# INTEGRATED CABIN-CARGO MAINTENANCE FOR OPTIMISED COMMERCIAL UTILISATION

Bernhard Meyer, Philotech GmbH, Buxtehude, Germany

**Abstract**

Airlines face a dual operations objective/ target, i.e. achieving flight safety goals set by the certification authorities, and achieving commercial viability goals set by the airline itself. This dilemma presents a real challenge to ensure simultaneously both flight safety and commercial viability.

Some underlying concepts are outlined that are suitable to be employed towards achieving this dual objective/ target. A common performance objective/ target is defined in terms of an Operations Readiness Objective (ORO). This incorporates both the Commercial Services Readiness (CSR), i.e. revenue earning, and the Safety Objective Readiness (SOR), i.e. flight safety, objective/ target respectively. An integration of both the safety objective and commercial services is possible by relating both of them to their constituent functions. Initially the owner/ operator defines a reference readiness performance objective/ target. During operation the current, actual performance status/ condition is assessed and compared to this reference to determine any possible deviation. This deviation drives the integrated maintenance to restore the readiness status/ condition in accordance with the reference readiness objective/ target.

An implementation approach is presented for a cabin-cargo environment, based on the underlying concepts. This approach offers a generalised framework with which similar applications can be implemented. Reference is made to a specific implementation that demonstrates some of the concepts such as a Commercial Dispatch Readiness (CDR) performance objective. The implementation approach shows how the integrated maintenance is implemented as the common enabler to achieve both the individual safety and services performance objective, as well as the overall performance objective.

An appraisal concludes that this approach represents a new and novel approach for driving an integrated maintenance towards enabling achievement of predefined commercial and safety performance objectives/ targets. It also indicates the potential to extend the concepts to other similar applications, e.g. transportation, industrial plants, and others, where an optimised performance of both safety and revenue is to be realised simultaneously.

## 1. INTRODUCTION

Commercial aviation has achieved a commendable result regarding flight safety. Figure 1-1 is taken from a recent EASA publication, where it is shown how the fatalities have decreased over a period covering the past 60 years from around 5 to less than 0,05 fatalities per 100 million passenger miles [Reference R1]. And flight safety is a prerequisite to any viable commercial aviation. In fact this paper presupposes this.

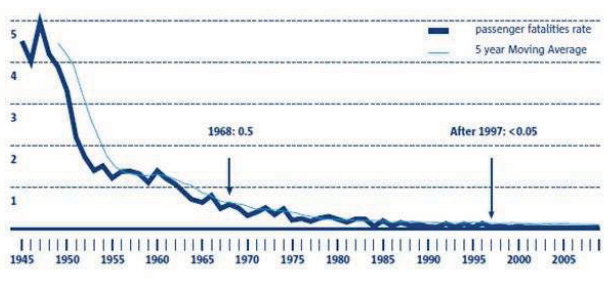


Figure 1-1 Global Passenger Fatalities per 100 million Passenger Miles, Scheduled Commercial Air Transportation, Excluding Acts of Unlawful Interference (EASA Annual Report 2011)

However, in addition to the flight safety consideration above it is a fact that airlines and/or air transportation operators acquire aircraft for sound business reasons, i.e. revenue earning by means of a high operational availability. From an utilisation perspective it is therefore important to view aircraft operations from both a

- Flight safety perspective, where an operational availability is ensured with commensurate flight safety as the primary driver, and
- Commercial revenue earning perspective, where operational availability is ensured with commercial services availability as the primary driver.

It is the objective of this paper to show how an integrated maintenance is employed as the common enabling driver. And thus it presents a conceptual framework that enables such an optimised operation for both the safety and commercial drivers simultaneously. In addition it is also intended to show that this is a generic frame work applicable to similar operations, e.g. transportation in general, commercial plants, and others.

## 2. SOME UNDERLYING CONCEPTS

This section outlines some important underlying concepts that find application in the proposed integrated maintenance approach.

