## UNLOCKING VALUE FROM COMPONENT EXCHANGE CONTRACTS IN AVIATION USING SIMULATION-BASED OPTIMISATION

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#### ABSTRACT

Motivated by the entry into service of new aircraft such as the Airbus A380 as well as the pressure to operate existing fleets at lower cost, not only in civil but also in military aviation, a new industry paradigm has emerged where MRO (Maintenance, Repair and Overhaul) service providers or OEMs (Original Equipment Manufacturers) supply spare parts to airline operators on a *maintenance-by-the-hour* basis. As a consequence, the associated logistics networks have reached unprecedented complexity: Component exchange commitments are now made to multiple operators, not only at their main bases but also at outstations. In this setting, the limitations of conventional Initial Provisioning methods can be overcome with high-fidelity simulation-based optimisation techniques. In particular, this paper discusses how value can be unlocked from new logistics policies for spare parts management in aviation.

#### **1** INTRODUCTION

On-time performance, based on the on-time departure of the aircraft, is considered as one of the key success factors of the airline industry. One of the major risks associated with on-time departure is technical delay. To minimise the risk of technical delay, airline operators position a certain number of aircraft system components (rotables) that have been identified critical for the dispatch of the aircraft at the destination airports. These parts are selected on the basis of the recommendation by the OEM (Original Equipment Manufacturer). Due to the costs involved, operators try to keep a minimum component inventory at most of the aircraft fleet's destination airports. To reduce this level of inventory as much as possible, operators make arrangement with other airlines operating the same type of aircraft out of this airport or join the International Airlines Technical Pool (IATP).

Motivated by the entry into service of new aircraft such as the Airbus A380, the emergence of Low-Cost-Carriers (LCCs) and the increasing pressure for legacy airlines to operate existing fleets at lower cost, a new business paradigm for spare parts management has been emerging in the aviation industry: Rather than selling spare parts to airlines, OEMs and MRO service providers are now supplying spare parts to airline customers on a *maintenance-by-the-hour* basis with a guaranteed service level whenever needed (AeroStrategy 2006). In this setting, new decision support tools are required that are able to portray with high fidelity the dynamic implications of advanced business practices for spare parts management and enable to address questions such as:

• How many spares should be kept where? What is the risk associated with not positioning any spares at certain locations?

- What service levels can be committed with what confidence? How can this be done at minimum cost?
- How to move inventory within the network to minimise risk?
- What is the effect of changes of critical parameters such as delivery time commitment or repair turnaround time?

#### 2 LIMITATIONS OF CONVENTIONAL INITIAL PROVISIONING METHODS

In the light of the above-mentioned paradigm change it turns out that conventional Initial Provisioning (IP) methods are not sufficient any more. Airbus, for example, has traditionally been making IP recommendations for rotables to operators based on a Protection Level  $PL_n$  which is defined as the probability of not having more than *n* spare units of a particular part number concurrently in the repair cycle. This can be computed with the Poisson cumulative probability function F(n|E) where *n* is the number of spare units in the repair cycle and E is the expected demand during a re-supply period:

$$PL_n = \mathbf{F}(n|E) = e^{-E} \sum_{i=0}^{floor(n)} \frac{E^i}{i!}$$

 $E = (FH \times QPA \times N \times TAT)/(MTBUR \times 365).$ 

- *FH*: Annual flight hours per aircraft
- QPA: Quantity per aircraft = Average number of units of that part number installed on an aircraft
- *N*: Number of aircraft in the fleet to be supported
- *TAT*: Turnaround time = Duration of component repair (including logistics transfer time to/from repair

*MTBUR*: Mean time between unscheduled removals = Reliability of component

This methodology, however, does not take into account that the demand during re-supply is considered at a time when the first spare part unit is already under repair (Rutledge 1997).

In turn, today's component service providers typically commit to a Service Level  $SL_n$ , defined as the number of demand instances that can be fulfilled in time divided by the total number of demand instances. The Service Level depends on when a no-fill event can happen, which is at any time when all available spare part units are in the repair cycle. Consequently, as shown in Figure 1 based on an example for E = 1 and n = 2, a Service Level  $SL_n$  that can be achieved with n spare part units is equal to  $PL_{n-1}$  only. Adding an additional unit for each part number, to make sure that Service Levels correspond to the required Protection Levels, would result in huge IP recommendations far beyond today's industry practice.

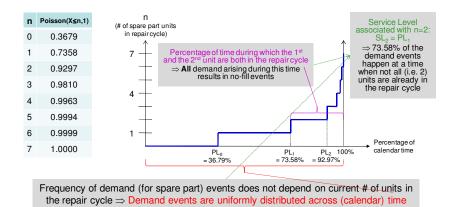


Figure 1: Illustration Fill Rate versus Availability

# **3** USE OF DISCRETE EVENT SIMULATION FOR COMPONENT SUPPORT CONTRACT OPTIMISATION

Mathematical approaches have been used to determine inventory policies to meet the required Service Level (Simao and Powell, 2009) and optimisation for forecasting spare part inventory (MacDonnell and Clegg, 2007). Safavi (2005) provides an overview of the statistical forecasting processes used in the Aerospace industry. MacDonnell and Clegg (2007) have also discussed how a contract with multiple part numbers should be optimised by trading-off MTBUR and cost. However, the complex interdependencies of random effects (i.e. component failures), response mechanisms, multi-airline schedules, delivery time constraints and service level commitments to multiple airline operators can only be sufficiently addressed through simulation analysis (Lye and Chan, 2007). At the same time, because of the large number of decision variables a sophisticated optimisation procedure is required as well.

The value of simulation-based decision support for the optimisation of such complex logistics system is demonstrated in this paper using a four-operator (Korean Air KE, Thai Airways TG, Virgin Atlantic VS, Qantas QF) A380-like test case with daily flights in a global network of destination airports as shown in Table 1 and a representative set of components with attributes as listed in Table 2.

