CLOCKWORK SOLUTIONS

PRODUCT APPLICATION

SPAR™ Project Briefs: Defense

Details have been omitted from the following report for security reasons. In most cases, post-study surveillance was undertaken and the predicted results obtained by SPAR™ were borne out. In some cases, the first phase of the SPAR™ analysis served to highlight the most important data on which to focus, leading to several additional cycles of model improvement, along with improved and more focused data collection.

Army

Communication Equipment

PROBLEM: An infantry unit makes use of a large stock of communications equipment. Management needs to understand how the availability of this communications equipment varies with changing scenarios.

In the event of failure, the equipment is first reviewed at a local repair station which has limited repair capabilities and a limited inventory of spare replacement units. Those which cannot be repaired locally are stored temporarily pending return to the depot. Stored components are shipped on to the depot periodically, or under some circumstances, components can be sent to depot by special shipment. At the depot, failed units are repaired or replaced then returned to the local storage.

SPAR™ SOLUTION: The SPAR™ model looked at the overall logistics of repair and storage at two levels. It took into account possible emergency situations and other interruptions to the logistics chain causing disruption, increased turnaround times, some loss of units as well as loss of the repair stations themselves. The results were validated by reviewing integrated systems availability data. The outcome was a series of recommended logistics options.

Tank Transporter Vehicles - Spares and Units

PROBLEM: Help the army to make optimal decisions regarding transport logistics for a tank squadron.

Tanks are transported on the backs of special transporters. Each transporter comprises a track and a ramp; these are further sub-divided into a number of LRUs (Line Repairable Units). The logistics chain includes three repair levels: a local repair depot, a remote depot, and the original manufacturer. Depending on the kind of failure and the circumstances, the LRU will be shipped to the level appropriate to the failure type with or without the entire ramp and/or the entire track. Cannibalization of tracks and ramps is a legitimate option and is done occasionally.

SPAR™ SOLUTION: The SPAR™ study predicted a one-year operational scenario with specified optimal local storage levels for spare parts. The model computed the number of transporters needed to guarantee (with a given probability) the success of the operational scenario.

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Communications Equipment: Design Specification Phase

PROBLEM: Help the army define the reliability requirements of a communications device in the early stages of its design specification.

In considering the reliability parameters (i.e., MTBF), the following factors were taken into consideration:

- Mission requirements
- Technological capability
- Life cycle cost (LCC)

Compliance with mission requirements provides only the minimal system reliability value. However, this value may not be optimal in terms of economic considerations. It may very well be that higher values which are technically plausible proved to be more beneficial.

The purpose of the SPAR™ model was to analyze the dependence of availability and life cycle cost as a function of the device MTBF values. It was assumed that the device is subjected to certain mission profiles and maintenance procedures.

SPAR™ SOLUTION: The SPAR™ model demonstrated that minimal cost will be achieved if the final specification requirements were higher by a factor of 2 than those required to comply with mission specification.

Armored Vehicles: Support Policies

PROBLEM: Optimize repair policies and spare parts storage and pooling policies for an armored vehicle fleet.

The study looked at several independent units of armored vehicles, each one having its own local spare parts storage and limited repair capability. The target was to arrive at optimal inventory of spares at each of four storage levels, while providing for the best possible vehicle availability in each unit within the imposed budgetary constraints.

SPAR™ SOLUTION: The SPAR™ model took account of four repair levels and the logistics logic, and arrived at a policy which optimized the logistics chain.

Some LRUs can be repaired at the first level. Those which cannot are shipped to a central (second) repair level; concurrently, a request for a spare part is registered at the dispatching unit. The central repair level may discard the received LRU, repair it locally or ship it on to the third level. If it is shipped on, a request is registered for a spare at the second level. The third level may also discard, repair or send further. The fourth and highest level is the manufacturer or a major repair depot. Spares are shipped from level to level according to a set of priority rules.

Repair Center for Armored Vehicles

PROBLEM: The logistics command called for a review of the repair facilities attached to an armored vehicle fleet.

The existing situation was that repair capacity was very limited and failed units had to be shipped to a central depot. This involved costly shipping, centrally stored spare parts, and the loss of availability of vehicles awaiting the arrival of a spare part. Costs were larger than expected because, in practice, it often turned out that expensive LRUs (engines, gearboxes etc.) were found to be suffering relatively mild failure conditions.

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SPAR™ SOLUTION: A simulation model of the repair process studied the cost-benefit breakdown of improved diagnostic and repair facilities in the field. It computed optimal resource allocations, enabling a reduction in spare parts inventories, with additional costs being allocated to repair teams. The SPAR™ model was able to quantify the contribution which additional repair diagnostic facilities would make to the enhanced availability of the fleet.

Support Policies for GPS Equipment

PROBLEM: Review the performance of Geographic Positioning Systems (GPS) systems in wartime conditions.

