Achieving Organizational Accountability for Aircraft Operational Availability – Systems Engineering and Contracting Strategies in the Canadian Forces

Lieutenant-Colonel Pierre-Paul Beland, CD1, BEng
Integrated Logistics Support Manager – Maritime Helicopter Program

Mr. Ludwig J. Hollick, CD, MSc
(Reliability Engineering), PBL Consultant

Project Management Office – Maritime Helicopter Project
National Defence Headquarters
Major General George R. Pearkes Building
101 Colonel By Drive
Ottawa, Ontario K1A 0K2
CANADA

beland.pp@forces.gc.ca / hollick.lj@forces.gc.ca

ABSTRACT

In response to the increasing demand for Canada to participate militarily in NATO and other International efforts aimed at stabilizing situations which pose a threat to world-wide peace, Canada's Department of National Defence (DND) has had to re-focus its staffing priorities on core military functions. On the heels of an almost decade long period of Government directed downsizing and budget reductions, which began in the early 1990's, DND has been forced to consider cost-effective alternatives to the traditional DND-labour intensive approach it has followed for acquiring and providing support to major Weapon Systems such as aircraft, ships and tanks.

Amongst many initiatives, DND has been exploring how to more cost-effectively leverage Industry support in functions traditionally performed organically within DND. This has included use of Performance Based Management concepts such as those being utilized by the US DoD under the banner of Performance Based Logistics (PBL). The Maritime Helicopter Project (MHP), charged with procuring a fleet of Maritime Helicopters (MH) to replace its aging Sea King fleet, and to set-up an integrated support capability with the selected OEM, was one of the first DND Major Crown Projects to seriously investigate and pursue the incorporation of a broad spectrum of such concepts within its procurement strategy and contractual documentation.

The focus of this paper is on the use of operational availability (A_O) as a Key Performance Indicator (KPI), not just for the aircraft, but for all of the organizations involved in supporting its operation. Specifically, it addresses the approach developed by the MHP for holding each of the DND and ISS Contractor organizations responsible for supporting MH operations, accountable for their contribution to the achievement of fleet A_O. This contribution, generically referred to as organizationally attributable aircraft unavailability ($A_{U\text{-}Org}$), is referred to as $A_{U\text{-}DND}$ and $A_{U\text{-}C}$ for DND and Contractor-attributable A_U, respectively. The paper discusses a refinement of the traditional A_O model and how it will be utilized in conjunction with the invocation of a system engineering standard to require the Contractor to 'design' an Integrated Support Service (ISS) Capability which will demonstrably be able to achieve specified $A_{U\text{-}C}$

requirements. As novel as this may be to some readers, the key innovation discussed in this paper is the in-service methodology that will be used to measure aircraft unavailability. This measurement will be performed in a way that unambiguously attributes the measured level of A_{U-C} to specific organizations involved in providing support to the Weapon System inclusive of organizations within DND and the ISS Contractor team. In addition to providing relevant technical and organizational background details, the paper concludes with a précis of factors critical to the successful implementation of the discussed A_O measurement concepts.

1.0 INTRODUCTION

The Canadian Department of National Defence (DND), like many of its western military counterparts around the world, have, since the early 1990's, been subject to significant Government directed downsizing and reductions to both capital and O&M budgets. Whether in response to these initiatives or coincidental to them, some level of coping was enabled by emergent methodologies/concepts such as business process re-engineering, alternative service delivery, and to a lesser degree, the Kaplan and Norton balanced scorecards. Although in recent years the operational demands have increased due to terrorist-propagated conflicts, there has not been a commensurate increase in either staffing or funding. The effect has been most pronounced in National Defence Headquarters which includes the group responsible for the acquisition and support of all materiel used by the Canadian Forces inclusive of new fleets of operational equipment such as aircraft, ships and tanks.

Within this group, referred to as the Associate Deputy Minister (Materiel) Group, or ADM(Mat) for short, early in the turn of the century, it had become increasingly apparent to senior Project and Weapon System managers that there was insufficient quantity of qualified and experienced HR to support continued use of the Materiel Acquisition and Support (MA&S) processes that had been institutionalized to that point in time. The key features and associated major shortcomings of this "traditional" approach have been characterized in an ADM(Mat) sponsored study as summarized below:

- DND Project Offices over prescribe the methodologies (e.g. LSA as per MIL-STD-1388) and deliverable data by and with which, respectively, DND will acquire and/or establish the support resources deemed to be needed to assure that an effective level of support will be provided to military operators, but without the benefit of sufficient verification due to cost constraints.
  - ➢ DND not only incurs the cost of producing often voluminous Contractual documentation, but often pays for data which may not be required while assuming the full cost-risk of OEM estimates that with experience are often proved to be inaccurate (too high or too low).

- During implementation of a new fleet of systems (e.g. aircraft), DND separately competes for a scope of in-service support that is limited to: re-supply of spare parts (e.g. both consumables and repairables); the provision of component R&O and major system; and, the provision of technical investigations and engineering support. The OEM has seldom been awarded even a contract even to provide in-service technical investigation and engineering support for the aircraft he produced.
  - ➢ The practice of tendering many small support contracts squarely places DND in the role of system integrator and has promoted a fragmented industrial base in Canada.
  - ➢ Beyond the limitations of acceptance testing, OEMs are not held accountable for system performance shortcomings once the system is fielded.

- Contracts, which are awarded to individual suppliers, are typically structured with a method of payment that is based on cost of time and materials.

  - Use of time and materiel based Contracts leaves little motivation for Contractors to improve component performance, in fact, this would be a major dis-incentive to the Contactor as the more an item breaks, the more the Contractor is paid.

- DND organically provides all logistics support to end-user operators, with the exception of that indicated above, on the belief that scales of economy are realized by centralization of functions.
  - Centralization of support functions have left DND with a support capability that is not only fractured (i.e. not integrated), but removes the practical possibility of inter-function enhancement trade-offs in consideration of the cost-effective achievement of system level objectives.
  - There is no organization that is centrally accountable for all common organizational factors that affect fleet performance or the overall cost-effectiveness of fleet support.

Being the lead Air Force major capital project during this time period, the Maritime Helicopter Project (MHP) provided ADM(Mat) an opportunity to investigate and be the lead implementer of resolutions to the above noted shortcomings. One of the resolutions adopted was to seek to establish a long-term contractual relationship with an OEM. This resolution was incorporated into the MH procurement strategy which reflected the Government of Canada's intent to award, to the single OEM which emerged as the least cost compliant respondent to an RFP, the following Contracts to begin at the same point in time:

- A Contract for the procurement of 28 Maritime Helicopters with an award fee for on-time delivery of the first MH; and
- A 20 year performance based Contract for the set-up and provision of a wide scope of support services.