Table 1: Structure of four-operator global network with 4 main bases (M/B) ICN, LHR, BKK, SYD and 10 additional outstations (O/S)

|     |        |        | # of inb | ound flig | hts       |         |            |
|-----|--------|--------|----------|-----------|-----------|---------|------------|
|     | KE O/S | TG O/S | VS O/S   | QF O/S    | Total O/S | Total M | / <b>B</b> |
| ICN |        |        |          |           |           | 3       | KE         |
| LAX | 1      | 1      | 1        | 2         | 5         |         |            |
| LHR | 1      |        |          | 1         | 2         | 4       | VS         |
| CDG | 1      |        |          |           | 1         |         |            |
| BKK |        |        |          |           |           | 4       | TG         |
| HKG |        | 1      | 1        | 1         | 3         |         |            |
| NRT |        | 1      |          | 1         | 2         |         |            |
| PVG |        | 1      |          | 1         | 2         |         |            |
| SFO |        |        | 1        |           | 1         |         |            |
| JFK |        |        | 1        |           | 1         |         |            |
| SYD |        |        |          |           |           | 7       | QF         |
| MEL |        |        |          | 2         | 2         |         |            |
| SIN |        |        |          | 4         | 4         |         |            |
| FRA |        |        |          | 1         | 1         |         |            |

Table 2: Sample of 13 components for which support services are to be optimized

| Component         | 1       | 2       | 3       | 4       | 5      | 6      | 7       | 8       | 9      | 10      | 11     | 12    | 13      |
|-------------------|---------|---------|---------|---------|--------|--------|---------|---------|--------|---------|--------|-------|---------|
| MTBUR (hrs)       | 400,000 | 200,000 | 520,000 | 100,000 | 75,000 | 55,000 | 50,000  | 140,000 | 12,000 | 10,000  | 8,000  | 5,000 | 45,000  |
| QPA               | 1       | 1       | 4       | 1       | 1      | 1      | 1       | 5       | 1      | 1       | 1      | 1     | 10      |
| MTBUR/QPA         | 400,000 | 200,000 | 130,000 | 100,000 | 75,000 | 55,000 | 50,000  | 28,000  | 12,000 | 10,000  | 8,000  | 5,000 | 4,500   |
| \$\$ per unit     | 75,000  | 180,000 | 10,000  | 30,000  | 60,000 | 8,000  | 150,000 | 45,000  | 22,000 | 150,000 | 15,000 | 5,000 | 55,000  |
| \$\$ per aircraft | 75,000  | 180,000 | 40,000  | 30,000  | 60,000 | 8,000  | 150,000 | 225,000 | 22,000 | 150,000 | 15,000 | 5,000 | 550,000 |

A component exchange contract based on a delivery time commitment of 4 hours at all main bases was to be optimised by minimising the aggregate of inventory cost (assumed to be 20% of the sales unit price), logistics cost (assumed to be \$2,000 for each urgent logistics movement) and penalty cost (assumed to be \$500 for each no-fill event), subject to a minimum overall service level of 97% to be achieved with 90% confidence level.

The analysis was carried out using D-SIMSPAIR, a simulation-based rotables optimisation system provided by D-SIMLAB Technologies in Singapore that meets the criteria mentioned in Section 1.

# Table 3: Optimised component support contract, no outstation coverage

|                           |                                | Component   | Component   | Component   | Component   | Component   | Component  | Component      | Component  | Component  | Component  | Component  | Component  | Component |
|---------------------------|--------------------------------|-------------|-------------|-------------|-------------|-------------|------------|----------------|------------|------------|------------|------------|------------|-----------|
|                           | Airport                        | 13          | 12          | 11          | 10          | 9           | 8          | 7 -            | 6          | 5          | 4          | 3          | 2          | 1         |
| Optimised Pool            | LHR                            | 3           | 5           | 5           | 2           | 3           | 2          | 1              | 2          | 1          | 1          | 1          | 1          | 1         |
| Stock                     | SYD                            | 4           | 5           | 3           | 2           | 3           | 2          | 1              | 2          | 1          | 1          | 1          | 1          | 1         |
|                           | ICN                            | 4           | 5           | 5           | 2           | 3           | 2          | 1              | 2          | 1          | 1          | 1          | 0          | 0         |
|                           | ВКК                            | 4           | 3           | 3           | 2           | 3           | 2          | 1              | 1          | 1          | 1          | 1          | 0          | 0         |
| To                        | al Pool Stock                  | 15          | 18          | 16          | 8           | 12          | 8          | 4              | 7          | 4          | 4          | 4          | 2          | 2         |
| Confidence level for      | observing at least 97% service |             |             |             |             |             |            |                |            |            |            |            |            |           |
| level within 3 mont       | hs performance measurement     |             |             |             |             |             |            |                |            |            |            |            |            |           |
|                           | period                         |             |             |             |             |             |            | 0.9002         |            |            |            |            |            |           |
|                           | Rebalance                      | No          | No          | No          | No          | No          | No         | No             | No         | No         | No         | No         | No         | No        |
| <b>Rebalancing Policy</b> | Threshold                      | -           | -           | -           | -           | -           | -          | -              | -          | -          | -          | -          | -          | -         |
|                           | From Immediate Maintenance     |             |             |             |             |             |            |                |            |            |            |            |            | [         |
| Expected value of         | Demands                        | 0.1401      | 0           | 0           | 0.2143      | 0.0315      | 0.018      | 0.0656         | 0.0046     | 0.0521     | 0.0189     | 0.0058     | 0.1336     | 0.0634    |
| no-fill events p.a.       | From Backfill Demands          | 0           | 0           | 0           | 0           | 0           | 0          | 0              | 0          | 0          | 0          | 0          | 0          | 0         |
|                           | Total                          |             |             |             |             |             |            | 0.7479         |            |            |            |            |            |           |
|                           | From Immediate Maintenance     |             |             |             |             |             |            |                |            |            |            |            |            | 1         |
| Constanting               | Demands                        | 99.59%      | 100.00%     | 100.00%     | 98.57%      | 99.76%      | 99.67%     | 97.89%         | 99.84%     | 97.47%     | 98.77%     | 99.51%     | 82.42%     | 83.14%    |
| Service Level<br>Achieved | From Backfill Demands          | N/A.        | N/A.        | N/A.        | N/A.        | N/A.        | N/A.       | N/A.           | N/A.       | N/A.       | N/A.       | N/A.       | N/A.       | N/A.      |
| Achieveu                  | Aggregated                     | 99.59%      | 100.00%     | 100.00%     | 98.57%      | 99.76%      | 99.67%     | 97.89%         | 99.84%     | 97.47%     | 98.77%     | 99.51%     | 82.42%     | 83.14%    |
|                           | Overall                        |             |             |             |             |             |            | 99.42%         |            |            |            |            |            |           |
|                           | MTBUR                          | 45000       | 5000        | 8000        | 10000       | 12000       | 140000     | 50000          | 55000      | 75000      | 100000     | 520000     | 200000     | 400000    |
| Component Details         | QPA                            | 10          | 1           | 1           | 1           | 1           | 5          | 1              | 1          | 1          | 1          | 4          | 1          | 1         |
| Component Details         | MTBUR / QPA                    | 4500        | 5000        | 8000        | 10000       | 12000       | 28000      | 50000          | 55000      | 75000      | 100000     | 130000     | 200000     | 400000    |
|                           | Unit Price                     | \$55,000    | \$5,000     | \$15,000    | \$150,000   | \$22,000    | \$45,000   | \$150,000      | \$8,000    | \$60,000   | \$30,000   | \$10,000   | \$180,000  | \$75,000  |
| Expected Value            | of Total Inventory Cost p.a.   | \$165,000   | \$18,000    | \$48,000    | \$240,000   | \$52,800    | \$72,000   | \$120,000      | \$11,200   | \$48,000   | \$24,000   | \$8,000    | \$72,000   | \$30,000  |
| Expected Value of #       | Deliveries                     | 18.491      | 16.0872     | 10.3066     | 8.447       | 7.0392      | 3.0078     | 1.7701         | 1.5083     | 1.1666     | 0.8132     | 0.6488     | 0.5497     | 0.26      |
| of Logistics              | Rebalancings                   | 0           | 0           | 0           | 0           | 0           | 0          | 0              | 0          | 0          | 0          | 0          | 0          | 0         |
| Movements p.a.            | Replenishments                 | 0           | 0           | 0           | 0           | 0           | 0          | 0              | 0          | 0          | 0          | 0          | 0          | 0         |
| Expected Value of         | Deliveries                     | \$36,982.00 | \$32,174.34 | \$20,613.26 | \$16,894.05 | \$14,078.38 | \$6,015.58 | \$3,540.19     | \$3,016.63 | \$2,333.23 | \$1,626.37 | \$1,297.60 | \$1,099.37 | \$520.06  |
| Total Logistics           | Rebalancings                   | \$0         | \$0         | \$0         | \$0         | \$0         | \$0        | \$0            | \$0        | \$0        | \$0        | \$0        | \$0        | \$0       |
| Costs p.a.                | Replenishments                 | \$0         | \$0         | \$0         | \$0         | \$0         | \$0        | \$0            | \$0        | \$0        | \$0        | \$0        | \$0        | \$0       |
| Expected Value of         | From Immediate Maintenance     |             |             |             |             |             |            |                |            |            |            |            |            | 1         |
| Total Penalty Cost        | Demands                        | \$70.04     | \$0.00      | \$0.00      | \$107.16    | \$15.76     | \$9.01     | \$32.78        | \$2.29     | \$26.06    | \$9.46     | \$2.91     | \$66.82    | \$31.68   |
| p.a.                      | From Backfill Demands          | \$0         | \$0         | \$0         | \$0         | \$0         | \$0        | \$0            | \$0        | \$0        | \$0        | \$0        | \$0        | \$0       |
| Expected Value o          | f Total Service Lifecycle Cost |             |             |             |             |             |            |                |            |            |            |            |            |           |
|                           | tics + Penalty) on an annual   |             |             |             |             |             |            |                |            |            |            |            |            |           |
| ,8.                       | basis                          |             |             |             |             |             |            | \$1.049.565.01 |            |            |            |            |            |           |
|                           |                                | I           |             |             |             |             |            | 21,045,003.01  |            |            |            |            |            |           |