### 2.1. Notion of Safety Objective and Commercial Service

#### 2.1.1. Safety Objective (SO)

ICAO defines safety as the state in which the risk of harm to persons or property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management. [Reference R2]

And ICAO then also describes a safety management process, comprising this hazard identification and risk management, which consists of the following steps:

- Identify possible safety hazard events
- Determine the safety risk in terms of severity and probability of occurrence
- Implement risk mitigation means

Figure 2-1 depicts such a generic safety risk space as defined by ICAO. Potential hazard events are mapped in accordance with their occurrence probability and occurrence severity. This determines its acceptability.

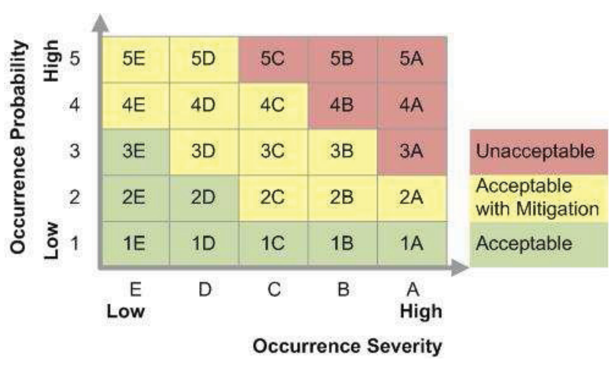


Figure 2-1 Generic Safety Risk Space for Establishing a Safety Objective (Source ICAO)

For the present purpose a safety objective (SO) is considered to comprise both the definition and employment of appropriate mitigation means. And the purpose of these means is to ensure commercial operation within the confines of the defined and certified safety boundary.

For mitigation means to be effective it is required that they will implement as a minimum the following:

- A means to detect a hazardous condition
- A means to determine if, when and what safety action is required
- A means to initiate the required mitigation action
- A means to inform the operations domain of the respective safety situation

And thus a safety objective (SO) is understood to comprise, amongst others, the constituent functions required to effect hazard mitigation.

#### 2.1.2. Commercial Service (CS)

A commercial service (CS) is understood to be composed of one or more functions, enabled through systems, equipment and/or fixtures belonging to the commercial domain. And a service represents a benefit that is offered to a potential customer/ client, e.g. passenger, for which he/ she is prepared to pay an equitable amount of money.

Airlines, for example, procure and operate aircraft to earn revenue through offering such commercial services. It is therefore of prime importance to ensure availability of these services, since that will determine such issues as customer/ client satisfaction, as well as airline/ operator revenue earning and thus economic viability of its operations.

In order to assess the commercial services status appropriate means are required that will implement as a minimum the following:

- A means to measure the service delivery
- A means to determine the service status/ condition
- A means to inform the operations domain of the respective commercial services situation

#### 2.1.3 A Common Base for Safety Objective and Commercial Service

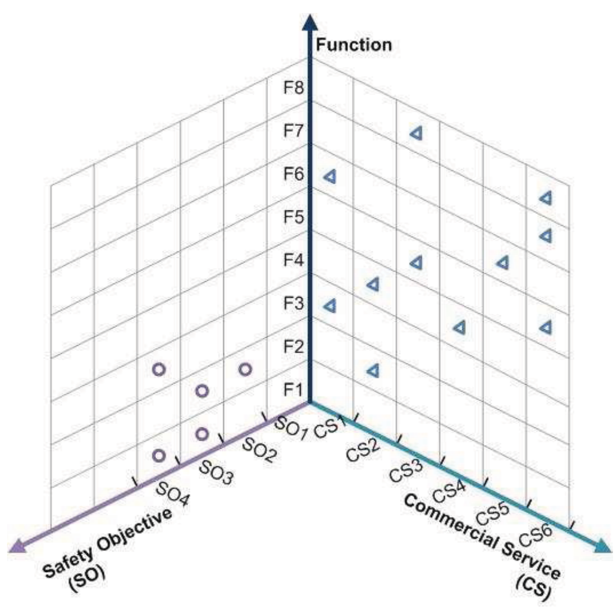


Figure 2-2 Mapping Safety Objectives and Commercial Services Against a Common Function Base

From the above outline it is concluded that both the safety objectives and the commercial services have a commonality as regards their implementation. Figure 2-2 above depicts how both can be related to a common function base.

