A Framework for Aircraft Maintenance Strategy including CBM

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ABSTRACT

Maintenance Planning plays a vital role in optimizing the benefits of Integrated Vehicle Health Management (IVHM). The challenge is to identify the right combinations of different types (Preventive, CBM and Run-to-Fail) of maintenance tasks for different subsystems or components of complex systems like an aircraft to achieve the most optimized solution in terms of availability, cost and safety. Maintenance Strategy plans most cost effective maintenance type for each fault of a sub-system in such a way that availability and safety are optimized. Also, the strategy should satisfy the important goals viz. technical feasibility and certifiability of the solution. This study presents a RCM based maintenance strategy framework with some modifications over the existing guidelines. The framework has been implemented and is demonstrated with a case study of EPGDS (Electrical Power Generation and Distribution System). The results with arbitrary costing for each task are outlined with the objective of demonstrating the effectiveness of the framework.

1. INTRODUCTION

With growing financial uncertainty, air vehicle operators (both commercial and military) are under tremendous pressure to reduce operational and support costs. Towards this end, it is accepted across the aerospace industry that IVHM is a potentially valuable strategy for the manufacture and management of vehicle platforms. Enhancing availability, reliability and reducing maintenance cost, which are the key matrices towards the goal, are achieved by integrating Maintenance Planning with present and future health assessment, flight / mission planning, resource planning and associated management functions. Optimization of KPIs happens through RCM analysis (maintenance strategy), CBM analysis (viz. selection of algorithms / analytics and sensors, sensor locations, etc.), planning of flight / mission, maintenance and logistics.

Maintenance Strategy, which is generally considered during design phase of development, greatly influences both the system availability and life cycle cost. Reliability-Centered Maintenance (RCM) is a systematic methodology used to identify the preventive maintenance tasks that are necessary to realize the inherent reliability of equipment at the lowest possible cost. Conventional practice of developing a scheduled maintenance program by means of RCM, consists of identifying those preventive tasks which are both applicable (technically feasible) and effective (worth doing). Condition Based Maintenance being a proactive maintenance philosophy is a core element of IVHM. RCM decision logic based on existing guidelines (SAE JA1012, NAVAIR 00-25-403 and ATA MSG-3) needs further extension to select CBM candidates along with Reactive, Preventive candidates in an aircraft.

A number of publications (Keller K., 2001; Feldman K. et al, 2009; Saxena A. et al., 2010; Saxena A., 2012; Nico B. H. et al, 2015) have already proposed cost-benefit analysis (CBA) for deciding CBM for a component. Standalone CBA for a component may not provide optimal solution for large complex systems. To arrive at optimal solution, sequential study of technical feasibility, risk (safety) feasibility and cost feasibility should be carried out in the decision process of all possible maintenance types for components, sub-systems, systems using a specific framework. RCM analysis for maintenance strategy is a

living process for complete lifecycle of the aircraft as periodic reevaluation of the analysis is needed with the maturity of technologies, operational and maintenance data. The data set generated through RCM analysis is used by Maintenance Planner (Adhikari P. P. et al.,2014) where dynamic and online planning of maintenance events are done by clustering different tasks to optimize availability and cost.

The novel approach presented here integrates CBM as part of the maintenance strategy. Additionally it also integrates cost feasibility check through study of 'worth doing' in individual task level, 'cost effectiveness' option of maintenance strategy (combination of tasks for all faults) in sub-system level and overall framework with shortlisting of maintenance tasks through different levels: fault consequence check, technical feasibility check, risk (safety) feasibility check and cost feasibility check.

2. MAINTENANCE STRATEGY IN IVHM DEVELOPMENT

Maintenance credits are acquired when an IVHM system can replace the existing industry standard maintenance for a given component or complete aircraft system and this enhances availability, maintainability and mission capabilities of aircraft. To reach this level, evolution of IVHM development has to pass through effective process for technology maturation, development, verification, validation, qualification and finally certification.

After determination of the potential functionality and benefits of IVHM, technology maturation efforts are initiated. The maturation efforts are often performed through technology development guided by appropriate roadmaps. Efforts are allocated to RCM analysis, design and analysis of algorithm for diagnostics, prognostics, sensor selection and other enablers related to off-board IVHM. This also includes enhancing the performance of IVHM in terms of increased accuracy, reduced weight, improved reliability, advanced communication and efficient data transfer. Technology gaps and risks are identified and efforts are allocated to fill the gaps and to mitigate the risks. During the maturation phase, the potential benefits and credits of IVHM are re-assessed and validation evidence is gathered through component rigs, integrated simulation framework, and other established processes. V&V process towards airworthiness certification of IVHM will be spread over the following phases (Buderath M. et al., 2012):

- Concept Refinement & Technology Development
- Development
- Controlled Introduction to Service
- Instruction for Continuous Airworthiness (ICA)
- In-service validation.