Table 3 shows how cost arbitrage opportunities can be exploited in such an optimised contract: The part numbers in the output table are sequenced in the order of increasing MTBUR/QPA. A simplistic partby-part optimisation according to the above-mentioned IP method would have resulted in decreasing spare parts pool stock recommendations from left to right. However, the simulation-based integrated optimisation approach allows to further reduce the number of units for the very expensive Component 10 below the overall trend (only 8 units compared to 12 units for Component 9) against an increase of the number of units for the cheap Component 6 above the overall trend (7 units compared to 4 units for Component 7). This means that total cost can be reduced without compromising the 97% service level.

It should be noted that the long-term service level for such a supply network is not equivalent to the performance required for observing *at least* that service level within a limited performance measurement period (which is assumed to be 3 months in this case) with a certain confidence level. This can also be seen in Table 3: Because the required confidence level to observe at least 97% service level is 90%, this can be achieved only with an inventory configuration corresponding to a long-term service level of 99.42%.

## 4 UNLOCKING VALUE FROM NEW SPARE PARTS LOGISTICS POLICIES

The above-mentioned paradigm shift for spare parts management has a number of new service models and logistics policies associated with it. This comprises outstation support for NO-GO items, pooling between stockholding locations at different airports, backfilling of operator-owned on-site stock, and dynamic re-balancing. Some important implications of these policies are showcased in the following subsections.

## 4.1 Outstation coverage

For so-called NO-GO items (i.e. critical-to-dispatch components), availability at wherever a fault is detected is essential because otherwise an affected aircraft has to be declared AOG (Aircraft-On-Ground) and cannot take off until the unserviceable unit has been replaced. However, in the scenario described in Section 3 it is assumed that spares are held only at main bases (M/B). This means that in case of a fault at an outstation (O/S), a serviceable replacement would always have to be shipped from one of the main bases to the affected outstation.

Ideally, a component service provider would provide component exchange services to an operator at all outstations for all critical-to-dispatch components. In such a case, outstations also have to be considered as stock holding locations in order to provide the required service levels. Table 4 shows how the spares inventory would be allocated in case of full outstation support commitment for the above-mentioned flight network and component range, and Table 5 summarises the differences of such a full-outstation-support scenario against the no-outstation-support scenario described in Section 3. It shows that the number of AOG instances can be reduced by two orders of magnitude although the spare parts inventory requirements would only go up by a factor of (approximately) two.