As an example consider the following mapping:

- Commercial Service CS2 is composed of the functions F2 and F4
- Safety Objective SO2 is composed of the Function F2

This illustrates how in some cases commercial services and safety objectives may share the same functions, while in other cases they may rather be complimentary to one another.

Necessary and sufficient attributes that describe both commercial services and safety objectives will typically include such items as

- Content, describing the "what"
- Quality, describing the "how well"
- Quantity, describing the "how many/ often"
- Time, describing the "when"
- Place, describing the "where"
- Etc.

However, for the present purpose only the function perspective will be further considered. And these constituent functions describe/ define status and/or condition of the particular safety objective and/or commercial service. For this purpose the respective function status is expressed in terms of one or more of the following general expressions, i.e.

- Available, the function performs as designed
- Degraded, the function performs only partially
- Disabled, the function is suppressed
- Failed, the function is unavailable to perform

## 2.2. Integrated Safety and Service Perspective

An integrated safety and service perspective requires a common performance objective/ target. And this is defined by means of a generic Operations Readiness Objective (ORO), which combines both the safety and the services perspective, i.e.

- A Safety Objectives Readiness (SOR) target, and
- A Commercial Services Readiness (CSR) target

This integrated perspective can be further developed based on the mapping shown in Figure 2-2. Figure 2-3 is a further elaboration and illustrates how systems enable functions. And these functions, again, constitute/ compose commercial services and/or safety objectives respectively. This interrelationship of service and safety is the basis of the integrated maintenance approach that optimises commercial utilisation. And both the safety and the service status/ condition drive the maintenance requirements simultaneously.

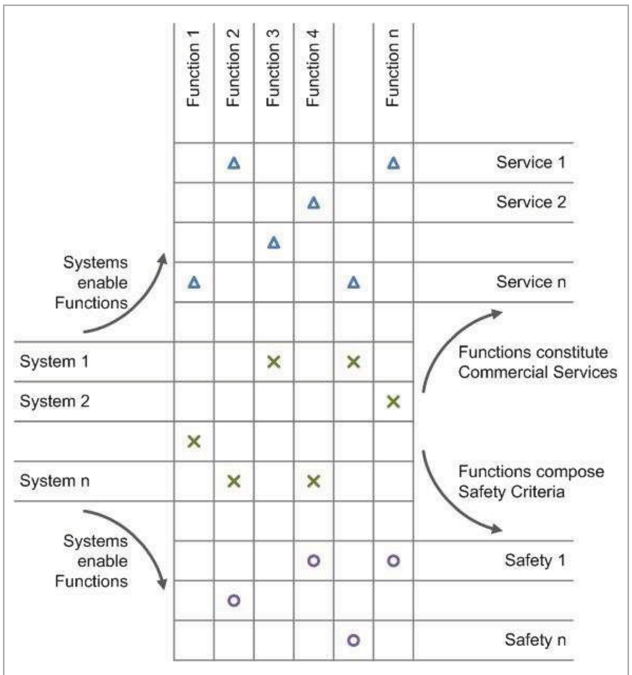


Figure 2-3 Integrated Perspective of Flight Safety and Commercial Service

The requirement is therefore fairly straight forward: An initial operation objective/ target is defined. This objective/ target again requires readiness references for both the safety objectives and commercial services in terms of function performance requirements. Monitoring the performance of the constituent functions of both safety and service gives an indication of their current, actual status/ condition. Comparing reference with actual function performance produces a delta, which becomes the maintenance demand. Corresponding maintenance action is directed towards restoring the system performance to ensure achieving the common performance objective/ target.

Since systems enable functions an integrated safety and service operation requires an integrated perspective as regards their hierarchical arrangement, as well.

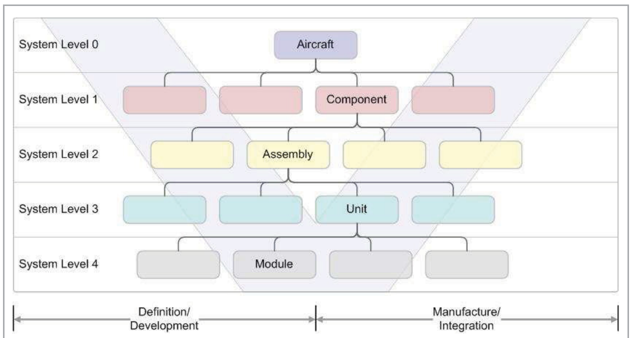


Figure 2-4 Typical Hierarchical Presentation/ Arrangement of the Different System Levels

Figure 2-4 is a generic presentation of hierarchical System Levels, typical in commercial aviation. This hierarchical presentation is superimposed on the V-Model, which is fairly well-entrenched in the systems engineering approach, and which comprises the two major periods/ phases of Definition/ Development and Manufacture/ Integration.