Other resolutions, now referred to in ADM(Mat) as Optimized Weapon System Support concepts, including those associated with the establishment of an A_O centric performance based contract, were determined through an extensive consultation with Aerospace Industry in general, and specifically, prospective MHP bidders. This pre-RFP release consultation occurred during the 2000-03 time period. Final resolutions were incorporated into the requirement specifications, statements of work and other contractual documentation contained in the RFP that was released to Industry in early 2004. Later that same year, on November 30th, the Government of Canada awarded the above listed contracts to Sikorsky Aircraft Corporation, and so doing marked the beginning of a new era in the In-Service Support posture for aircraft fleets operated by the Canadian Forces.

Figure 1: The Canadian Forces new Maritime Helicopter, dubbed the CH148 Cyclone, is a derivative of the civil certified S-92A SuperhawkTM Helicopter produced by Sikorsky Aircraft Corporation.

2.0 OBJECTIVE

The main objective of this paper is to provide the reader with an understanding of the approaches that will be taken to ensure specified A_O requirements for the CH148 Cyclone will be satisfied, and specifically, the methodologies that will be employed to measure A_O performance so as to achieve organizational accountability for the outcomes. This accountability is referred to in the MH In-Service Support Contract as Performance Based Accountability (PBA).

3.0 OVERVIEW OF THE CH148 SUPPORT CONCEPT

In order to better appreciate the challenge before DND in establishing a performance-based ISS contract that is A_O centric, it is important for the reader to understand that both DND and the Contractor will be required to work in a coordinated manner to achieve the level of fleet A_O specified by DND in the MH Requirement Specification (MHRS). A summary of the CH148 support service responsibilities of each of DND and the Contractor is provided in **Table 1.** It is particularly important for readers to note that the prime mission of the CH148 requires it to be operated from Her Majesty's Canadian (HMC) Ships which are deployed to locations around the globe including climatic environments that range from arctic to tropical. The aircraft may also be deployed to land-based theatres-of-operations. For this reason, DND will be responsible for the conduct and control of all first and second level on-aircraft maintenance of the CH148 Cyclone.

Table 1: Division of CH148 support service responsibilities between DND and the Contractor.

Function	DND	Contractor
Maintenance Support	Conduct and control all first and second level on-aircraft maintenance at each of two main operating bases and while deployed aboard HMC Ships, and second level off-aircraft maintenance of components as determined by the Contractor through the performance of a LORA.	Aircraft third level R&O including periodic painting; Provision of Field Service Representatives at each of two main operating bases, and Mobile Repair Party support as requested by DND.
Supply Support	Management of supply chain and ownership of Government Supplied Materiel (<1% of aircraft inventory); ownership of contractor supplied items installed on the aircraft and custodianship of uninstalled materiel while deployed.	Management of warehouses on east and west coast main operating bases including timely provision of serviceable spare parts to point-of-maintenance; management of the CH148 supply chain including packaging and transportation/shipping of components between the warehouses and individual suppliers, and to deployed CH148 helicopters; arrangement for depot level R&O of repairables.
Support and Test Equipment (STE) Support	Management of supply chain and ownership of Government Supplied Materiel; custodianship and care of STE used during deployments aboard HMC ships.	Timely provision of serviceable STE to the Point-of-Maintenance including maintenance and repair of STE as required to maintain its serviceability.
Training Support	Delivery of CH148 operations and maintenance training including use of operational flight simulators and aircraft maintenance trainers, and training in the use of Integrated Information Environment tools.	Development of all CH148 operations and maintenance training content and courseware, except operational tactical training; provision of serviceable operational tactical simulators and aircraft maintenance trainers to meet training schedule requirements.

Function	DND	Contractor
Engineering/ Logistics Support Analysis Support	Approval of proposed Class 1 design changes to the CH148; participate in IPT for all ECP development including Software Change Requests; provide full scope of engineering support and management for GSM; facilitate the identification of technical problems against the MHWS inclusive of software.	Provision of configuration and data management, timely investigation and resolution of technical problems raised against the CH148 type design inclusive of the maintenance program, and development of MHWS design change requirements – includes all engineering specialty disciplines including LSA; Provision of an MH Avionics Equipment Integration Environment (MHAEIE) provision of a software maintenance and enhancement services within a Software Support Facility (SSF) located at the east coast main operating base.
Integrated Information Environment Support	Provide Certification and Accreditation of contractor supplied I.S. installed on or accessed from the Defence Wide Area Network; maintenance and enhancement of DND supplied I.S.	Provision, maintenance and enhancement of information systems capable of satisfying the requirements of the: Integrated Electronic Technical Information Service; the Contractor Integrated Technical Information Service; and the Training Information Management Service. Provision of timely help desk support to DND.

4.0 OPERATIONAL AVAILABILITY BACKGROUND

4.1 The Importance of Aircraft Operational Availability to a Military Force

Performance Based Contracting (PBC) is a key component of DND’s emerging strategy to partner with Industry for the provision of long-term integrated support services for flight and maintenance operations. Typically, these contracts will specify a wide scope of performance requirements that are associated with quality and timeliness of goods and services provided by a single support Contractor; however, the critical requirement from a strategic perspective is end-system A_O. For a new fleet, the A_O requirement is typically first specified in a document known as the Statement of Operation Requirements (SOR) prepared by strategic level operational planning staffs. The importance of A_O to the Canadian Air Force, and military forces in general, is illustrated in Figure 2 below.

Figure 2: The importance of aircraft A_O to a Military Force.

The successful completion of a mission depends upon many factors as illustrated. First, the aircraft design inclusive of flight and mission systems must be capable of reliably performing specified functions. Both the inherent mission capability and the reliability associated with the use of mission systems in the prescribed environment is a product of the design activity of the OEM team. This is often accomplished as an integrated effort of an aircraft manufacturer and mission system vendors. Another important factor is the efficiency with which flight line maintenance organizations are able to make flight ready and dispatch aircraft that are available for assignment to operations. Lastly, the mission readiness of the fleet is determined by the level of knowledge and skills of aircrew to operate the aircraft to accomplish mission goals, and the availability of mission capable aircraft to be assigned to the flight schedule. Each of the determinants of mission success are of importance. A deficiency in any determinant will adversely affect the outcome. All of the dispatch reliability, aircraft availability and aircrew proficiency in the world cannot make up for an aircraft whose fundamental capability is deficient. Conversely, if the standards set for all determinants are exceeded save A_O, all of this capability is of little use if an aircraft is unavailable to be assigned to meet the mission requirements of the moment.