# Table 4: Optimised component support contract, full outstation coverage

|                     |   | Component    | Component   | Component   | Component    | Component   | Component    | Component    | Component   | Component    | Component   | Component   | Component    | Component_   |
|---------------------|---|--------------|-------------|-------------|--------------|-------------|--------------|--------------|-------------|--------------|-------------|-------------|--------------|--------------|
|                     | Airport   | 13           | 12          | 11          | 10           | g           | 8            | 7            | 6           | 5            | 4           | 3           | 2            | 1            |
|                     | LHR   | 3            | 3           | 3           | 10           | 3           | 1            | 1            | 1           | 1            | 1           | 1           | 1            | 1            |
|                     | LAX   | 3            | 4           | 3           | 2            | 2           | 1            | 1            | 1           | 1            | 1           | 1           | 1            | 1            |
|                     | SYD   | 3            | 3           | 2           | 2            | 1           | 1            | 1            | 1           | 1            | 1           | 1           | 1            | 1            |
| Ontimicad Daal      |   | 2            | 3           | 2           | 2            | 2           | 1            | 1            | 1           |              |             | 1           | 1            | 1            |
| Optimised Pool      | SIN   | 2            | 2           | 2           | 1            | 2           | 1            | 1            | 1           | 1            | 1           | 1           | 0            | 1            |
| Stock               |   |              |             |             |              |             |              |              |             |              |             |             | -            |              |
|                     | BKK   | 2            | 3           | 2           | 1            | 2           | 1            | 1            | 1           | 1            | 1           | 1           | 0            | 1            |
|                     | HKG   | 2            | 2           | 2           | 1            | 1           | 1            | 1            | 1           | 1            | 1           | 1           | 0            | 1            |
|                     | NRT   | 2            | 2           | 2           | 1            | 1           | 1            | 1            | 1           | 1            | 1           | -           | 0            | 0            |
|                     | MEL   | 1            | 2           | 1           | 1            | 1           | 1            | 1            | 1           | 1            | 1           | 1           | 0            | 0            |
|                     | PVG   | 2            | 2           | 1           | 1            | 1           | 1            | 0            | 1           | 1            | 1           | 1           | 0            | 0            |
|                     | FRA   | 1            | 2           | 1           | 1            | 1           | 1            | 0            | 1           | 1            | 1           | 1           | 0            | 0            |
|                     | SFO   | 1            | 2           | 1           | 1            | 1           | 1            | 0            | 1           | 1            | 1           | 0           | 0            | 0            |
|                     | CDG   | 1            | 2           | 1           | 1            | 1           | 1            | 0            | 1           | 1            | 1           | 0           | 0            | 0            |
|                     | JFK   | 1            | 2           | 1           | 1            | 1           | 1            | 1            | 1           | 1            | 1           | 1           | 0            | 0            |
| Tot                 | tal Pool Stock  | 26           | 34          | 24          | 17           | 20          | 14           | 10           | 14          | 14           | 14          | 12          | 4            | 7            |
|                     | observing at least 97% service<br>ths performance measurement<br>period |              |             |             |              |             |              | 0.9005       |             |              |             |             |              |              |
|                     | Rebalance   | No           | No          | No          | No           | No          | No           | No           | No          | No           | No          | No          | No           | No           |
| Rebalancing Policy  | Threshold   | -            | -           | -           | -            | -           | -            | -            | -           | -            | -           | -           | -            | -            |
|                     | From Immediate Maintenance  |              |             |             |              |             |              |              |             |              |             |             |              |              |
| Expected value of   | Demands   | 0.084        | 0           | 0.0158      | 0.1765       | 0.0315      | 0.0405       | 0.1009       | 0.0092      | 0.0101       | 0.0063      | 0.0048      | 0.2326       | 0.0199       |
| no-fill events p.a. | From Backfill Demands   | 0            | 0           | 0           | 0            | 0           | 0            | 0            | 0           | 0            | 0           | 0           | 0            | 0            |
|                     | Total   |              | , i i       |             |              |             |              | 0.7321       | -           |              |             |             |              |              |
|                     | From Immediate Maintenance  |              |             |             |              |             |              | 0//021       |             |              |             |             |              |              |
|                     | Demands   | 99.75%       | 100.00%     | 99.92%      | 98.82%       | 99.76%      | 99.26%       | 96.76%       | 99.67%      | 99.51%       | 99.59%      | 99.60%      | 69.40%       | 94.71%       |
| Service Level       | From Backfill Demands   | N/A.         | N/A.        | N/A.        | N/A.         | N/A.        | N/A.         | N/A.         | N/A.        | N/A.         | N/A.        | N/A.        | N/A.         | N/A.         |
| Achieved            | Aggregated  | 99.75%       | 100.00%     | 99.92%      | 98.82%       | 99.76%      | 99.26%       | 96.76%       | 99.67%      | 99.51%       | 99.59%      | 99.60%      | 69.40%       | 94.71%       |
|                     | Overall   |              |             |             |              |             |              | 99.43%       |             |              |             |             |              |              |
|                     | MTBUR   | 45000        | 5000        | 8000        | 10000        | 12000       | 140000       | 50000        | 55000       | 75000        | 100000      | 520000      | 200000       | 400000       |
|                     | QPA   | 10           | 1           | 1           | 1            | 1           | 5            | 1            | 1           | 1            | 1           | 4           | 1            | 1            |
| Component Details   | MTBUR / QPA   | 4500         | 5000        | 8000        | 10000        | 12000       | 28000        | 50000        | 55000       | 75000        | 100000      | 130000      | 200000       | 400000       |
|                     | Unit Price  | \$55.000.00  | \$5,000.00  | \$15.000.00 | \$150,000.00 | \$22.000.00 | \$45.000.00  | \$150,000.00 | \$8,000.00  | \$60,000.00  | \$30,000.00 | \$10,000.00 | \$180,000.00 | \$75,000.00  |
| Expected Value      | of Total Inventory Cost p.a.  | \$286,000.00 | \$34,000.00 | \$72,000.00 | \$510,000.00 | \$88,000.00 | \$126,000.00 | \$300,000.00 | \$22,400.00 | \$168,000.00 | \$84,000.00 | \$24,000.00 | \$144,000.00 | \$105,000.00 |
| Expected Value of # | Deliveries  | 0.5884       | 0.2269      | 0.2049      | 0.8573       | 0.2837      | 0.2476       | 0.5068       | 0.0711      | 0.037        | 0.0151      | 0.0727      | 0.3549       | 0.0785       |
| of Logistics        | Rebalancings  | 0            | 0           | 0           | 0            | 0           | 0            | 0            | 0           | 0            | 0           | 0           | 0            | 0            |
| Movements p.a.      | Replenishments  | 0            | 0           | 0           | 0            | 0           | 0            | 0            | 0           | 0            | 0           | 0           | 0            | 0            |
| Expected Value of   | Deliveries  | \$1,176.70   | \$453.87    | \$409.74    | \$1,714.62   | \$567.34    | \$495.29     | \$1,013.64   | \$142.12    | \$73.96      | \$30.26     | \$145.47    | \$709.80     | \$156.96     |
| Total Logistics     | Rebalancings  | \$0.00       | \$0.00      | \$0.00      | \$0.00       | \$0.00      | \$0.00       | \$0.00       | \$0.00      | \$0.00       | \$0.00      | \$0.00      | \$0.00       | \$0.00       |
| Costs p.a.          | Replenishments  | \$0.00       | \$0.00      | \$0.00      | \$0.00       | \$0.00      | \$0.00       | \$0.00       | \$0.00      | \$0.00       | \$0.00      | \$0.00      | \$0.00       | \$0.00       |
| Expected Value of   | From Immediate Maintenance  |              |             |             |              |             |              |              |             |              |             |             |              |              |
| Total Penalty Cost  | Demands   | \$42.02      | \$0.00      | \$7.88      | \$88.25      | \$15.76     | \$20.26      | \$50.43      | \$4.58      | \$5.04       | \$3.15      | \$2.42      | \$116.30     | \$9.93       |
| p.a.                | From Backfill Demands   | \$0.00       | \$0.00      | \$0.00      | \$0.00       | \$0.00      | \$0.00       | \$0.00       | \$0.00      | \$0.00       | \$0.00      | \$0.00      | \$0.00       | \$0.00       |
| Expected Value o    | f Total Service Lifecycle Cost<br>tics + Penalty) on an annual<br>basis |              |             |             |              |             |              |              |             |              |             |             |              |              |