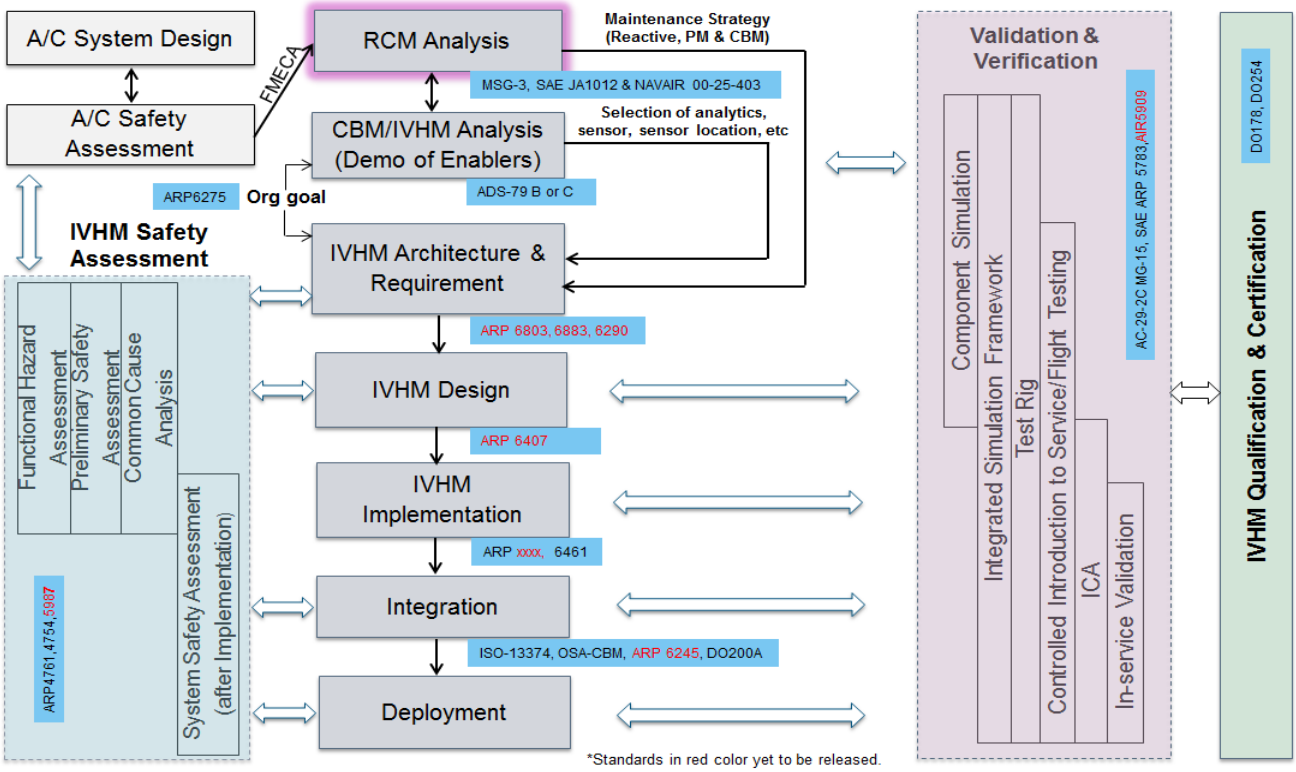

Figure 1. RCM Analysis in IVHM Development Roadmap

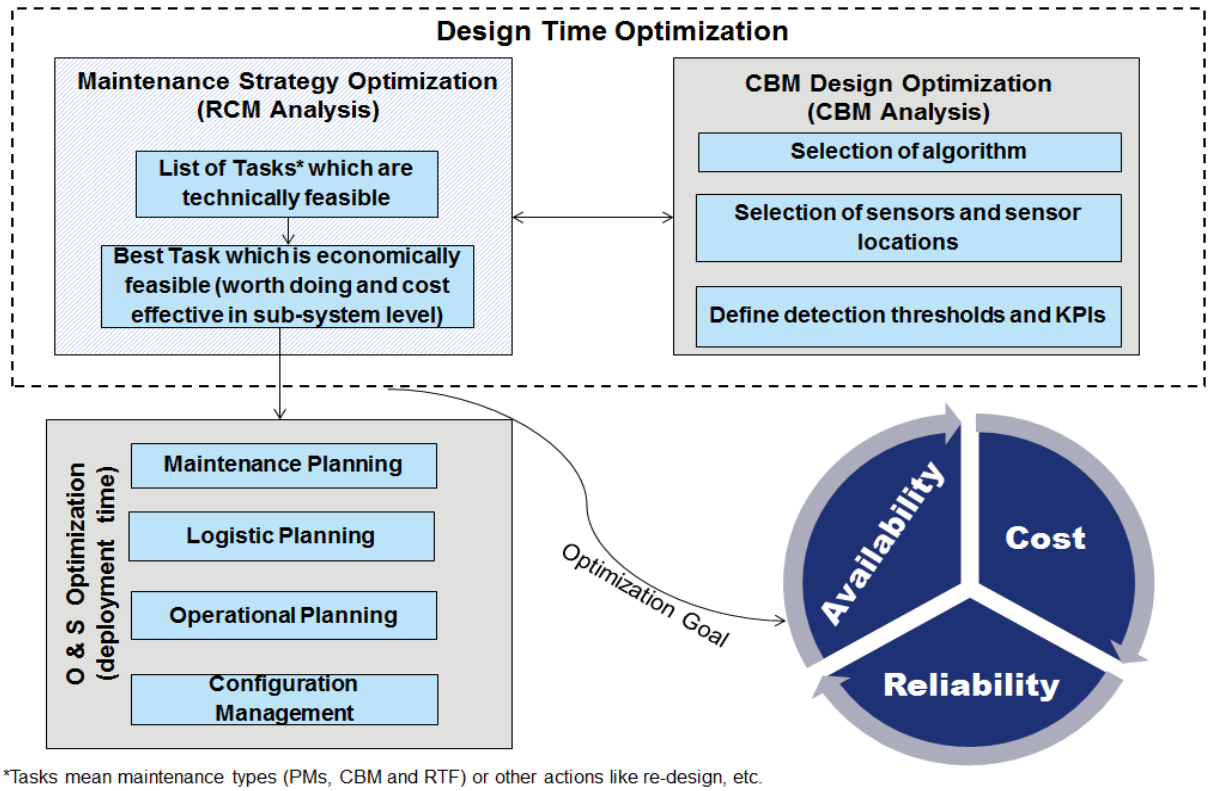

Figure 2. Different categories of Optimization or CBA for IVHM

Figure 1 details the typical activities for legacy A/C during concept refinement and technology development, engineering development, certification and qualification. This figure also mentions different SAE ARPs and other guidelines in different phases. During concept refinement and technology development phase, RCM Analysis strategizes maintenance types for sub-systems/components considering technical, safety and economic aspects. This is pre-requisite for CBM analysis which includes selection of analytics, sensors and sensor locations, etc.

3. FRAMEWORK OF MAINTENANCE STRATEGY INCLUDING CBM

There are at least six key factors required for maintenance to achieve its purpose of optimizing operating performance. These are to reduce operating risk, avoid aircraft failures, provide reliable equipment, achieve least operating costs, eliminate defects in operational aircraft and maximize availability. These purposes are determined by three KPIs: enhancement in mission availability, enhanced reliability and reduction of maintenance cost. To realize these goals, there exist several categories of optimization or Cost Benefit Analysis (CBA) during design and deployment phase.

Suitable maintenance strategies are selected during design stage to provide the required values of the KPIs. However, maintenance strategy may need to be adapted based on periodic evaluation of maintenance effectiveness and risk assessment during operation phase. Maintenance Strategy aims to map all fault modes at individual and LRU levels to different maintenance categories:

- Preventive Maintenance (PM) (which includes S-Servicing, L-Lubrication, OC-Scheduled On-condition, HT-Hard Time and FF-Failure Finding Inspection)
- Condition Based Maintenance (CBM)
- Run-to-Fail (RTF)
- Other Action (which includes redesign, change in operation or maintenance procedure or restriction in operation)

Optimized maintenance strategy is also derived at component/sub-system level. RCM analysis is the basis to establish a framework for candidate selection. Figure 3 depicts the logic for deciding maintenance strategy for a LRU. The proposed decision logic is based on existing guidelines (SAE JA1011, SAE JA1012, NAVAIR 00-25-403 and ATA MSG-3) with minor augmentations.

3.1. Drivers for Maintenance Strategy

Applicability of the different maintenance types (preventive / predictive / reactive / other actions like redesign, etc.) for a particular fault depends upon various factors like failure