4.2 Operational Availability – Brief Historical Overview

Logisticians and engineers, and academics have long been aware of factors that contribute to the achievement of A_O for a major weapons system such as an aircraft; however, the focus of design methodologies and associated standards have been on system reliability and maintainability factors. Some methodologies that readily come to mind are: Reliability Centred Maintenance; Failure Modes and Effects Analysis (FMEA); and Logistics Support Analysis (LSA). Maintainability analyses have typically excluded delay time factors as uncontrollable by the designer, and as such, definitions and demonstrations always assume that required resources (e.g. qualified and authorized HR, spare parts, support and test equipment, etc) are readily available. Although advanced techniques have evolved to model the supply chain for a system, no model has been advanced that factors both equipment and ISS design capabilities into consideration to realize a standard for a single measure of effectiveness such as A_O. As such, despite advances in each of these separate areas of focus, the achieved levels of A_O for aircraft fleets operated by military air forces in general, and Canada in particular are, on the balance, mediocre, not only for legacy fleets, but for many newly acquired fleets as well.

Other factors that have combined to result in this unsatisfactory outcome include:

- Inadequate investment in R&M testing combined with weak contractual clauses for in-service accountability have resulted in significantly lower equipment R&M performance than predicted by the OEM.
- Inadequate investment in procurement of spare parts.
- Poor responsiveness of procurement/delivery systems to variances in equipment performance relative to that which was predicted.
- Inadequate obsolescence management.
- Insufficient access to OEM design data to enable in-context root cause analysis.
- In-service logistics support information systems failure to collect complete, accurate and standardized data with respect to the performance of the system, as well as that of the support organizations.
- Accountability ambiguity for the performance of unavailability drivers.

The last two items in the above list are of particular relevance to this paper. Although it is and has been relatively simple to generate an accurate measurement of A_O for a fleet of equipment, because of the diversity of unavailability drivers which have their effect in overlapping periods of time, on simultaneously occurring on-system maintenance tasks, it has been historically impossible to isolate specific unavailability root causes which would be an essential input to a Pareto of organizational accountability. This practical ambiguity has forced DND in-service Weapon System managers to focus on secondary performance indicators such as system reliability. However, as discussed, due to other issues, this has not resulted in a significant improvement in system A_O performance.

5.0 RE-THINKING OPERATIONAL AVAILABILITY

5.1 General

In considering alternative approaches to A_O specification and measurement, the PMO assessed each individual approach or approach variation to a set of criteria known as SMART: **S**pecific; **M**easurable and **M**odel-able; **A**greeable; **R**ealistic and **R**eflective; and **T**ime-Bound. It was additionally required that the data required for performance measurement had to be collected within an Integrated Information Environment (IIE) as part of the routine work of those performing the activities of interest to the measure. That said, the only constraint from the perspective of performance measurement was that organizational attribution data had to be invisible to those inputting the data; no constraint was imposed to require the IIE to make use of legacy forms or work processes. The plan is to leverage Information Technology as much as possible to ensure the data collected will be accurate and complete, so that measurement outcomes using such data will be irrefutable to both DND and the Contractor.

The genesis of the A_O measurement approach eventually adopted by the PMO was achieved by performing a top-down decomposition of A_O into mutually exclusive unavailability driver (A_U) design attributes of the Weapon System as illustrated in Figure 3. Reading the figure from left to right, the first branch of the breakdown identifies the two main categories of A_U drivers as being: the design of the Integrated Service Support (ISS) System; and aircraft design. The former is a function of aircraft unavailability (A_U) that has been historically associated with Active Maintenance Time ($A_{U,MDT}$), and the latter, Maintenance Delay Time ($A_{U,MDT}$). These in turn are further sub-divided into more specific cause factors. The specific meaning of these terms is discussed in more detail below. Through an association of the resources or services to be provided by either DND or the Contractor, A_U factors are re-combined into organizationally attributable sub-groupings (e.g. $A_{U\text{-}C}$ and $A_{U\text{-}DND}$ for aircraft unavailability controllable by the Contractor or DND, respectively). These sub-grouping are combined to yield the same fleet A_O value.

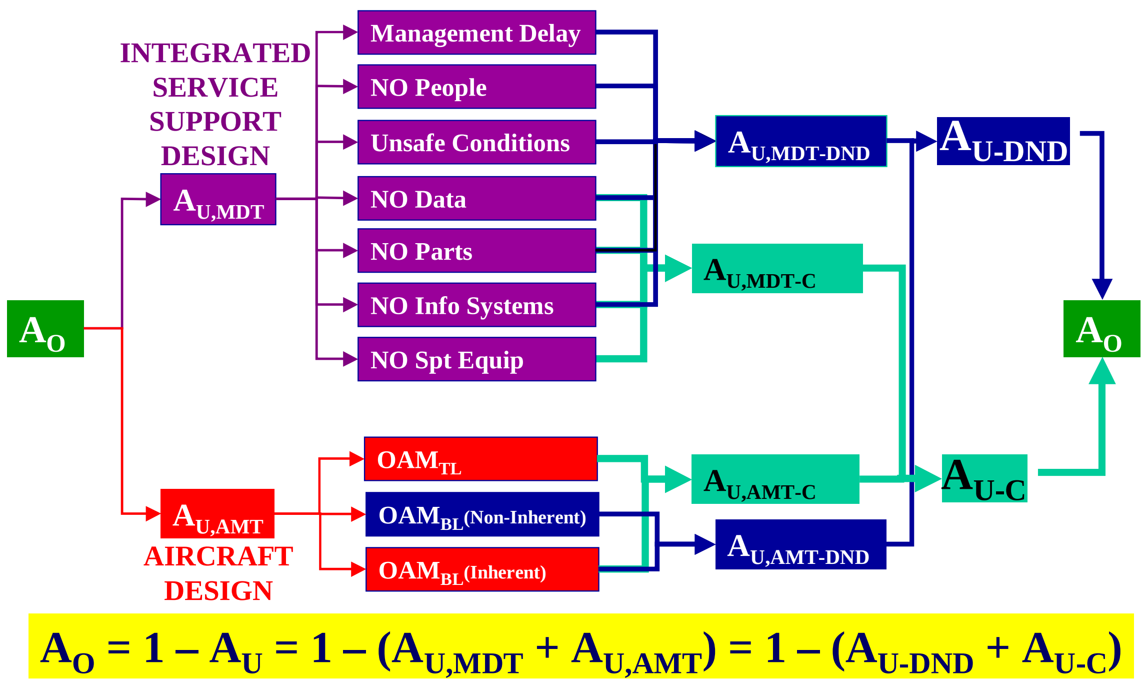

Figure 3: Decomposition of Aircraft A_O by Design Attribute to the Organizational Level.