|   | Delivery Cor | nmitment at    |
|---|--------------|----------------|
|   | M/B and O/S  | Main Base only |
| Expected total inventory cost p.a. (\$)   | \$1,963,400  | \$909,000      |
| Total inventory value (\$)                | \$9,817,000  | \$4,545,000    |
| Expected Logistics cost p.a. (\$)         | \$7,090      | \$140,191      |
| Expected Penalty cost p.a (\$)            | \$366        | \$374          |
| Expected total lifecycle cost p.a. (\$)   | \$1,970,856  | \$1,049,565    |
| Total inventory (units)                   | 210          | 104            |
| Expected annual unprotected faults at O/S | -            | 76.53          |
| Expected annual no-fills at O/S           | 0.73         | -              |

Table 5: Implications of full outstation coverage

## 4.2 **Pooling between locations**

Since in many cases contractual delivery commitments made by the component service provider to the operator are not immediate, it is possible to pool spare components across several airports. To what extent this is possible for the outstation coverage scenario described in Section 4.1 is illustrated in Table 6. Only for a 2 hours delivery commitment, spares have to be positioned at all airports. In turn, if the delivery commitment were 12 hours only, spares would have to be positioned at the three out of the four main bases and – because of the large number of incoming flight hours (see Table 1) – LAX and SIN.

|                                    |       |       |       | Compo | nent_7 |        |        |        |
|------------------------------------|-------|-------|-------|-------|--------|--------|--------|--------|
| MTBUR/<br>QPA                      |       |       |       | 500   | 00/1   |        |        |        |
| Delivery<br>Time<br>Commit<br>ment | 2 hrs | 4 hrs | 6 hrs | 8 hrs | 10 hrs | 12 hrs | 14 hrs | 16 hrs |
| LHR                                | 1     | 1     | 2     | 2     | 2      | 2      | 2      | 2      |
| LAX                                | 1     | 1     | 1     | 1     | 1      | 1      | 1      | 1      |
| SYD                                | 1     | 1     | 1     | 1     | 2      | 1      | 1      | 1      |
| SIN                                | 1     | 1     | 1     | 1     | 1      | 1      | 1      | 1      |
| ICN                                | 1     | 1     | 1     | 1     | 1      | 1      | 1      | 1      |
| BKK                                | 1     | 1     | 1     | 1     | 1      | 0      | 0      | 0      |
| HKG                                | 1     | 1     | 1     | 1     | 0      | 0      | 0      | 0      |
| NRT                                | 1     | 1     | 1     | 1     | 0      | 0      | 0      | 0      |
| MEL                                | 1     | 1     | 1     | 1     | 0      | 0      | 0      | 0      |
| JFK                                | 1     | 1     | 1     | 1     | 0      | 0      | 0      | 0      |
| FRA                                | 1     | 0     | 0     | 0     | 0      | 0      | 0      | 0      |
| SFO                                | 1     | 0     | 0     | 0     | 0      | 0      | 0      | 0      |
| CDG                                | 1     | 0     | 0     | 0     | 0      | 0      | 0      | 0      |
| PVG                                | 1     | 0     | 0     | 0     | 0      | 0      | 0      | 0      |
| Total                              | 14    | 10    | 11    | 11    | 8      | 6      | 6      | 6      |

Table 6: Pooling potential for Component 7

## 4.3 Backfilling of Operator-Owned On-Site Stock

In many cases, for example for the Airbus A380, operators still buy or lease a subset of most important spare parts and keep it at their own main base as on-site stock. Such on-site stock is not accessible to the component service provider for use for other operators. In case such a component fails the operator takes a serviceable unit from his on-site stock and returns the unserviceable unit to the component service provider then also might have to "backfill" the on-site stock from his pool within a certain time frame. Table 7 shows an optimisation result for such a backfill scenario.

With a backfill delivery commitment, obviously the associated delivery time becomes an important parameter, especially because of the typically long ( $\geq$ 24 hours) time frame. Figure 2 shows how for the above-described four operator scenario the total lifecycle cost depends on the backfill delivery time.