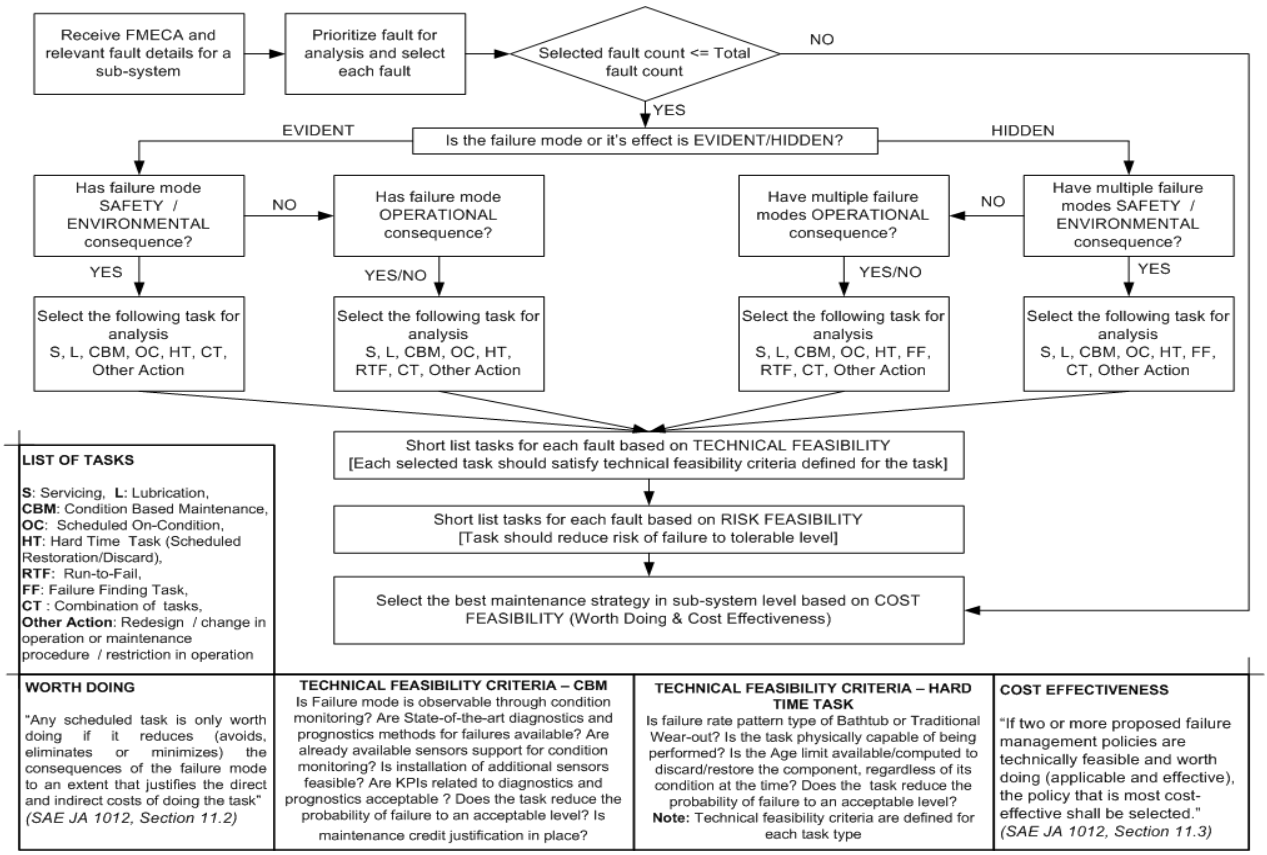

Figure 3. RCM Decision Logic including CBM

pattern, failure rate, failure consequence, severity of failure, detectability and diagnosability (present or future state) of the failure with acceptable KPIs, cost of maintenance, availability of the system and certifiability of selected method. Maintenance strategy should consider all these aspects to decide maintenance type for particular fault of a component / sub-system. A complex system like an aircraft has a huge number of sub-systems. As those factors vary widely across different components or subsystem, there will be a distribution of different maintenance types. This means that maintenance strategy results in a specific ratio of PM, CBM and RTF candidates for a specific vehicle or system.

Specific equipment failure modes exhibit a variety of failure patterns and failure rates depending on the dominant system failure mechanisms, system operation, system operating environment and legacy maintenance type. There exist at-least six unique failure patterns which can be defined in form of a Weibull plot (probability of failure correlated with time). The patterns are named as Bathtub (e.g. overhauled reciprocating engine, etc.), Traditional Wear-out (e.g., reciprocating engine, pump impeller, etc.), Gradual Rise with no Distinctive Wear-out Zone (e.g., gas turbine, etc.), Initial Increase with a Levelling off (e.g., hydraulic systems, etc.), Random failure (e.g., roller, ball bearing, etc.) and Infant Mortality (e.g., electronics components, etc.).

By identifying failure pattern, one can get some insight in the decision of maintenance strategy. For example, if the equipment has a failure rate pattern type of Bathtub or Traditional Wear-out, PM may be applicable. A basic understanding of failure rate helps in determining whether maintenance or equipment redesign is necessary. For example, equipment failure modes that exhibit high failure rates (e.g., fail frequently) are usually best addressed by redesign rather than applying more frequent maintenance.

The present discussion clarifies the dependency on different factors in the process of maintenance strategy. The extended RCM decision logic framework as in Figure 3 (for maintenance strategy including CBM) broadly analyses the following aspects:

- Fault Consequence
- Technical Feasibility
- Risk Feasibility
- Cost Feasibility

3.2. Fault Consequence Check

Failure consequences check assesses evidence of failure (evident or hidden) and different consequences, viz.

safety/environmental, operational impact, etc. The primary branching (four braches) of RCM decision logic is due to shortlist tasks (maintenance types and other actions) for each failure. For example, a Run-to-Fail (RTF) task may be applicable for both evident and hidden failures which do not have safety/environmental consequences and a Failure Finding (FF) task may be applicable for hidden failures.

3.3. Technical Feasibility

After fault consequence check, technical aspects are checked to eliminate tasks from the list already shortlisted. Technical aspects generally deal with failure pattern, P-F interval, diagnostics/prognostics methods with acceptable KPIs, certifiability, etc. To arrive to the decision, it may require significant amount of historical data, survey, analysis of the algorithms, simulation and testing. As it is not possible to get all information in the beginning stage of IVHM development, this maintenance strategy framework should be run iteratively with the maturity of technology development to revalidation of the decision.