This emphasises the fact that an integrated maintenance approach is only possible when it is purposefully engineered into the product from the start. And it also highlights another important fact, that an integration of the operational safety and the commercial utilisation is only possible at the same Level of Abstraction (LoA), i.e. hierarchical System Level.

### 2.3 Integrating Maintenance with Operations

And now to finally integrate the maintenance with the operations it is required to "close the loop", so to speak.

Figure 2-5 depicts a functional architecture that accomplishes this integration. Safety and service performance is continuously assessed to determine actual performance regarding safety and services status/ condition. Subsequently this current, actual performance is compared with the overall performance objective/ target embodied in the Operations Readiness Objective (ORO). This comparison produces a performance delta, from which it is determined if, what and when maintenance action is required. Appropriate maintenance action is performed to restore safety objective and commercial service performance in accordance with required performance reference.

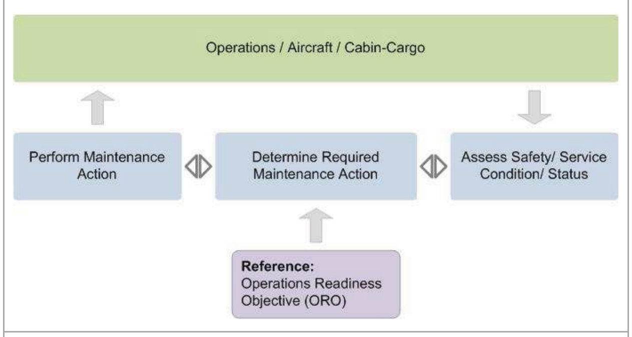


Figure 2-5 Integrating Maintenance with Operations to Achieve the Operations Readiness Objective

## 3. IMPLEMENTATION APPROACH

Since this is a conceptual paper, an implementation outline is presented that illustrates the intended approach to be followed when realising this dual, maintenance driven, optimised utilisation concept.

### 3.1. Selecting an Example

Application is illustrated with reference to the Cabin-Cargo (CC) domain of an aircraft.

Figure 3-1 shows a schematic presentation of a superimposed hierarchical system definition and V-model of the selected example under consideration. Arbitrarily the aircraft is located at System Level 0. And thus the Cabin-Cargo element, which is a constituent element of the Aircraft, is located at System Level 1. For this illustrative example two constituent elements of the Cabin-Cargo are also considered, i.e. In-Flight Entertainment and Fire Protection, both located at System Level 2 of the system hierarchy. In systems engineering these system levels are often also generally referred to as the Levels of Abstraction (LoA).

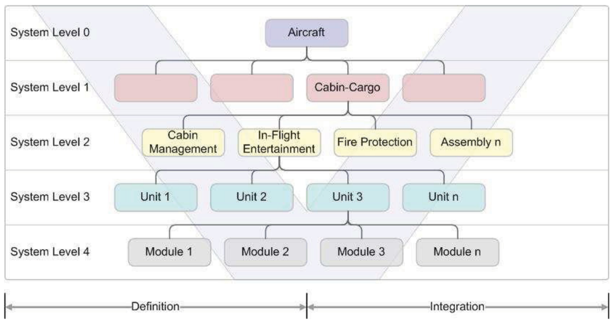


Figure 3-1: Example of Cabin-Cargo Commercial Domain within Aircraft Hierarchical Context

### 3.2 Defining Functional Relationship

Figure 3-2 shows an IDEF0 functional relationship representation of the selected Cabin-Cargo example [Reference 3].

It shows a functional architecture at System Level 1, i.e. at the Cabin-Cargo level of abstraction. It clearly shows the functional relationships that exist between the different main functional entities that are involved at this Level of Abstraction, i.e.

