RETURN-ON-INVESTMENT (ROI) FOR ELECTRONIC PROGNOSTICS IN MIL/AERO SYSTEMS

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Abstract - This paper describes a methodology for quantifying the return-on-investment (ROI) for the adoption of Electronic Prognostics in Mil/Aero systems.

An example using the methodology will be taken from publicly-available data on switch-mode power supplies for the Eurofighter but the principles described are extensible to other Mil/Aero systems.

INTRODUCTION

In recent years, military and aerospace systems have adopted various forms of prognostics to improve operational readiness, reduce the cost of provisioning and spares, and increase operator safety.

In the initial phases of adoption, the focus was on mechanical prognostics, where precursor signatures to wear-out could be easily detected and processed. As the state-of-the art improved, Program Managers began to ask that this requirement be extended to Electronic Prognostics. This newly emerging field is in need of a deterministic framework to base an ROI analysis.

PROGNOSTICS

Prognostics is defined as, "Predictive Diagnostics which includes determining the remaining useful life or time span of useful operation for a component" [1] It is best understood by reviewing a standard reliability "bathtub" curve, as shown in Figure 1.

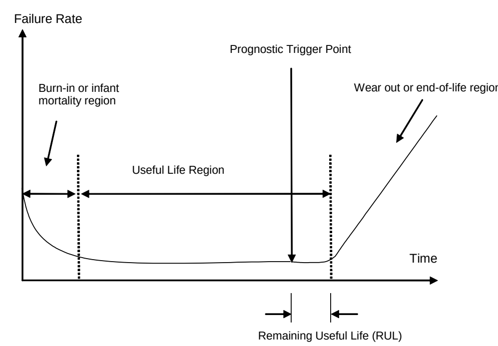

Figure 1 – Reliability Bathtub Curve and Prognostic trigger point, and Remaining Useful Life (RUL)

For a system, the RUL is a key parameter that drives the ROI analysis. The concept can be extended to Prognostic Health Management (PHM) and provide a more holistic view of system engineering. [4]

ELECTRONIC PROGNOSTICS

Electronic prognostics differs from mechanical prognostics in that there are far more components that can contribute to the failure rate of a module, the precursor "signatures" can be difficult to detect and there is a relatively short distance to failure. For each of the electronic components comprising a printed circuit board or module, it is necessary to follow a methodical process of determining the highest failure-rate components within a module, extract the precursors and fuse the data in a meaningful way to the operator [2]. The usual technique is to rank the failure rates, apply weighting functions to the components, and then apply an algorithm to produce a composite indication of the electronic module's health. [3]

RETURN ON INVESTMENT

In general, the return on investment for the adoption of electronic prognostics consists of an analysis of the savings associated with the implementation, less the cost of implementation, divided by the investment required. This relationship is mathematically stated in (1);

ROI = (Savings – Implementation costs)/ (Investment required) (1)

The identified sources of savings from prognostics include:

- Increased Aircraft availability
- Reduced loss of Aircraft
- Reduction in unplanned maintenance (all aircraft not just those in the battlefield)
- Moving spares to the proper place (logistics)
- Better use of Inventory
- Better spending controls on spare inventory
- Reduced expenditure in armaments required to accomplish mission
- increase in mission success rate

Costs of Applying Prognostics

The costs of applying prognostics can be separated into three categories:

- Non-recurring engineering (NRE) cost of adding the prognostics to a power supply
- Per unit costs of the prognostic components
- False Alarm Cost (if failure rate of the prognostic circuitry approaches the failure rate of the component being monitored)

The NRE costs include the upfront costs of designing a suitable sensor array, extracting the precursor signatures to failure, and providing the off-board calculation "engine" to provide the advanced warning. [3] This is estimated to be 20% of the development cost of a power supply. If the power supply costs $5 Million to design, the incremental cost of adding prognostics is estimated at $1 Million.

The per-unit cost of components is estimated to range between 10 and 20% of the total bill-of-materials (BOM) cost of the power supply.