5.2 Operational Unavailability Drivers

5.2.1 General

As illustrated in Figure 3, the A_O of a system can be determined by its operational unavailability (A_U), the two major determinants of which are: the practically measurable elapsed time required to actively perform on-aircraft maintenance, $A_{U,AMT}$ (Aircraft Operational Unavailability – Active Maintenance Time); and the elapsed time that maintenance is interrupted or delayed because of management related delays or the unavailability of a required resource, $A_{U,MDT}$ (Aircraft Operational Unavailability – Maintenance Delay Time). This is further explained below.

5.2.1.1 Active Maintenance Time (AMT)

AMT that is practically measurable includes the elapsed time taken by a qualified and authorized technician to perform an on-aircraft maintenance task (OAMT) inclusive of various administrative supporting tasks such as reviewing maintenance instructions, obtaining and setting up Support and Test Equipment or tools, and making entries into the maintenance record set. Many of these administrative supporting tasks are so integral to the performance of a maintenance task that to attempt to separate out measurement of the elapsed time taken to perform them would not be practical to implement. In general, maintenance may be sub-divided into inherent and non-inherent maintenance as follows:

a) Inherent (Inh) On-Aircraft Maintenance (OAM). Inherent OAM is that maintenance anticipated to be required based upon the known failure characteristics of the aircraft when it is operated IAW prescribed procedures and within environmental limits. This includes scheduled maintenance (i.e. preventive) and unscheduled maintenance (i.e. corrective) performed at a Base Level (BL) – first and second level maintenance – OAM_{BL}, and Third Line OAM (OAM_{TL}).

b) Non-Inherent (Non-Inh) On-Aircraft Maintenance(OAM). This includes maintenance which arises due to: aircraft modification requirements; aircraft operations outside of the approved flight envelope (e.g. hard landing); damage incurred as a result of the aircraft being struck or striking other objects (e.g. battle damage or bird strike, respectively); etc.

5.2.1.2 Maintenance Delay Time (AMT)

MDT is the elapsed time that performance of a maintenance task is interrupted due to time waiting for a management decision or because one or more resources required to control and/or conduct maintenance is or are unavailable. Resources include, but are not limited to:

a) People – technicians that are duly qualified and authorized to conduct aircraft maintenance;

b) Parts – spare repairables and consumables including GSM – Government Supplied Materiel;

c) Data – technical data required to conduct maintenance (e.g. maintenance instructions applicable to an observed fault usually provided in a Technical Manual);

d) Information Systems (Info Systems) – hardware and software used to display maintenance instructions, record maintenance transactions, order materiel, etc (e.g. Interactive Electronic Technical Manuals; Computerized Maintenance Management Systems; Supply Chain Management Systems; etc);

e) Support Equipment (Spt Equip) – support and test equipment including tools; and

f) Unsafe Conditions – involves ambient conditions (e.g. temperature, wind, weather, etc for work that must be done outdoors), motion states for aircraft operated from and maintained on ships, and lighting/ daylight for post maintenance test flight purposes.

6.0 DESIGNING THE SUPPORT TO SUPPORT THE DESIGN: THE APPLICATION OF SYSTEMS ENGINEERING TO THE IN-SERVICE SUPPORT DOMAIN

6.1 Specifying Contractual A_U Requirements

PMO MHP used the above A_O model construct to establish A_U sub-requirements unique to each Bid solution with the separate input of each of the Bidders during a Pre-Qualification Process. It did this by first establishing the requirement for fleet A_O, and amount of A_U performance for $A_{U,AMT\text{-}DND}$ and $A_{U,MDT\text{-}DND}$. The performance reservation for DND attributable aircraft operational unavailability was obtained through an analysis of maintenance data captured for legacy fleets. PMO MHP also developed a prediction model for $A_{U,AMT\text{-}C}$ that factored into consideration standard R&M performance attributes as well as those directly associated with the maintenance concept for the Maritime Helicopter. The requirements, performance reservations and model were then given to Bidders for use in predicting $A_{U,AMT\text{-}C}$ leaving an allocation for $A_{U,MDT\text{-}C}$ to be calculated as the only unknown variable in the equation provided in Figure 4.

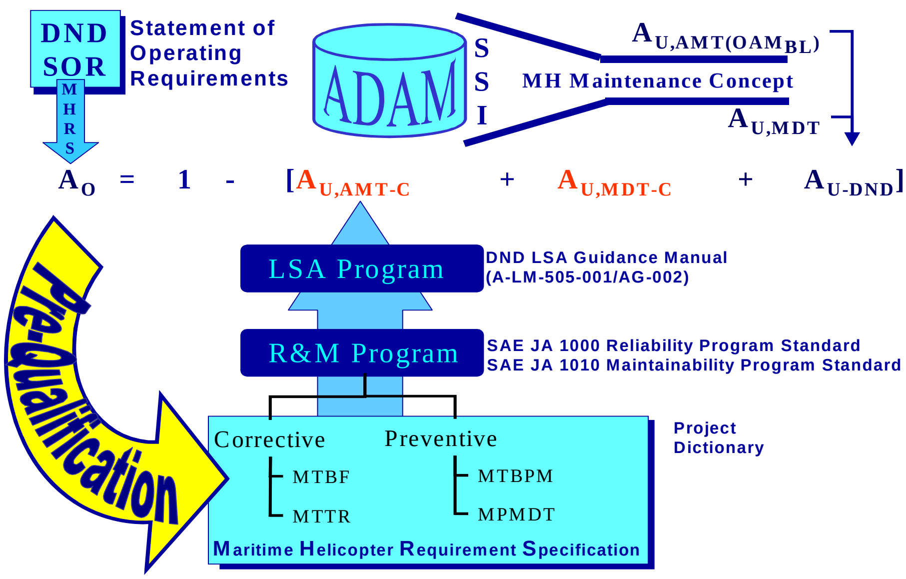

Figure 4: Aircraft design contribution to the achievement of aircraft A_O.