For each task, there should be pre-defined a set of technical feasibility criteria. Specific criteria for each task are defined in section 13 of SAE JA 1012. For example, a set of criteria for CBM, which is not available in the same reference, is defined here.

- Is the failure mode observable through condition monitoring?
- Are state-of-the-art diagnostics and prognostics methods for failures available?
- Do already available sensors support for condition monitoring? Or, is the installation of additional sensors feasible?
- Are KPIs related to diagnostics and prognostics acceptable?
- Does the task reduce the probability of failure to an acceptable level?
- Is maintenance credit justification in place?

To select algorithm, the following attributes/metrics (KPIs) may be used (Saxena A. et al. 2012).

- Algorithm Performance (Figure 4)
  - Correctness (Accuracy, Precision, etc.)
  - Timeliness (Prediction Response Time, Prediction Horizon, etc.)
  - Confidence (Sensitivity, Robustness, Convergence, etc.)
- Computational Performance (Time & complexity, memory & I/O, etc.)
- Ease of Algorithm Certification

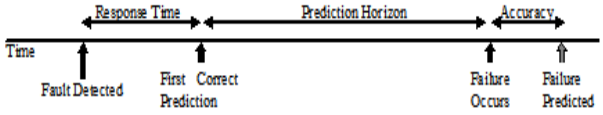

Figure 4. KPIs in time scale (Source: Saxena A. et al. 2012)

3.4. Risk Feasibility

Risk is measured by multiplying probability by severity. Based on consequence, different types of risks, viz. safety risk, operational risk, economic risk, etc. can be analyzed. Here, only safety risk is focused. Risk analysis is carried out using Hazard Risk Table. If a selected maintenance task or other action moves the metric into the green/yellow zone from yellow/red zone, task is treated as feasible. This means the maintenance strategy selected reduces the probability of failure within acceptable limits. With this risk feasibility, the task list is further shortlisted. Here (Figure 5) is an example of a Hazard Risk Table (HRT) compiled from NAVAIR.

RISK CATAGORIZATION		SEVERITY			
		CATASTROPHIC(1)	CRITICAL(2)	MARGINAL(3)	NEGLIGIBLE(4)
PROBABILITY OF FAILURE	FREQUENT(A)	1	3	7	13
	PROBABLE(B)	2	5	9	16
	OCCASIONAL(C)	4	6	11	18
	REMOTE(D)	8	10	14	19
	IMPROBABLE(E)	12	15	17	20

Uacceptable	1-5: High Safety Risk	Acceptable with Review	11-17: Low Safety Risk
Undesiarble	6-10: Medium Safety Risk	Acceptable without Review	18-20: Very Low Safety Risk

Figure 5. Hazard Risk Table (source: NAVAIR 00–25–403)

3.5. Cost Feasibility

Based on cost feasibility analysis, the specific maintenance type or task is decided for a particular fault. This study is carried out on the list of tasks shortlisted based on fault consequence check, technical feasibility and risk feasibility check. This reduces the effort on Cost Benefit Analysis (CBA) significantly as a number of options for maintenance types or other action like redesign may get eliminated in this