False alarm cost is evaluated in terms of the cost of increased maintenance and spares and in aircraft downtime. Considering that:

- Power Supply Unit (PSU) MTBF = 20,000 hours
- False Alarm Rate of Prognostic Circuitry for PSU = 5 fpmh
- Cost of PSU/Line Replaceable Module (LRM) system replacement ~ $50K
- Probability of Prognostic Circuitry-caused False Alarm = 10% (adding $50K in cost every 200K hours)

Results are that 144 aircraft operating for four hours per day over a service life of ten years

= 2.1 million operating hours
= 10.5 false alarms
= 525K in additional cost
= small amount in comparison to the savings ($1.83 Billion).

PROFORMA ROI FOR EUROFIGHTER TYPHOON

The ROI calculation is now applied using some typical numbers obtained from public sources, in order to examine the financial efficacy.

The Eurofighter Typhoon was used for the calculations, due to its publicly-available information on pricing and suppliers. The four-nation Eurofighter Typhoon is a foreplane delta-wing, beyond-visual-range, close air fighter aircraft with surface attack capability. Eurofighter has 'supercruise' capability: it can fly at sustained speeds of over Mach 1 without the use of afterburner. The first of 620 Eurofighters were delivered in 2003, with 89 destined for the RAF.[5]

Assumptions for financial calculations:

1. 55 Tranche 1 and 89 Tranche 2 = 144 Eurofighters to be deployed in the UK.
2. 20 Switch Mode Power Supply (SMPS) modules are in each Eurofighter totaling 1780 SMPS supplies, amounting to $13.35 Million.

3. Mean Time Before Failure (MTBF) of power supplies a minimum of 20,000 hours of operation.
4. Through proper design, Prognostics for the SMPS does not degrade MTBF more than 10%.
5. The incremental cost of prognostics per SMPS is estimated at $1,000 per supply.
6. Cost of each SMPS module with prognostics is $7,500.
7. Cost of Jet Aircraft is £4.3bn / 89 = 48 Million Pounds each ($85 Million USD)
8. Cost of capital is 10%
9. Service life of aircraft assumed to be 10 years.
10. Cost of spares is estimated at 20%, or 576 supplies. This amounts to $4.32 Million.

<u>Savings Estimate for Eurofighter</u>

Over the Service Life of the Aircraft, if one aircraft is “saved” from hull loss from a bad avionic system within the aircraft, then the savings amount to $85 Million. (Not to speak of the prevention of loss of pilot’s loss of life!)

The total cost of deploying the Eurofighter in the UK totals $12.24 Billion (144 aircraft at $85 Million each). If the annual maintenance is assumed to be 15% of the deployed equipment, then this amounts to $1.83 Billion per year. The electronics/avionics portion of this cost is estimated at 20%, or $36.6 Million. If the savings from adding electronic prognostics amounts to 10% of this total, then this totals $36.6 Million. Over the 10 year service life, using a 10% cost of capital, the total savings amounts to $247.5 Million.

<u>Implementation Cost Estimate</u>

The costs of implementation are estimated to be $1 Million per supply, times 20 supplies. This amounts to an incremental cost of prognostics of $20 Million for the Switch Mode Power Supplies on the Aircraft.

<u>Return on Investment Estimate for Eurofighter</u>

Assuming the savings of one aircraft:

ROI = ($85 Million + $247.5 Million) - $20 Million / $20 Million

ROI = 15,625 %

Assuming no loss of aircraft, only maintenance savings:

ROI = $247.5 Million - $20 Million / $20 Million

ROI = 11,375 %

Conclusion

The purpose of the article was to provide a basic framework for calculation of ROI for electronic prognostics. It has been shown that the ROI for adoption of Electronic Prognostics can be very favorable. For the example aircraft used, the Eurofighter Typhoon, the savings can range from $247.5 Million (1.72 Million per aircraft) to $332.5 Million ($2.31 Million per aircraft), if a single aircraft is saved from a catastrophic crash. We applied standard estimates due to the inability to obtain some classified performance criteria and these should be compared with actuals for the particular aircraft or Mil/Aero system deployed.

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