6.2 Deriving and Allocating A_U Sub-Requirements

Although the MHP OEM-Prime Contractor will be accountable for the on-going achievement of the $A_{U\text{-}C}$ requirement for the time period of the contract following aircraft acceptance, PMO MHP requires the Contractor to follow the system engineering life cycle processes prescribed in ISO/IEC 15288 to develop, set-up and provide an integrated support solution that will satisfy these requirements. This necessitates that the Contractor derive performance requirements for $A_{U\text{-}C}$ sub-measures and allocate these requirements to the aircraft or applicable contractor supplied support services as indicated in the Figure 5 below.

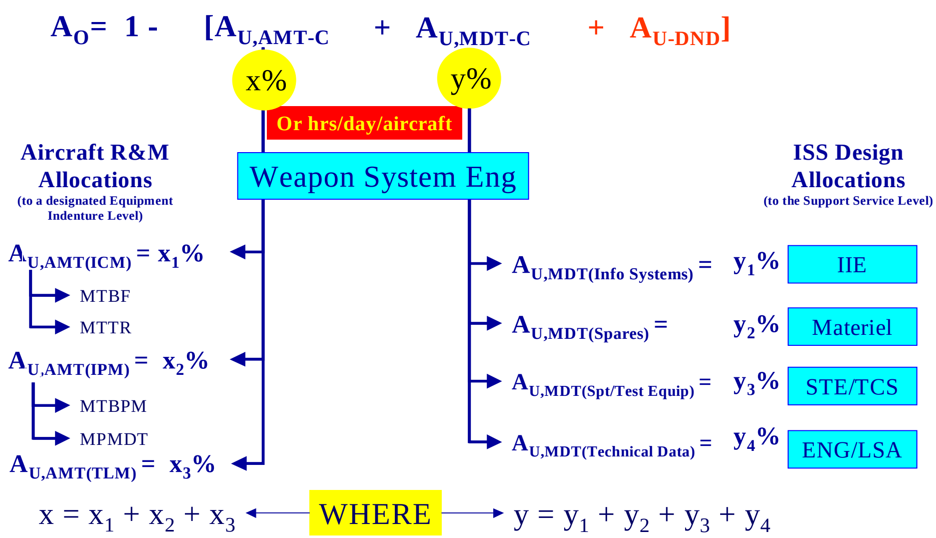

Figure 5: Weapon System design allocation to $A_{U\text{-}C}$ sub-metrics.

Support service IPTs for their part will develop new models or leverage existing models including those mandated by DND in the contract to determine whether the allocated requirements can be satisfied, and if not, a Weapon System Engineering led trade-off analysis will be performed. Prior to acceptance by DND of the ISS into service, the MHP OEM-Prime Contractor will be required to formally demonstrate to DND the compliance of their ISS design with DND specified requirements including those for $A_{U,AMT\text{-}C}$ and $A_{U,MDT\text{-}C}$ performance. This demonstration includes DND validation of the models which the Contractor will have developed for predicting $A_{U\text{-}C}$ performance, as well as any scenario based input data used by the model.

7.0 THE STRATEGY FOR MEASURING ORGANIZATIONALLY ATTRIBUTABLE OPERATIONAL AVAILABILITY

7.1 General

Notwithstanding the unique challenges of the ISS set-up phase from a support service design perspective, the critical success factor for implementation of a performance based contract that is A_O centric, is the ability to measure organizationally attributable A_U performance in a manner that all accountable parties will agree is complete and irrefutably accurate. This ability is a function both of a measurement process inclusive of business rules that will produce a mathematically valid result, and of the technology to accurately capture the appropriate input data. Although subject to implementation constraints not yet fully known by DND, the first condition has been satisfied with DND's provision of a requirement specification for A_U measurement that was accepted by all Bidders prior to release of the RFP.

The measurement methodology specified is built on the fundamental definition of A_O, which essentially involves summing mutually exclusive organizationally attributable aircraft unavailable time for each aircraft in the fleet, and dividing the cumulative result with the Total Program Time (TPT). To perform this arithmetic function involves capturing within the fleet Computerized Maintenance Management System (CMMS), in real time, each date/time that the aircraft availability and downtime state changes, first and most fundamentally at the maintenance task level. The difference in date/time for successive state changes, when associated with a captured data attribute that explains the cause of the change, enables organizationally attributable elapsed times to be calculated.

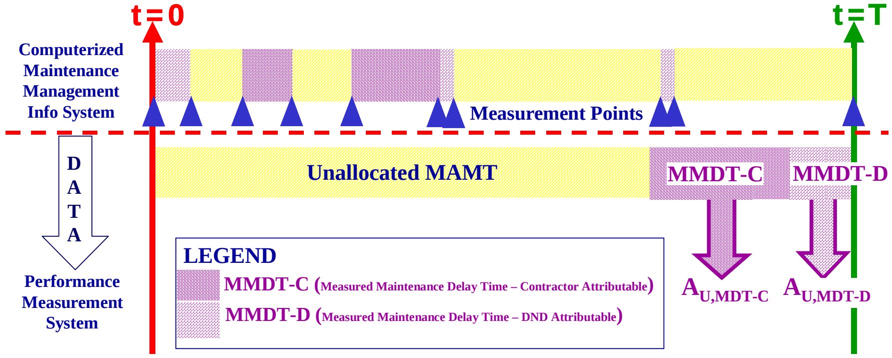

Figure 6: Measuring organizationally attributable aircraft unavailability at the task level – Build #1.

7.2 Measuring Organizationally Attributable Aircraft Unavailable Time at the Task Level

To illustrate the basic measurement approach, consider an on-aircraft downing event (OADE) that is comprised of a single corrective maintenance task as depicted in Figure 6 above. At the date/time that an observation is entered into the fleet CMMS of the existence of an unserviceable condition, the aircraft availability state will change from available to unavailable, and it will change back from unavailable to available when the appropriate certification is provided that the applicable corrective maintenance task has been completed. The elapsed time between these two points in time is called the Measured Maintenance Task Time (MMTT), and is also the Measured Downing Event Time (MDET) for this simple example. Hidden within this amount of elapsed time is the DND and Contractor Attributable Measured Maintenance Delay Time (MMDT) and Measured Active Maintenance Time (MAMT).