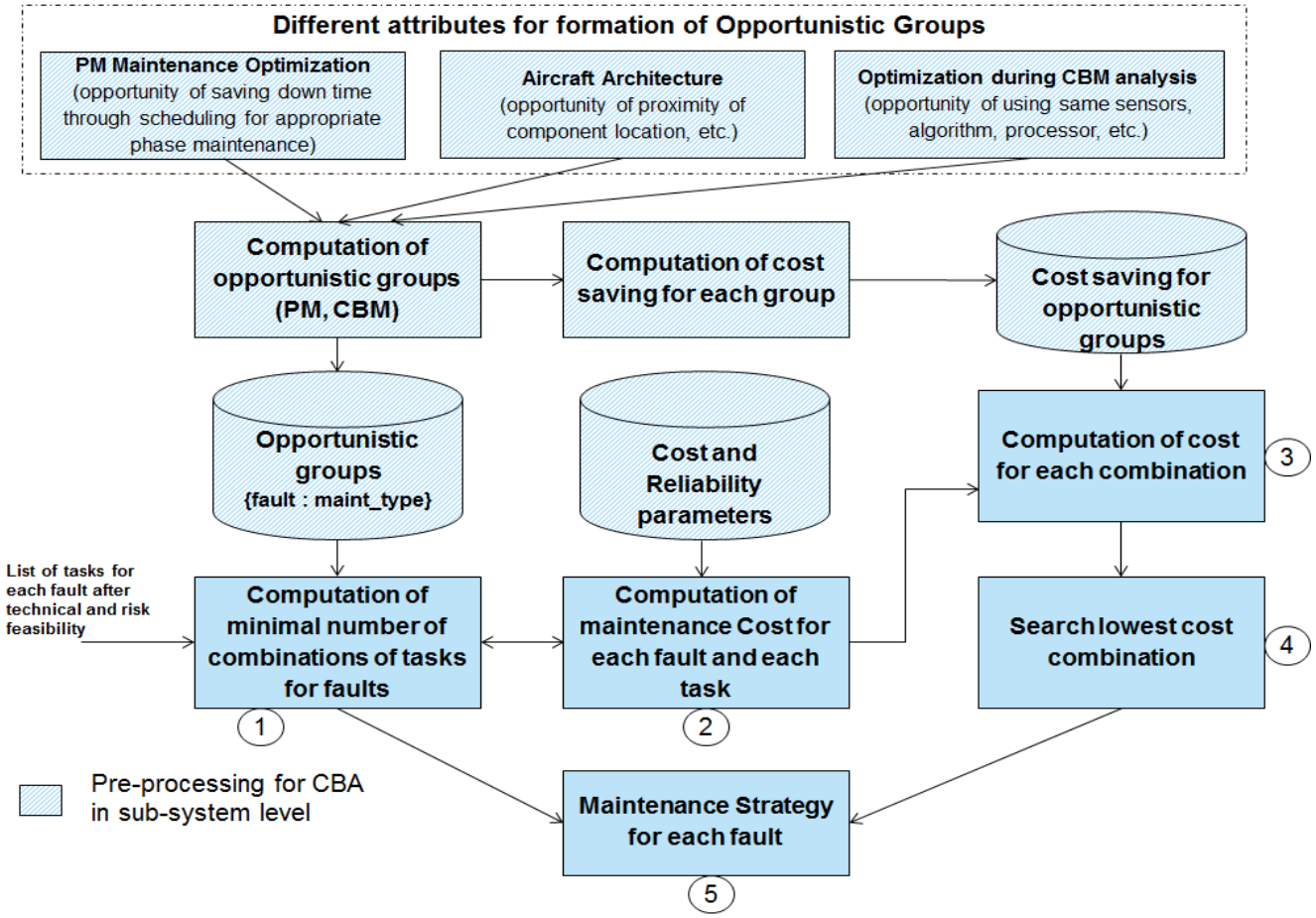

Figure 6. Computational Framework for Cost Feasibility Study

stage based on the checks mentioned. As per SAE guideline (JA 1012), both aspect of cost feasibility, viz. 'Worth Doing' and 'Cost Effectiveness' are to be checked.

'Worth Doing' means "any scheduled task is only worth doing if it reduces (avoids, eliminates or minimizes) the consequences of the failure mode to an extent that justifies the direct and indirect costs of doing the task" (JA 1012, Section 11.2). This can be checked at individual fault level. 'Cost Effectiveness' means "if two or more proposed failure management policies are technically feasible and worth doing (applicable and effective), the policy that is most cost-effective shall be selected" (JA 1012, Section 11.3). Cost effectiveness should be analyzed at sub-system level as opportunity of common down-time, different phase maintenance slots and maintenance mechanization (viz. same root cause, condition, detection mechanism, etc.) may reduce cost as maintenance types are decided for group of faults. A significant amount of work and related publications already addressed cost-benefit analysis (CBA) for deciding CBM for a component. Unique contribution of this paper in this regard is how existing cost benefit analysis can be extended to sub-system level. Here, major focus is on the logic of defining different opportunistic groups (fault list and corresponding maintenance types; grouping creates cost advantage) for the sub-system (Figure 6), forming maximum possible combinations / groups for cost analysis, computation of cost for each group and finally select a group with lowest cost to decide maintenance type / other action for each fault of the sub-system. Here the algorithm for cost feasibility check is elaborated.

Input: List of tasks with all possible maintenance after risk feasibility

Pre-processing / Initialization:

Step I1: Replace maintenance list with proprietary maintenance type (specified by LRU manufacturer, if any) for selected fault of specific sub-system

Step I2: Align PM tasks with nearest phase maintenance slots (viz. A, B, C &D) of the aircraft

Step I3: Define all possible opportunistic groups (viz. with same root cause, same condition measurement, same phase maintenance, etc.) with set of faults and associated maintenance types.

Step I4: Define cost reduction factor (i.e. cost advantage due to grouping) for each opportunistic group

Algorithm:

Step1: Calculate cost (maintenance cost + over maintenance cost + investment cost + downtime cost) for each maintenance type of each fault. [For maintenance cost, refer section 3.6.1.1 of NAVAIR 00-25-403]

Step2: Create number of sets (combinations of tasks) with list of maintenance type for each fault

Step2.1: Formation of group with maintenance type of lowest cost for each fault type

Step2.2: Formation of rest groups. Repeat the following for each opportunistic group and each fault.

If the fault is matching with a group, the maintenance type is added in the selected group; otherwise the lowest cost maintenance type for the same fault id is added.

Step3: Calculate cost of maintenance for all sets of options. For each option, reduction factor gets subtracted from total cost of the group.

Step4: Select the best option with lowest maintenance cost.

Output: Task for each fault in selected option.

Success of this algorithm depends upon accuracy in deriving opportunistic groups and associated cost saving (i.e. reduction factor) due to grouping. There are number of conventional methods (Bartholomew-Biggs M et al., 2006; Nguyen D et al., 2008) to form opportunistic groups for PM tasks. To define other categories of opportunistic groups (viz. proximity of component location, using same sensor and processor, etc.), Functional Fault Analysis (FFA) (Tolga K., et al., 2008), different safety analysis methods, sensor suite analysis and physical architecture etc. play an important role.