These systems are deployed in different units, sharing a single stock of spares and a single repair depot. Turn-around time depends on the unit in which the system is located. They are repaired in a single repair depot.

GPS devices may fail in one of two modes. The mode of failure determines the time of repair. The time to transport a failed device to the depot depends on the location of the combat unit. Every failed device is replaced by a spare that is shipped back to the unit.

SPAR™ SOLUTION: The purpose of the study was to quantify the time-dependent relationship between the system's logistic support (i.e. spares procurement) and the probability of all systems being available.

The study considered varying emergency scenarios. For example, in one scenario, the combat units are regarded as being disconnected from any logistic support. Failed units cannot be replaced nor can they be sent back to the repair depot. In another scenario, the model considers what happens when the connection between combat units and logistic support is re-established.

The SPAR™ model quantified and articulated the dependency existing between spares procurement and the time-dependent availability of the GPS equipment.

Equipment Upgrades in Maintenance Workshop

PROBLEM: A study was conducted on the relationship between the resources allocated for upgrading military equipment and the time needed to complete the upgrade process. The process had to comply with certain readiness restrictions, in particular, minimum stock levels in emergency storage locations, and with preventive maintenance procedures (i.e., every device has to be inspected and treated not less frequently than once every X years).

SPAR™ SOLUTION: The SPAR™ model considered both operating and stored devices, different failure modes requiring different resource allocations for repair and upgrade, different failure rates and maintenance procedures of upgraded and non-upgraded devices. The purpose of the SPAR™ study was:

- To analyze the relationship between the resources allocated to the depot and the time required for completing the upgrading of all equipment
- To determine when and whether to simply maintain or to upgrade the equipment
- To propose alternate inspection policies of stored devices

Among its conclusions, this study proved that fewer resources were required to complete the upgrading process than the number which was computed by analytic methods.

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Air Force

Air Defense -- Mission Analysis

PROBLEM: Model the operational performance of a missile battery.

A number of systems are situated at different geographic locations. Each system includes detection and identification elements, communication elements, command and control elements, and a launch system. The model has to cope with considerable complexity, with each system comprising more than 300 modeling elements. The detection system incorporates a majority voting system and, in addition, is dependent on atmospheric parameters.

SPAR™ SOLUTION: The SPAR™ model considered the development of threats in terms of the statistics of appearance as a function of time. It looked at the complete logistics of deployment of the missiles upon depletion from both local storages and remote storages. Mission success was defined in terms of neutralization of the incoming threats. A complete scenario analysis was performed involving a large number of parametric studies. The extent of the results was so profound that parts of the system had to be redesigned; this was particularly true of the salvo optimization and firing sequence.

Capital Investment and Aging

PROBLEM: A class of aviation systems had been in service for a considerable period of time. Management needed to consider how to respond to the increase in the number of equipment failures and the indicators of aging which were detected from analysis of the failure distributions of the units comprising the systems. Budgets were under critical review, and the decision whether to replace, repair, revamp, or retain needed to be considered in light of “political,” as well as operational considerations.

SPAR™ SOLUTION: Several SPAR models of the systems were constructed. A number of time-dependent options were considered including: complete rejuvenation of the systems, partial rejuvenation, moderate inspection and repair protocols, and increased inspection intervals. All options were considered in terms of budgetary limitations, return-on-investment, and system availability. The results obtained by the models allowed management to arrive at the best overall option for a given scenario.

Operational Procedures for Airborne Equipment

PROBLEM: A series of weapons systems are ground-stored. At the start of a mission, one or more systems are selected and become airborne. This occurs on a periodic basis for specific operational purposes. During the mission there is a high failure rate. Depending on the nature of the mission, equipment failure in a system might not be detected. At the end of the mission, the equipment is removed and returned to storage. Periodic sample testing is done on the ground with varying levels of coverage.

SPAR™ SOLUTION: The target of the analysis was to identify the optimal queuing procedure for selecting systems for airborne operations, and to compute optimal periodic testing procedures, including the intervals between tests, the size of test samples and the appropriate coverage levels. Budgets were limited.

The result of this study was very quickly validated by field experience, and led to a considerable increase in mission success with no additional cost. The study showed that changes in the queuing procedure and testing methods were critical to success.

Aviation Systems: Low-Cost Engines

PROBLEM: An expensive airborne system was dependent on a low-cost engine. If the engine failed during a mission, the entire system was lost, with consequences far more serious than the financial loss alone. Replacement of the engine was one solution, but this was a time consuming process, with a strongly negative impact on system availability.

The low-cost engine experiences a number of failure modes, most of them related to fast-aging processes and slow/fast processes. (This is a process by which a phenomenon develops slowly and, following a critical point, full failure becomes imminent.) Inspection is applied before every mission to identify the occurrence of slow/fast critical processes and the extent of aging.

SPAR™ SOLUTION: A complete mission analysis model was built. This included a detailed description of all failure modes, inspection procedures, and replacement policies. The target was to optimize the overall policy of inspections and engine-initiated preventative replacements.