However, within the maintenance task, the task status may change from active to inactive or delayed as a function of the availability of resources, or the time taken by management to assign, from a pool of potentially limited resources, a technician with the necessary qualifications and authorizations to perform a given maintenance task. Given that some delay causes will be traceable to the unavailability of a Contractor supplied resource, such as a replacement part, and some to a resource to be provided by DND, such as a qualified and authorized technician, it will be relatively easy to calculate the Contractor and DND attributable MMDT, MMDT-C and MMDT-D, respectively. The difference between the MMTT and the sum of MMDT-C and MMDT-D will be the Measured Active Maintenance Time (MAMT) for the OAMT. If the maintenance task is non-inherent (e.g. repair required as a result of a Bird Strike), or the maintenance task is for an item supplied by the Government of Canada (i.e. Government Supplied Materiel), the full duration of the MAMT will be attributed to DND, if not, a separate calculation process is required to apportion this block of time between DND and the Contractor.

7.3 Attributing Accountability for Measured Active Maintenance Time – the Book Value Concept

7.3.1 Background

A separate process is required to apportion MAMT between the Contractor and DND because, in the case of the MH fleet, DND is performing organizational level on-aircraft maintenance, and the Contractor is being held accountable for the duration of the maintenance downtime even though the Contractor will not control the performance of the technicians. While this is completely logical from a design perspective, the logic may not be intuitively obvious, especially from the perspective of the accountable Contractor who does not directly control the maintenance workforce.

From a design perspective, the major determinants of aircraft downtime are the inherent reliability and maintainability characteristics of the aircraft which, though subject to satisfying customer requirements, are controlled by the OEM-Contractor. Additionally, in the case of the MH Project, the OEM-Contractor will also produce and be responsible for the maintenance of the Interactive Electronic Technical Manuals and Computerized Maintenance Management System the layout/design of which could be a significant maintenance turnaround time driver. The OEM-Contractor will also be responsible for producing the technical training course curricula, courseware and training aids that will be used in the delivery of technical training, and as such, will largely determining the aircraft type specific knowledge of a DND technician which is another maintenance downtime driver.

All of this said, if the non-accountable organization which performs on-aircraft maintenance is highly inefficient in that function, the downtime will be significantly greater than inherent minimums. Such a circumstance would be fundamentally unfair to the organization accountable for the inherent design capability. Although DND does not consider itself to be any more inefficient than it’s civilian equivalent organizations, it agreed that some mechanism was required to limit the Contractor’s liability for design attributes only (i.e. active maintenance time). After some considerable deliberation on the subject, DND decided to leverage a modified form of a concept well used in the Automobile repair industry – that of the Book Value (BV), referred in PMO MHP contractual documents as the Active Maintenance Time Book Value (AMTBV). For brevity sake, AMTBV will be hereafter abbreviated to BV.

The BV is basically a design characteristic of an OAMT, and at the limit, is the minimum elapsed time required for the task to be performed (excluding delays). The nuance between a BV and maintainability metrics such as MTTR or MTTRS is that the BV is provided for all inherent on-aircraft maintenance tasks, whereas, maintainability metrics are typically estimated for a physical item. Another distinction is that the BV is intended to include some aspects of administrative support time such as: time required to consult technical manuals; time required to record maintenance work progress; time required to set-up Support and Test Equipment (STE); etc. The good news is that BVs can be produced for qualified OAMT with only minor adjustment to standard maintainability roll-ups accomplished by Logistics Support Analysis Record systems widely used by defence aviation industry.

7.3.2 General Application of the Book Value

The BV will be used by the Performance Measurement System to apportion unallocated MAMT between DND and the Contractor for qualified OAMT (e.g. mainly inherent maintenance of the airframe and Contractor produced LRUs). In general, the Contractor will be accountable for the lesser of the MAMT or the BV for a task. If the MAMT is larger than the BV, DND will be accountable for the difference. To reduce the effort required to validate BVs as part of aircraft acceptance and eliminate disputes over their accuracy, DND has specified the requirement for an auto-adjustment process to compensate for estimation inaccuracies that are not found during acceptance testing.

Returning to our simple example of an On-Aircraft Downing Event that is comprised on one task, as illustrated below in Figure 7 and Figure 8, one will observe that after organizationally attributed MMDT is subtracted from the MMTT there is an amount of MAMT that is 'unallocated'. This unallocated MAMT is compared to the BV for the task, resulting in the apportionment between the Contractor and DND as illustrated.

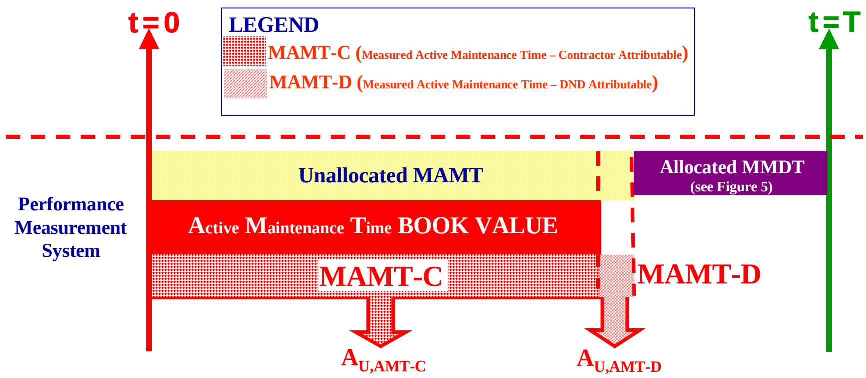

Figure 7: Use of BV to apportion Unallocated MAMT when BV < Unallocated MAMT.

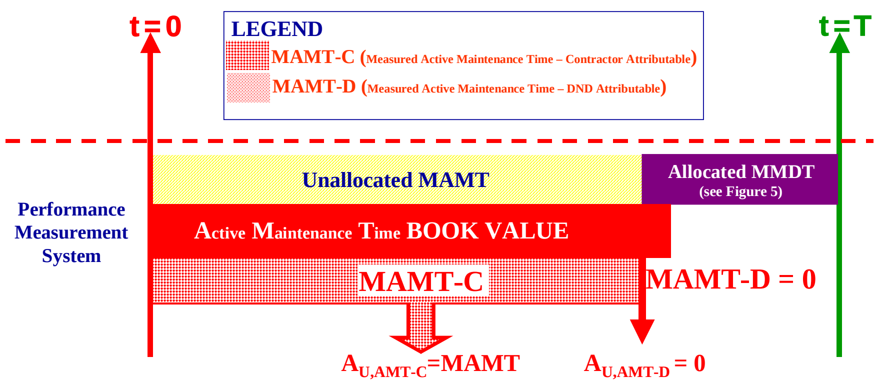

Figure 8: Use of BV to apportion Unallocated MAMT when BV > Unallocated MAMT.