|                     |                                 | Component   | Component   | Component   | Component   | Component   | Component  | Component    | Component  | Component  | Component  | Component  | Component  | Component |
|---------------------|---------------------------------|-------------|-------------|-------------|-------------|-------------|------------|--------------|------------|------------|------------|------------|------------|-----------|
|                     | Airport                         | 13          | 12          | 11          | 10          | 9           | 8          | 7            | 6          | 5          | 4          | 3          | 2          | 1         |
| Optimised Pool      | LHR                             | 2           | 3           | 2           | 2           | 2           | 1          | 1            | 1          | 0          | 1          | 1          | 0          | 0         |
| Stock               | SYD                             | 2           | 3           | 2           | 1           | 1           | 1          | 1            | 1          | 0          | 1          | 1          | 0          | 0         |
|                     | ICN                             | 4           | 3           | 2           | 2           | 1           | 1          | 1            | 1          | 0          | 1          | 1          | 0          | 0         |
|                     | ВКК                             | 2           | 2           | 1           | 1           | 2           | 1          | 0            | 1          | 2          | 0          | 0          | 1          | 1         |
| То                  | tal Pool Stock                  | 10          | 11          | 7           | 6           | 6           | 4          | 3            | 4          | 2          | 3          | 3          | 1          | 1         |
|                     | ВКК                             | 2           | 2           | 1           | 1           | 1           | 1          | 1            | 1          | 1          | 1          | 1          | 1          | 1         |
|                     | ICN                             | 2           | 3           | 2           | 1           | 1           | 1          | 1            | 1          | 1          | 1          | 1          | 1          | 1         |
| On Site Stock       | LHR                             | 1           | 4           | 2           | 1           | 1           | 1          | 1            | 1          | 1          | 1          | 1          | 1          | 1         |
|                     | SYD                             | 1           | 2           | 2           | 1           | 1           | 1          | 1            | 1          | 1          | 1          | 1          | 1          | 1         |
| Total P             | Pool + On Site Stock            | 16          | 22          | 14          | 10          | 10          | 8          | 7            | 8          | 6          | 7          | 7          | 5          | 5         |
|                     | observing at least 97% service  |             |             |             |             |             |            |              |            |            |            |            |            |           |
|                     | ths performance measurement     |             |             |             |             |             |            |              |            |            |            |            |            |           |
|                     | period                          |             |             |             |             |             |            | 0.9013       |            |            |            |            |            |           |
|                     | Rebalance                       | No          | No          | No          | No          | No          | No         | 0.9013<br>No | No         | No         | No         | No         | No         | No        |
| Rebalancing Policy  | Threshold                       | NO          | NO          | NO          | NO          | 110         | 110        | NO           | NO         | NO         | NO         | NO         | NO         | NO        |
| Rebarancing Foricy  | From Immediate Maintenance      | -           | -           | -           | -           | -           | -          | -            | -          | -          | -          | -          | -          | -         |
| Expected value of   | Demands                         | 0.0841      | 0           | 0           | 0.0378      | 0           | 0.0045     | 0.005        | 0          | 0.0841     | 0.0013     | 0          | 0.0485     | 0.0164    |
| no-fill events p.a. | From Backfill Demands           | 0.1119      | 0           | 0.0632      | 0.1134      | 0.0208      | 0.0271     | 0.0479       | 0.0046     | 0.0151     | 0.0063     | 0.0039     | 0.024      | 0.006     |
| no in creno plui    | Total                           | 0.1115      | 0           | 0.0002      | 011101      | 0.0200      | 0.0271     | 0.7257       | 0.0010     | 0.0101     | 0.0005     | 0.00000    | 0.021      | 0.000     |
|                     | From Immediate Maintenance      |             |             |             |             |             |            |              |            |            |            |            |            |           |
|                     | Demands                         | 99.59%      | 100.00%     | 100.00%     | 99.58%      | 100.00%     | 99.86%     | 99.73%       | 100.00%    | 93.07%     | 99.86%     | 100.00%    | 89.28%     | 92.59%    |
| Service Level       | From Backfill Demands           | 99.19%      | 100.00%     | 99.17%      | 98.07%      | 99.60%      | 98.77%     | 96.08%       | 99.59%     | 98.22%     | 99.03%     | 99.20%     | 92.18%     | 96.12%    |
| Achieved            | Aggregated                      | 99.43%      | 100.00%     | 99.67%      | 98.99%      | 99.84%      | 99.42%     | 98.30%       | 99.84%     | 95.19%     | 99.51%     | 99.68%     | 90.45%     | 94.04%    |
|                     | Overall                         |             |             |             |             |             | •          | 99.44%       |            |            |            |            |            |           |
|                     | MTBUR                           | 45000       | 5000        | 8000        | 10000       | 12000       | 140000     | 50000        | 55000      | 75000      | 100000     | 520000     | 200000     | 400000    |
| Component Dataila   | QPA                             | 10          | 1           | 1           | 1           | 1           | 5          | 1            | 1          | 1          | 1          | 4          | 1          | 1         |
| Component Details   | MTBUR / QPA                     | 4500        | 5000        | 8000        | 10000       | 12000       | 28000      | 50000        | 55000      | 75000      | 100000     | 130000     | 200000     | 400000    |
|                     | Unit Price                      | \$55,000    | \$5,000     | \$15,000    | \$150,000   | \$22,000    | \$45,000   | \$150,000    | \$8,000    | \$60,000   | \$30,000   | \$10,000   | \$180,000  | \$75,000  |
|                     | of Total Inventory Cost p.a.    | \$110,000   | \$11,000    | \$21,000    | \$180,000   | \$26,400    | \$36,000   | \$90,000     | \$6,400    | \$24,000   | \$18,000   | \$6,000    | \$36,000   | \$15,000  |
| Expected Value of # | Deliveries                      | 19.1074     | 16.4654     | 11.0946     | 9.1026      | 7.6696      | 3.2644     | 1.992        | 1.5748     | 1.8323     | 0.938      | 0.7594     | 0.6266     | 0.3237    |
| of Logistics        | Rebalancings                    | 0           | 0           | 0           | 0           | 0           | 0          | 0            | 0          | 0          | 0          | 0          | 0          | 0         |
| Movements p.a.      | Replenishments                  | 0           | 0           | 0           | 0           | 0           | 0          | 0            | 0          | 0          | 0          | 0          | 0          | 0         |
| Expected Value of   | Deliveries                      | \$38,214.73 | \$32,930.79 | \$22,189.20 | \$18,205.23 | \$15,339.13 | \$6,528.88 | \$3,983.97   | \$3,149.58 | \$3,664.58 | \$1,876.00 | \$1,518.72 | \$1,253.19 | \$647.40  |
| Total Logistics     | Rebalancings                    | \$O         | \$O         | \$0         | \$0         | \$O         | \$0        | \$O          | \$O        | \$O        | \$0        | \$0        | \$0        | \$O       |
| Costs p.a.          | Replenishments                  | \$0         | \$0         | \$0         | \$0         | \$0         | \$0        | \$O          | \$0        | \$0        | \$0        | \$0        | \$0        | \$0       |
| Expected Value of   | From Immediate Maintenance      |             |             |             |             |             |            |              |            |            |            |            |            |           |
| Total Penalty Cost  | Demands                         | \$42.03     | \$0.00      | \$0.00      | \$18.91     | \$0.00      | \$2.25     | \$2.52       | \$0.00     | \$42.03    | \$0.63     | \$0.00     | \$24.27    | \$8.19    |
| p.a.                | From Backfill Demands           | \$55.94     | \$0.00      | \$31.59     | \$56.69     | \$10.38     | \$13.54    | \$23.97      | \$2.29     | \$7.56     | \$3.16     | \$1.95     | \$11.98    | \$3.00    |
| Expected Value of   | of Total Service Lifecycle Cost |             |             |             |             |             |            |              |            |            |            |            |            |           |
| (Inventory + Logis  | stics + Penalty) on an annual   |             |             |             |             |             |            |              |            |            |            |            |            |           |
|                     | basis                           |             |             |             |             |             |            | \$729,664.26 |            |            |            |            |            |           |

# Table 7: Optimised component support contract with backfilling of on-site stock at all main bases



Figure 2: Effect of backfill delivery time on total lifecycle cost

In some cases, an operator might have on-site stock but does not require backfilling. The component service provider only has to deliver from his pool when the operator has a need for immediate maintenance in a situation where either the on-site stock is depleted to zero (i.e. previously exchanged unserviceable components have not yet returned from repair to the pool) or for part numbers where no on-site stock has been provisioned for in the first place.