4. CASE STUDY WITH ELECTRICAL SYSTEM

Airbus Defense and Space developed a tool to run RCM decision logic extended framework to derive maintenance strategy. This tool is demonstrated with a case study of EPGDS (Electrical Power Generation and Distribution System). FMECAs of the major sub-systems (viz. AC Generator, Battery, Battery Charger, Transformer Rectifier unit, etc.) are carried out. After running the tool with input as FMECAs, maintenance type or other the maintenance action is decided for each fault in sub-system level.

A sample use case considering a hypothetical scenario is defined where AC Generator with ten faults is considered as sub-system. The following description shows how maintenance type is finalized based on cost feasibility with input computed after technical and risk (safety) feasibility. Here, cost parameters (Table 1) are fictitious.

Table 1. List of Tasks after Technical and Risk Feasibility

Fault ID	Fault	List of Tasks after Technical & Risk Feasibility	Cost of Individual Maintenance Tasks ($)
ACG09	Bearing Failure	[CBM, PM_OC, PM_HT1]	[2600,2500,4000]
ACG12	Brush Wear	[CBM, PM_OC, PM_HT1]	[2200,2300,3000]
ACG01	Stator armature winding short circuit	[CBM, PM_OC]	[2500,2600]
ACG03	Stator insulation fault	[CBM, PM_S, PM_OC, PM_FF]	[2800,2500,3000,3200]
ACG02	Stator armature winding open circuit	[CBM, PM_OC]	[2600,2500]
ACG07	Rotor Shaft Crack	[CBM, PM_OC, PM_HT1]	[3000,2900,4000]
ACG04	Stator Core Defects	[CBM, PM_OC]	[2900,3200]
ACG13	Weakened Brush Holder Spring	[CBM, PM_OC, PM_HT1]	[4000,3500,3200]
ACG05	Stator End Winding Fault	[CBM, PM_OC]	[2800,2900]
ACG19	Crack / rupture of Generator Casing	[PM_OC, PM_HT1]	[3000,6000]

The different opportunistic groups are defined here (Table 2). The definition of the groups is configurable. Here, reduction factors are defined due to reduction in the total cost of maintenance of opportunistic maintenance group compared to sum of cost of maintenance of each fault of the group.

Table 2 : Definition of Opportunistic Groups

Group 1 →	**{ACG01:CBM, ACG02:CBM, ACG03:CBM}**
Group 2 →	**{ACG03:CBM, ACG04:CBM, ACG05:CBM}**
Group 3 →	**{ACG09:PM_OC, ACG12:PM_OC, ACG19:PM_OC}**
Reduction Factor ($) →	**IG1 = 1500, IG2 = 900, IG3 = 1000**

For a cost feasibility study in sub-system level, this tool forms four possible groups, viz. the group with lowest cost (combination 1) and three opportunistic groups (combinations 2-4). The Maintenance cost for each group is computed and the maintenance type is decided for a particular fault from the group with lowest cost. Table 3 depicts the results.

Table 3. All possible combinations for cost comparison

Fault ID	Combinations				
	1	2	3	4	**Selected Maintenance**
ACG09	PM_OC	PM_OC	PM_OC	PM_OC	PM_OC
ACG12	CBM	CBM	CBM	PM_OC	CBM
ACG01	CBM	CBM	CBM	CBM	CBM
ACG03	PM_S	CBM	CBM	PM_S	CBM
ACG02	PM_OC	CBM	PM_OC	PM_OC	CBM
ACG07	PM_OC	PM_OC	PM_OC	PM_OC	PM_OC
ACG04	CBM	CBM	CBM	CBM	CBM
ACG13	PM_HT1	PM_HT1	PM_HT1	PM_HT1	PM_HT1
ACG05	CBM	CBM	CBM	CBM	CBM
ACG19	PM_OC	PM_OC	PM_OC	PM_OC	PM_OC
Cost ($)→	27000	25900	26400	26100	25900