Aviation: Large Expensive Engines

PROBLEM: To find the optimal budget allocation between local and remote storages of spare engines.

In this study of aircraft powered by twin engines, each engine was regarded as comprising a number of SRUs (Shop Repairable Units). Upon failure, an engine is removed and sent to a remote depot with a given probability that it could be locally repaired. At the remote depot, failed SRUs are identified and shipped to a higher repair level.

Engine maintenance procedures are a function of a complex set of considerations, i.e., the number of flight hours on the clock. After an engine reaches a given number of flight hours, it must be removed and shipped away for repair or replacement. This can take a relatively long amount of time, thus creating a load on spare engine requirements. An unanticipated emergency under this policy can lead to undesirable results.

SPAR™ SOLUTION: The operational scenario of the aircraft was modeled along with the complete logistic chain. Possibilities of modulating the maintenance dispersion were studied and an optimal maintenance policy was obtained.

Continuous Operation of Airborne Systems

PROBLEM: A number of airborne systems must operate continuously over a period of time. Of the 10 units available in the fleet, five must be airborne at any given time. These units are controlled by a limited number of ground-based control systems. Mission success can be achieved by increasing redundancies but there are a number of options to consider, including: many complete systems with no local repair capability, less systems with local repair capability, varying degrees of local repair capability (and spare parts) with appropriate logistic facilities to yield a small enough turnaround time, etc.

SPAR™ SOLUTION: The model evaluated several maintenance and spare parts strategies, arriving at and validating an optimum overall strategy. The strategy takes account of mission success criteria, costs, and operational risk.

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Air Squadron: Operational Scenario and Attrition

PROBLEM: An aircraft squadron was analyzed over a lengthy period.

SPAR™ SOLUTION: The model includes:

- Detailed description of each aircraft in terms of major LRUs
- Logistic sequence of failures
- Repairs at several repair levels
- Recycling and maintenance
- Operations and missions in emergency periods as reflected in the number and duration of sorties
- Attrition during sorties resulting from mission risks
- Elements of emergency logistics such as faster repair cycles and loss of repair depot

This project, like many others described herein, is on-going. The models are used for decision support purposes in relation to a variety of problems, including spare parts allocations, repair policy, and other issues. Availability, readiness, and mission success are the system performance parameters.

Engine Maintenance Optimization at Repair Shop

PROBLEM: Engines may need to be sent to a workshop as a result of three general events: regular failure, foreign object damage, or several kinds of date expirations relating to various elements in the engine. The expiration date is a complex function of time, flight hours, number of landings, and other mission-related parameters. When an engine arrives at the workshop for a particular reason—say, for replacement of element X—a set of prescribed operations must be done.

This sequence is typical of the element to be treated. However, since a considerable effort is already being invested in the engine (removal from aircraft, shipment to workshop, sequence of operations etc.), it may be worthwhile to use that opportunity to deal with other logistical issues such as replacing other elements in the engines, especially those units whose sequence of operations overlaps those already being done and those which are approaching their expiration dates.

Two extreme policies are possible: replace only unit X; and replace *every* element of the engine. The optimum operating policy lies somewhere between these two extremes, but finding it involves complex calculations.

SPAR™ SOLUTION: In the SPAR™ study, a clear optimum was identified in terms of operations done in the workshop. The optimum was originally defined in terms of minimal cost of repairs over a long period of time (say, 20 years). However, the repair policy also affects turnaround time of engines since the amount of time the engine spends in repair depends on the number of operations done in repair.

On the other hand, long recycling times have an adverse impact on the availability of aircraft as well as on the number of expensive full engines that must be stored at level A to maintain a given availability. A study of these effects was conducted so as to achieve a global optimum of the operation of the whole system**.**

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Navy

Naval Small Fleet

PROBLEM: Modeling a logistics scenario involving a mother ship escorting a number of operational vessels. When any unit on one of the operational ships fails, it is removed to the mother ship which carries spare units (quantity limited by weight and available volume) and has a limited repair capability. Units which cannot be repaired on board may be transported to shore base with a longer turnaround time, higher cost, and some logistic and operational difficulties.

SPAR™ SOLUTION: The complete scenario was analyzed to obtain the optimal mix of spares on board the mother ship and optimal levels of repair capacity.

Missile Boats

PROBLEM: To study the overall mission success probability of a missile boat and its supply of anti-missile missiles. The model had to predict the operation of the overall system and its sensitivity to a variety of parameters.

SPAR™ SOLUTION: The entire operational logic of the missile system, including the detection, identification, communication, and launch sequences, was modeled. The model also took account of the repair sequence of various missile elements, including the operation of the repair team, in varying sea and emergency time eventualities, and under various classes of external threat.

Contact:

Email: **info@clockwork-solutions.com**
Website: **www.clockwork-solutions.com**