Table 8 shows the comparison between the with-backfilling and the without-backfilling scenario. The total lifecycle cost is obviously higher in case backfilling is required since backfilling imposes a significant constraint on the system by requiring inventory movements even if there is no spare part requirement for immediate maintenance.

|   | With 24hr Backfill | No Backfill |
|---|--------------------|-------------|
| Expected total inventory cost p.a. (\$) | \$579,800          | \$485,000   |
| Total inventory value (\$)              | \$2,899,000        | \$2,425,000 |
| Expected Logistics cost p.a. (\$)       | \$149,502          | \$139,168   |
| Expected Penalty cost p.a (\$)          | \$363              | \$212       |
| Expected total lifecycle cost p.a. (\$) | \$729,664          | \$624,380   |
| Total inventory (units)                 | 61                 | 53          |

Table 8: Removal of backfill constraint: Implications

#### 4.4 Dynamic Re-Balancing

Since the above-described four-operator scenario involves many stockholding nodes it also bears significant potential for dynamic "re-balancing". If, for example, the default inventory in LHR is 2 units and in FRA 1 unit and the FRA unit is taken, the question arises whether for the duration of the repair turnaround time one of the LHR units should be moved to FRA. Obviously, such re-balancing can be an economical option only for expensive components (otherwise one would have stored an additional default unit at FRA right away to avoid logistics cost for the transport from LHR to FRA), for which the repair turnaround time is long (otherwise the risk of an additional demand occurring in FRA is too low), and if the number of flights to be protected in FRA is high (otherwise again the risk of an additional demand in FRA is too low).

Table 9 shows for which components such re-balancing is an economically viable option. The comparison with the case in which re-balancing is not considered at all as a logistics policy is made in Table 10: The total annual lifecycle cost can be reduced by another 5%.