Table 4. Difference in Decision Logic among different standards & proposed one

SL No	Feature	Logic as per SAE JA 1012	Logic as per NAVAIR – 00-25-403	Proposed Logic
1	**Types of RCM Analysis**	Mentions two approaches: Decision Diagram Approach & Rigorous Approach. Decision. Diagram Approach based Flow Diagram presented.	Flow diagram is more aligned to Rigorous Approach which is much more practical. (sections 15.2 & 15.3 of SAE JA 1012)	Flow diagram is more aligned to Rigorous Approach.
2	**Categorisation of failure consequences check**	Evident Safety/ Environmental / Regulation; Evident Operational; Hidden Operational, Hidden Safety/ Environmental / Regulation **(No mention of Economic)**	Evident Safety/Environmental; Evident Economic/Operational; Hidden Economic/Operational; Hidden Safety/Environmental	Evident Safety/Environmental; Evident Operational; Hidden Operational; Hidden Safety/Environmental **(Economic not considered in primary branching)**
3	**Task List**	Scheduled On-condition Task, Scheduled Discard / Restoration Task, No Scheduled Maintenance / Failure, Combination of Task, Redesign.	Servicing, Lubrication, On-condition Task, Hard Time Task, No PM, Failure Finding Task, Other Action. (Note1)	CBM, PM Tasks (Servicing, Lubrication, Scheduled On-condition Task, Hard Time Task, Failure Finding Task), Run-to-Fail, Other Action.
4	**Logic of Significant Function**	No Concept of Significant Function.	Functions whose failures result in safety, environmental, operational or economic consequences are termed "Significant Functions" and are subjected to RCM analysis.	Logic of significant function is embedded in Flow Diagram.
5	**Scheduled on-condition Task vs CBM**	Embedded PHM may be one method to monitor condition for periodic evaluation. Scheduled on-condition is a PM Task. But CBM is not mentioned separately.	Embedded PHM may be one method to monitor condition for periodic evaluation. Scheduled on-condition is a PM Task. But CBM is not mentioned separately.	CBM is considered as a separate task beside scheduled on-condition (PM type) task.
6	**Technical Feasibility Criteria**	Technical Feasibility Criteria for Servicing, Lubrication & CBM is not mentioned.	Technical Feasibility Criteria for CBM is not mentioned.	Technical Feasibility Criteria for all task types including CBM are compiled.
7	**Risk Feasibility**	Risk feasibility is not explicitly mentioned in RCM decision Logic.	Risk feasibility is not explicitly mentioned in RCM decision Logic. However, this standard provides details coverage for task prioritization and task selection using Hazard Risk Table (HRT).	RCM decision logic embeds explicitly for task prioritization and selection.
8	**Cost effectiveness Analysis**	Cost–effectiveness is mentioned in individual task level. The cost of undertaking a task over a period of time should be less than the total cost of the consequences of failure.	Cost–effectiveness is mentioned in individual task level.	This includes both: cost effectiveness in individual task level and option of RCM strategy (combination of tasks for all faults) in LRU level.
9	**Task Packaging**	Task packaging is separately addressed.	Task packaging is separately addressed.	Task packaging in LRU level is part of decision logic as it impacts cost effectiveness for a particular option. However, task packaging in A/C or fleet level is not the scope of Decision Logic.

Note 1: *Servicing & Lubrication are additional task. Hard Time is synonymous with Scheduled Discard or Restoration Task. "No PM" is synonymous with "No Scheduled Maintenance" or Run-to-Fail. "Other Action" is more extensive: not only Redesign also includes change in an operational or maintenance procedure and operating restrictions.*

5. COMPARISON OF PROPOSED FRAMEWORK

The proposed decision logic (as depicted in Figure 3) is based on existing guidelines viz. SAE JA1012 (Section 15.3.3, Figure-16 & 17), NAVAIR 00-25-403(Section 3.4, Figure 3.3) with some augmentations.

The present framework proposes some key improvements over those two guidelines.

- Integrates CBM as part of the maintenance strategy.
- Integrates cost feasibility check through study of 'worth doing' in individual task level, 'cost effectiveness' option of maintenance strategy (combination of tasks for all faults) in sub-system level.
- Overall framework with shortlisting of maintenance tasks through multiple levels of feasibility checks: fault consequence, technical feasibility, risk (safety) feasibility and cost feasibility.

The Table 4 summarizes the additional features of the proposed framework with respect to existing.

6. CONCLUSION

This paper attempted to present the linkage among different types of optimizations or CBAs in the context of IVHM. The relevance of maintenance strategy to reach to desired goals in terms of availability, cost and reliability has been emphasized. The need for extending RCM decision logic with CBM is outlined. A framework for extended RCM decision logic along with cost feasibility in sub-system level has been elaborated. This study may provide useful input towards enriching logic for maintenance strategy as an important step in the design phase of IVHM. Effectiveness of the proposed framework can be further established through a use case with more practical data set and detailed cost benefit analysis in the context of IVHM development.

7. ACKNOWLEDGMENTS

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NOMENCLATURE

A/C	Aircraft
AC	Alternating Current
APU	Auxiliary Power Unit
BIT	Built-In Test
CBM	Condition Based Maintenance
EPGDS	Electrical Power Generation and Distribution System
FF	Failure Finding Inspection
FH	Flying Hour
FHP	Flying Hours Program
FMECA	Failure Mode, Effects and Criticality Analysis
HRT	Hazard Risk Table
HT	Hard Time (task)
ISHM	Integrated System Health Monitoring
IVHM	Integrated Vehicle Heath Monitoring
KPI	Key Performance Indicator
L	Lubrication
LRU	Line Replaceable Unit
OC	On-condition (maintenance)
PHM	Prognostic Health Management
PM	Preventive Maintenance
RCM	Reliability Centered Maintenance
ROI	Return on Investment
RUL	Remaining Useful Life
RTF	Run-to-Fail (maintenance)
S	Servicing

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