7.3.3 Measuring Organizationally Attributable Aircraft Unavailable Time at the Downing Event Level – Treatment of Multiple Simultaneous Tasks

The application of this measurement approach to an OADE that is comprised of a single OAMT is all well and good, but the reality is that most OADE involve multiple simultaneously performed OAMT. This is certainly true for pre-planned OADE such as a Consolidated Maintenance Schedule, but also for unplanned OADE due to the simultaneous occurrence of multiple independent failures. To account for this reality, the MHP measurement approach incorporates a normalization process as illustrated in Figure 9. Through this process, the outputs of measurement attribution conducted at the task level are first summed for all OAMT contained within the OADE, as is the MMTT for each OAMT. As illustrated below, these yield the following summations: Σ_{DE}MAMT-C; Σ_{DE}MAMT-DND; Σ_{DE}MMDT-C; Σ_{DE}MMDT-DND; and Σ_{DE}MMTT. For complex downing events, it is expected that Σ_{DE}MMTT will be significantly greater than the MDET. Normalization of the OADE summations will be accomplished by multiplying the ratio of each summation to the Σ_{DE}MMTT by the MDET to yield each of MAMT-C_{DE}, MAMT-DND_{DE}, MMDT-C_{DE} and MMDT-DND_{DE}.

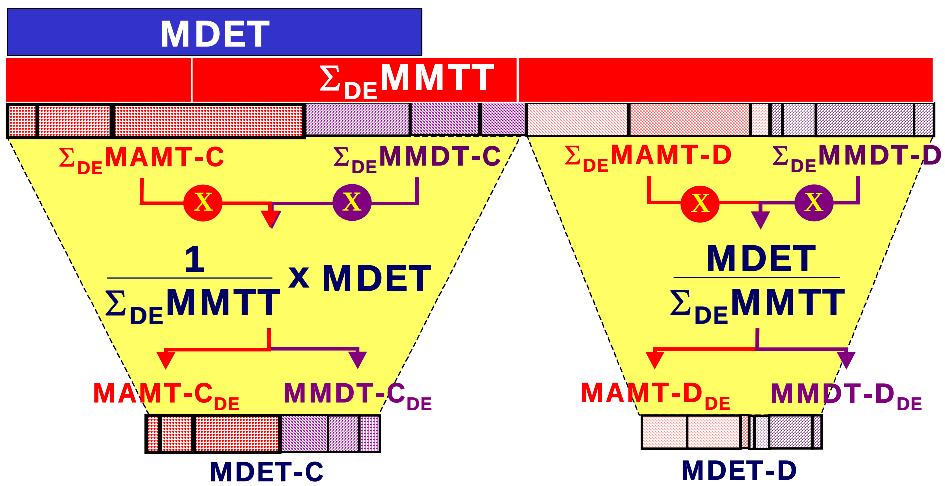

Figure 9: Normalizing MMTT to real-time to yield organizationally attributable MDET.

7.4 Calculating Organizationally Attributable A_U at the Fleet Level for a Fixed Period of Time (e.g. Daily, Weekly, Monthly, Quarterly, Annually)

Once measured maintenance task time and associated delay times are normalized within downing event, calculating organizationally attributable $A_{U\text{-}C}$ is a simple arithmetic summation of organizationally attributed downing event data for all events contained within the measurement period. As such, when each of MAMT-C_{DE}, MAMT-DND_{DE}, MMDT-C_{DE} and MMDT-DND_{DE} are summed for each OADE for each aircraft in the fleet over an annual measurement period (AMP), the yield is MAMT-C_{AMP}, MAMT-DND_{AMP}, MMDT-C_{AMP} and MMDT-DND_{AMP}, respectively. Finally, when these are proportioned with the Total Program Time (TPT) for the fleet, the result is the measured values for $A_{U,AMT\text{-}C}$, $A_{U,AMT\text{-}DND}$, $A_{U,MDT\text{-}C}$ and $A_{U,MDT\text{-}DND}$.

8.0 CRITICAL SUCCESS FACTORS (CSF) FOR THE MEASUREMENT OF ORGANIZATIONALLY ATTRIBUTABLE AIRCRAFT OPERATIONAL AVAILABILITY

8.1 General

For the purposes of this paper, CSF are divided into those which are technical and those which are organizational, and those which have a combination of technical and organizational factors. Technical CSFs speak to the enabling environment while CSFs that are organizational are associated with cultural and human behavioural issues.

8.2 Technical Critical Success Factors (CSF)

The first technical factor that is critical to the success of the measurement of A_O as described in this paper is having access to a robust electronic means of capturing maintenance transactional data. Such a capability must capture data in real time, or synchronized real time (i.e. each transaction entry should be date/time stamped), and the data must be irrefutably complete and accurate.

A second technical CSF is the complete automation of the calculation and reporting of current levels of performance. Although the process for measuring A_{U-C} performance involves the execution of arithmetic calculations that are not complex, the sheer volume and ordering of such calculations dictates a process that is automated. Creation of such a capability demands a system engineering approach to design so that the end result is fully verified and validated. This will also serve to minimize, if not totally eliminate, any disputes associated with errors in the calculation function once the system is implemented; although, the capability will be required to be re-verified and re-validated any time a change is made to it.

8.3 Combined Critical Success Factors (CSF)

A CSF that has both technical and organizational components is the requirement for organizational attribution of events to be automated. The main user who will input data with which organizationally attributable operational unavailability will be measured is the technician who needs to be focused on performing his or her job IAW prescribed standards, not on thinking about the organizational cause of the maintenance he or she is performing. This would introduce an element of human bias into the measurement function, which would unnecessarily lead to disputes. As such, the enabling environment must be designed to automatically capture the data, which together with design data, can be processed by a measurement tool, using pre-determined business rules, to assign organizational responsibility for every logically separable slice of time. When such is not possible, provisions for organizational attribution must be left to the management function and subject to Contractor acceptance.