| Optimised Pool<br>Stock | Airport<br>LHR<br>LAX<br>SYD<br>SIN | Component_<br>13<br>2<br>2<br>2<br>2 | Component_<br>12<br>3 | Component_<br>11<br>2 | Component_<br>10 | Component_<br>9 | Component_<br>8 | 7              | Component_<br>6 | Component_<br>5 | Component_<br>4 | Component_<br>3 | Component_<br>2 | Component_ |
|-------------------------|-------------------------------------|--------------------------------------|-----------------------|-----------------------|------------------|-----------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------|
|                         | LHR<br>LAX<br>SYD<br>SIN            | 2<br>2                               | 3                     |                       | 10               |                 |                 |                |                 |                 |                 |                 |                 | 1          |
|                         | LAX<br>SYD<br>SIN                   | 2                                    | -                     |                       | 1                | 3               | 1               | 1              | 1               | 2               | 1               | 1               | 1               | 1          |
|                         | SYD<br>SIN                          |                                      | 4                     | 2                     | 3                | 2               | 1               | 1              | 1               | 1               | 1               | 1               | 1               | 1          |
|                         | SIN                                 |                                      | 3                     | 2                     | 1                | 1               | 1               | 1              | 1               | 1               | 1               | 1               | 1               | 1          |
|                         |                                     | 2                                    | 3                     | 2                     | 1                | 2               | 1               | 1              | 1               | 1               | 1               | 1               | 1               | 1          |
|                         |                                     | 2                                    | 2                     | 2                     | 1                | 2               | 1               | 1              | 1               | 1               | 1               | 1               | 0               | 1          |
|                         | ICN<br>BKK                          | 2                                    | 4                     | 2                     | 1                | 2               | 1               | 1              | 1               | 1               | 1               | 1               | 0               | 0          |
|                         | HKG                                 | 1                                    | 2                     | 2                     | 1                | 1               |                 | 1              |                 | 1               | 1               |                 | 0               | 0          |
|                         | NRT                                 | 1                                    | 2                     | 2                     | 1                | 1               | 1               | 1              | 1               | 1               | 1               | 1               | 0               | 0          |
| , <u> </u>              |                                     | _                                    | _                     | _                     | _                | _               | _               | _              | -               | _               |                 | _               | -               | ÷          |
|                         | MEL                                 | 1                                    | 2                     | 2                     | 1                | 1               | 1               | 1              | 1               | 0               | 1               | 1               | 0               | 0          |
|                         | PVG                                 | 1                                    | 2                     | 1                     | 1                | 1               | 1               | 0              | 1               | 1               | 1               | 1               | 0               | 0          |
|                         | FRA                                 | 1                                    | 2                     | 2                     | 1                | 1               | 1               | 0              | 1               | 0               | 1               | 1               | 0               | 0          |
|                         | SFO                                 | 1                                    | 2                     | 2                     | 1                | 1               | 1               | 0              | 1               | 0               | 1               | 0               | 0               | 0          |
|                         | CDG                                 | 1                                    | 2                     | 2                     | 1                | 1               | 1               | 0              | 1               | 0               | 1               | 0               | 0               | 0          |
|                         | JFK                                 | 1                                    | 2                     | 2                     | 1                | 1               | 1               | 1              | 1               | 0               | 1               | 1               | 0               | 0          |
|                         | Pool Stock                          | 20                                   | 35                    | 27                    | 16               | 20              | 14              | 10             | 14              | 10              | 14              | 12              | 4               | 5          |
|                         | bserving at least 97% service       |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
|                         | performance measurement             |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
| <u>p</u>                | period                              |                                      |                       |                       |                  |                 |                 | 0.9002         |                 |                 |                 |                 | 1               |            |
|                         | Rebalance                           | Yes                                  | No                    | No                    | Yes              | No              | No              | No             | No              | Yes             | No              | No              | No              | Yes        |
| Rebalancing Policy      | Threshold                           | N/A.                                 | -                     | -                     | N/A.             | -               | -               | -              | -               | N/A.            | -               | -               | -               | N/A.       |
|                         | rom Immediate Maintenance           |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
| Expected value of       | Demands                             | 0.056                                | 0                     | 0                     | 0.1261           | 0.0315          | 0.0585          | 0.0958         | 0.0092          | 0.0572          | 0.005           | 0.0048          | 0.2326          | 0.0602     |
| no-fill events p.a.     | From Backfill Demands               | 0                                    | 0                     | 0                     | 0                | 0               | 0               | 0              | 0               | 0               | 0               | 0               | 0               | 0          |
|                         | Total                               |                                      |                       |                       |                  |                 |                 | 0.737          |                 |                 |                 |                 |                 |            |
| Fro                     | rom Immediate Maintenance           |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
| Service Level           | Demands                             | 99.84%                               | 100.00%               | 100.00%               | 99.16%           | 99.76%          | 98.93%          | 96.92%         | 99.67%          | 97.23%          | 99.67%          | 99.60%          | 69.40%          | 83.98%     |
| Achieved                | From Backfill Demands               | N/A.                                 | N/A.                  | N/A.                  | N/A.             | N/A.            | N/A.            | N/A.           | N/A.            | N/A.            | N/A.            | N/A.            | N/A.            | N/A.       |
|                         | Aggregated                          | 99.84%                               | 100.00%               | 100.00%               | 99.16%           | 99.76%          | 98.93%          | 96.92%         | 99.67%          | 97.23%          | 99.67%          | 99.60%          | 69.40%          | 83.98%     |
|                         | Overall                             |                                      |                       |                       | -                |                 |                 | 99.43%         |                 | -               | -               | -               |                 |            |
|                         | MTBUR                               | 45000                                | 5000                  | 8000                  | 10000            | 12000           | 140000          | 50000          | 55000           | 75000           | 100000          | 520000          | 200000          | 400000     |
|                         | QPA                                 | 10                                   | 1                     | 1                     | 1                | 1               | 5               | 1              | 1               | 1               | 1               | 4               | 1               | 1          |
| Component Details       | MTBUR / QPA                         | 4500                                 | 5000                  | 8000                  | 10000            | 12000           | 28000           | 50000          | 55000           | 75000           | 100000          | 130000          | 200000          | 400000     |
|                         | Unit Price                          | \$55,000                             | \$5,000               | \$15,000              | \$150,000        | \$22,000        | \$45,000        | \$150,000      | \$8,000         | \$60,000        | \$30,000        | \$10,000        | \$180,000       | \$75,000   |
| Expected Value of T     | Total Inventory Cost p.a.           | \$220,000                            | \$35,000              | \$81,000              | \$480,000        | \$88,000        | \$126,000       | \$300,000      | \$22,400        | \$120,000       | \$84,000        | \$24,000        | \$144,000       | \$75,000   |
| Expected Value of #     | Deliveries                          | 0.2802                               | 0.1009                | 0.1103                | 0.1513           | 0.2206          | 0.2431          | 0.5119         | 0.0711          | 0.3093          | 0.0139          | 0.0727          | 0.3549          | 0.1352     |
| of Logistics            | Rebalancings                        | 29.8658                              | 0                     | 0                     | 13.0235          | 0               | 0               | 0              | 0               | 1.6591          | 0               | 0               | 0               | 0.3035     |
| Movements p.a.          | Replenishments                      | 0                                    | 0                     | 0                     | 0                | 0               | 0               | 0              | 0               | 0               | 0               | 0               | 0               | 0          |
| Expected Value of       | Deliveries                          | \$560.33                             | \$201.72              | \$220.63              | \$302.58         | \$441.26        | \$486.29        | \$1,023.73     | \$142.12        | \$618.61        | \$27.74         | \$145.47        | \$709.80        | \$270.43   |
| Total Logistics         | Rebalancings                        | \$59,731.53                          | \$0.00                | \$0.00                | \$26,047.10      | \$0.00          | \$0.00          | \$0.00         | \$0.00          | \$3,318.29      | \$0.00          | \$0.00          | \$0.00          | \$607.05   |
| Costs p.a.              | Replenishments                      | \$0                                  | \$0                   | \$0                   | \$O              | \$0             | \$0             | \$0            | \$0             | \$0             | \$0             | \$0             | \$0             | \$0        |
| Expected Value of Fro   | rom Immediate Maintenance           |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
| Total Penalty Cost      | Demands                             | \$28.02                              | \$0.00                | \$0.00                | \$63.04          | \$15.76         | \$29.27         | \$47.91        | \$4.58          | \$28.58         | \$2.52          | \$2.42          | \$116.30        | \$30.10    |
| p.a.                    | From Backfill Demands               | \$0                                  | \$0                   | \$0                   | \$0              | \$0             | \$0             | \$0            | \$0             | \$0             | \$0             | \$0             | \$0             | \$0        |
| Expected Value of To    | otal Service Lifecycle Cost         |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
|                         | cs + Penalty) on an annual          |                                      |                       |                       |                  |                 |                 |                |                 |                 |                 |                 |                 |            |
|                         | basis                               |                                      |                       |                       |                  |                 |                 | \$1,894,623.19 |                 |                 |                 |                 |                 |            |

# Table 9: Optimised component support contract with re-balancing for selected components

|   | With        | Without     |
|---|-------------|-------------|
|   | Rebalancing | Rebalancing |
| Expected total inventory cost p.a. (\$) | \$1,799,400 | \$1,963,400 |
| Total inventory value (\$)              | \$8,997,000 | \$9,817,000 |
| Expected Logistics cost p.a. (\$)       | \$94,855    | \$7,090     |
| Expected Penalty cost p.a (\$)          | \$369       | \$366       |
| Total inventory (units)                 | 201         | 210         |
| Expected total lifecycle cost p.a. (\$) | \$1,894,623 | \$1,970,856 |

Table 10: Value-add of re-balancing for 13-parts contract

# 5 SUMMARY AND OUTLOOK

In this paper, the advantages of using simulation-based decision support for optimisation of rotables support contracts and how this can contribute to considerable cost savings have been illustrated. It should be noted that the concepts described are also applicable for mission-centric scenarios such as helicopter operations or military aviation.

An important topic particularly for military aviation is how availability of prognostics information from a health-monitoring system can help increase fleet readiness and further reduce spare parts requirements. This is currently being analysed in a joint project between EADS Innovation Works and D-SIMLAB Technologies.

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