failures. Reduced rework effort.	Fasteners of similar length i.e. 22mm and 25mm bolts.
Common threads	Reduced maintenance induced failures. Reduced rework effort.	Metric and imperial threads i.e. Ford cars had both 0.5” (12.7mm) and 13mm bolts securing the alternator for many years resulting in thread and head damage.
Common lubricants and greases	Smaller logistic footprint Reduced maintenance induced failures	MoD common fuel policy.
Colour coded User servicing	Reduced maintenance induced failures Reduced maintenance times	Service points, plugs and sockets, replaceable items colour coded.
Are content indicators easily visible	Reduced maintenance induced failures Reduced maintenance times	Fuel, hydraulic oils, water, coolant containers.

	Advantage	**Example(s)**
Provision of Safety lockouts/isolation switches	H&S	Large & remote systems, rotating shafts, turrets and aerials, cutting blades, moving components and assemblies etc. where a maintainer may be injures should the equipment be operated, started, switch on without their knowledge.
Earth/Safety Bonding is not compromised by maintenance intervention	H&S	Assembly repair, replacement and adjustments can be completed without disconnecting bonding components.
Electrostatic discharge does not damage components during assembly, testing and handling.	H&S Reduced maintenance induced failures	Capacitors, discharge tubes, rotating machinery, aircraft and helicopters.
Routing of cables is tolerant not to cause interference with adjacent circuits.	Reduced maintenance induced failures. Retention of design integrity	The critical routing of cables which may compromise EMC /TEMPEST capability
Identification of wiring looms and air/hydraulic/fuel pipes	Reduced maintenance induced failures. Reduce maintenance times	Systems and equipments where cables and pipes could be confused and incorrectly connected.
Lock-wire used only where there are no suitable alternatives	Reduced maintenance induced failures. Reduce maintenance times	Lock wiring is time intensive and a skilled process. When applied incorrectly can easily encourage many fasteners to become loose.
Maintainability as an integral part of the modification design process.	Reduced maintenance effort. Increased availability	Bar and other armour fitted to vehicles in Iraq and Afghanistan has to be removed to permit much of the maintenance. Hinged and armour in smaller sections to aid removal would have aided access.
ACCESS		
‘Lifed Items’ are easy to access and replace.	Reduced maintenance times Improved availability	Filters, cam belts, oils, etc

	Advantage	Example(s)
Quick release fasteners preferred over screws/bolts when application allows	Reduced maintenance times Improved availability	
Servicing and preventative maintenance points easy to access	Reduced maintenance times Improved availability	A lamp can be replaced without dismantling equipment. Brake wear can be determined without removing the wheel or stripping the hub assembly.
Access sufficient to allow the wearing of Nuclear Biological Chemical (NBC) and cold weather clothing and gloves	Reduced maintenance times during operational constraints. Reduced maintenance induced failures resulting from operational constraints.	Maintaining equipment in an NBC and/or cold weather environment.
Special Tooling & Test Equipment (ST&TE) can be used wearing of NBC and cold weather clothing and gloves	Reduced maintenance times during operational constraints. Reduced maintenance induced failures resulting from operational constraints.	Maintaining equipment in an NBC and/or cold weather environment.
Are suitable connectors provided where frequent disconnection is required.	Reduced maintenance times, Improved availability. Reduce connector wear and future maintenance	Not limited to electrical plugs and sockets but to air and hydraulics connectors.
Cables and pipes which pass through bulkheads and panels can be maintained without disassembly.	Reduced maintenance induced failures. Reduced maintenance times, Improved availability.	Cables and pipes on most military equipments.
Where disconnection is necessary for test or repair, is sufficient free wire available for reconnection	Reduced maintenance induced failures. Reduced maintenance times, Improved availability.	Cables and pipes on most military equipments.

	Advantage	Example(s)
Drain plugs and cocks are easily accessible with sufficient room to collect/channel liquids/oils/ lubricants to appropriate containment.	H&S, Environmental Reduced maintenance times, Improved availability.	Vehicle radiator coolants, engine oils and hydraulic fluids.
Safe working height	H&S Reduced maintenance times, Improved availability.	Where there would otherwise be the need to climb onto an equipment to maintain it, suitable safe access is be provided together with a suitable working platform
Suitable diagnostic connectivity	H&S Reduced maintenance induced failures. Reduce maintenance times	Diagnostic connectors are easily accessible. Do not require cables to be routed where they may be damages or cause damage
TOOLS, JIGS & TEST EQUIPMENT		
Common tool set	Smaller maintenance footprint Reduced initial cost/ Whole Life Cost (WLC)	
Reduced need for Material Handling Equipment (MHE)	Reduced WLC Reduced logistic delays	Non-availability of MHE and operators
Reduced need for special tools	Reduced logistic footprint	Redesign of special fittings and fasteners to permit the use of standard tools i.e. replace pin spanners with slotted or hex/torque drive.
Government Procured test Equipment (GPTE) preferred over STE/STTE	Reduced logistic footprint Reduced calibration overhead. Reduced WLC and greater flexibility.	

	Advantage	Example(s)
Suitable diagnostic connectivity	Reduced maintenance induced failures. Reduce maintenance times	Diagnostic connectors are of suitable length to enable diagnostic equipment to be used safely and without the risk of damage.
Optimum use of jigs	Optimise WLC	Use jigs only where a H&S, and/or cost/time benefit can be demonstrated.
CALIBRATION		
Reduce need for equipment, tools and test equipment calibration.	Reduced WLC	
Extended calibration periods	Reduced maintenance times, Improved availability.	
Pre adjusted/aliened components and assemblies	Reduced maintenance times, Improved availability.	Electronic circuits, sensors, bearings
PUBLICATIONS		
Maintenance publications that are clear, accurate and unambiguous.	Reduce maintenance induced failures. Reduced maintenance times, Improved availability.	Operating, Maintenance, Calibration and Servicing manual, spares lists etc. (all media)
Electronic Viewers are suitable for In-Service use	Reduced maintenance times, Improved availability. H&S, reduce eye strain.	Electronic Viewers are robust, light, easy to read in poor and bright light and have long battery life. Are not susceptible to damage by contaminants, and have an appropriate user interface.

Table 1 – Examples of Maintainability Best Practice