Another combined CSF is required to minimize the potential for human bias in the input function. To avoid Average Measured Active Maintenance Time being forced to an associated task Book Value, it is critical that this value not be visible to those performing or directly supervising the performance of maintenance tasks. The intent is to allow for the duration of a maintenance task to vary as a function of the natural variance of drivers such as: individual proficiency levels; personal health and motivation; location of an aircraft relative to support resources; the ambient conditions and environment within which a task is performed; and the condition of items requiring maintenance. In this way, significant differences between Average Measured Active Maintenance Time and the Book Value for a task is more likely to be real than biased with the latter being a another cause for disputes.

8.4 Organizational Critical Success Factors (CSF)

It is possible to have the most technically robust Performance Measurement System (PMS), and yet experience failure in its implementation because insufficient attention is paid to organizational CSF. In recognition that organizations not accustomed to working in an environment that is quantifiably performance-oriented will ultimately resist changing to such an environment, it is critical that management take positive action to educate the workforce at all levels. It is also critical that management develop positive and not personally punitive strategies for correcting for performance shortcomings. The PMS is a powerful enabler of positive or negative change depending on how it is used.

8.5 CSF Summary

In the MHP, the technical CSF will be realized through their inclusion in requirements for the provision of an Interactive Electronic Technical Information System (IETIS) with which maintenance data is to be captured by DND, and of a Performance Measurement System (PMS) with which current levels of performance are to be measured and reported. The provision of these enabling systems will be subject to the same ISO/IEC 15288 systems engineering processes that are required to be applied to the provision of each of the support services. As for the Organizational CSF, this will be addressed as an element of the MH Project Implementation Plan.

9.0 APPLICATION OF OPERATIONAL UNAVAILABILITY CONCEPTS WITHIN THE MHP ISS CONTRACT

9.1 Contractual Accountability Provisions

The most basic accountability provision of the MHP ISS Contract is the scaling of ISS payments to the Contractor as a function of the number of hours flown by the MH fleet in a given Fiscal Year. This is known as Cost-per-Hour, or Power-by-the-Hour™[1]. If the aircraft does not fly, the Contractor does not get paid. For planning purposes, DND has projected a nominal annual flying rate, and provides a guaranteed minimum.

The ISS Contract also incorporates a number of dis-incentive and incentive adjustments to Cost-per-Hour payments based upon levels of performance achieved relative to specified requirements for several performance measures. The key dis-incentive is that associated with a failure of the Contractor to satisfy the $A_{U\text{-}C}$ requirements; for each percentage point $A_{U\text{-}C}$ is above the specified requirement the Cost-per-Hour rate is reduced by one percent, to a maximum of 15.00%. Satisfaction of this key contractual requirement is also a gate through which the Contractor would be eligible to earn incentive payments against additional performance requirements that are incentivized.

Although performance measurement will begin upon DND acceptance of the MH, the financial accountability provisions of the Contract will not be enforced until the Fiscal-Year following that in which the MH fleet has accumulated a grand total of 10,000 flying hours from the date/time of acceptance. This is intended to provide appropriate duration of time for initial learning related impacts on performance to be realized without formal consequences that would be inappropriate, and for the Contractor to fine-tune the PMS to provide the most-accurate outputs practicable.

9.2 MHP Implementation Status and Schedule

As of January 2007, Sikorsky has achieved the critical design review milestone for the aircraft, and the preliminary design review milestone for the Integrated Support System. Over the next two years, the design of the Performance Measurement Service and its associated Integrated Information Environment Enabling System will be finalized and implemented. DND will participate in this process in an advisory capacity only to clarify stakeholder requirements, to witness iterative verification activities, and to conduct final scenario based validations both of each individual support service, and of the entire integrated support system.

[1] Power-by-the-Hour is a registered trade name owned by Rolls-Royce plc.

10.0 CONCLUSION

The Defence Industry within Canada and its allies will perform an increasingly vital role in supporting DND's ability to achieve mission success. This will be accomplished within contractual frameworks that are optimized to leverage commercial best practices in consideration of operational constraints, and within which provision is made for PBA. The DND MHP has been cited in this paper as a lead DND implementer of a performance based contract that is A_O centric.

As a key determinant of military mission success, fleet A_O is decomposable into organizationally attributable unavailability metrics. The MHP used such decomposition as the basis for specifying Contractor attributable unavailability requirements, $A_{U\text{-}C}$ in its In-Service Support Contract with Sikorsky Aircraft Corporation.

Contractor-attributable aircraft unavailability requirements are divided into two groupings each of which are treated as system design attributes. $A_{U\text{-}C}$ due to active maintenance time, $A_{U,AMT\text{-}C}$ is treated as a design attribute of the aircraft system, and $A_{U\text{-}C}$ due to maintenance delay time, $A_{U,MDT\text{-}C}$ is treated as a design attribute of the contractor supplied support system. For this reason, PMO MHP has required the Contractor to apply a system engineering approach to the design of these each of these entities, which will culminate in a demonstration of the design's compliance with the applicable $A_{U\text{-}C}$ requirements.

When an aircraft is fielded, organizationally attributable aircraft unavailability must be measurable in a way that the outcomes are irrefutable by any and all organizations involved in providing support to MH operations. This paper describes a measurement model that accomplishes this aim by separating maintenance task time into organizationally-attributable maintenance delay time and active maintenance time. Organizational attribution of delay time is accomplished by associating the cause of the delay (e.g. unavailable resource) with an organization's specific related responsibilities. Comparing the average Measured Active Maintenance Time for a task with its Book Value will be used to organizationally separate active maintenance time; this will limit the Contractor's liability for downtime to a maximum of the Book Value. The Book Value is the duration of time, agreed to by the operator and the OEM, that it will take a qualified and authorized technician to perform a task in a representative support environment. The model also has a means for treating multiple simultaneous maintenance tasks within a downing event to provide an aggregation of A_U for each accountable organization.

The main accountability provisions in the MH ISS Contract are financial in nature. The first is payment that is based on the product of the number of hours flown in a given Fiscal Year and the quoted rate per flight-hour. The second is a dis-incentive adjustment to the rate should $A_{U\text{-}C}$ requirements exceed maximums specified in the ISS Contract. The last financial provision, eligibility for which is conditional on $A_{U\text{-}C}$ requirements being satisfied, is an incentive program based on levels of performance achieved relative to other performance requirements specified in the ISS Contract.

PMO MHP has recognized and acted upon the factors that are critical to the successful implementation of the measurement model described in this paper. Even more important than the various technical CSF which are associated with the Information Technology enabling system, are organizational CSF to address cultural acceptance of transitioning to a an environment that is quantifiably performance-oriented.