- Manage Cabin-Cargo Operations
- Provide Cabin-Cargo Capability
- Deliver Cabin-Cargo Services
- Maintain Cabin-Cargo Capability

Inputs point horizontally into a function block. Outputs point horizontally out from a functional block. Enablers flow into the function block from below. Controls enter the function block from the top.

In accordance with IDEF0 convention the Manage Cabin-Cargo Operations function generates the Commercial Operations Directive (COD), and which contains the following directives, i.e.

- Safety Directive, comprising Safety Dispatch Readiness (SDR) and Safety Objectives Profile (SOP), and
- Commercial Directive, comprising Commercial Dispatch Readiness (CDR) and Commercial Services Profile (CSP).

Thus COD comprises the directive/ guideline for both safety and commercial utilisation. And this drives/ directs both the Deliver Cabin-Cargo Services and the Maintain Cabin-Cargo Capability functions. This functional interrelationship depicts how management directs the maintenance capability towards enabling the delivery function in accordance with the directive that management provides. And management receives status/ condition information from the delivery function.

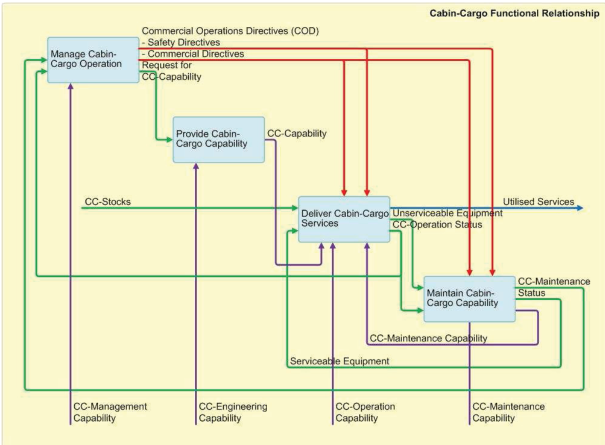


Figure 3-2 IDEF0 Functional Relationship Presentation of Commercial Operations

### 3.3 Mapping Safety and Services to a Common Function Base

Figure 3-3 below depicts this integration of safety and commercial operations in another way.

It shows, as an example, some of the systems that constitute the commercial capability, i.e.

- In-Flight Entertainment
- Fire Protection
- Cabin Management

These systems are the enablers for, amongst others, the functions as shown, i.e.

- Display commercial operation status
- Provide internet connection
- Deliver video on demand
- Deliver audio on demand
- Detect fire
- Extinguish fire

And these functions again constitute the commercial services and safety criteria as illustrated, i.e.

- In-Seat Audio Service
- In-Seat Video Service
- In-Seat Internet Service
- Cargo Fire Protection
- Cabin Fire Protection

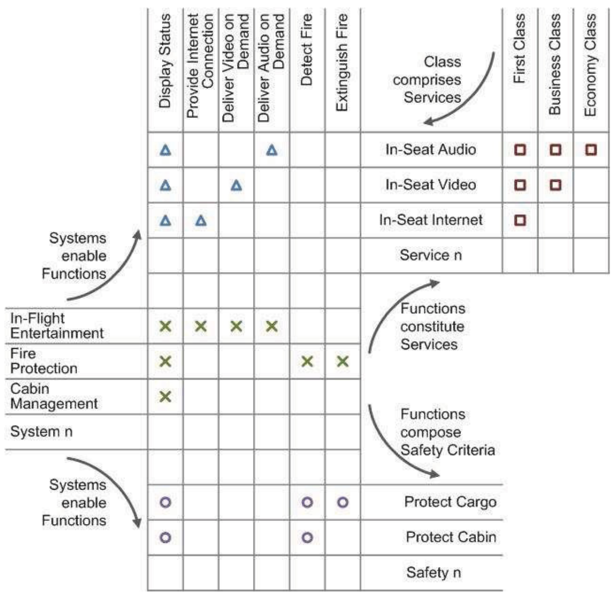


Figure 3-3 Illustrating the Integration of Commercial Service and Operational Safety

Figure 3-3 illustrates another interesting feature. It shows how commercial services can be grouped together into, for example, different classes, commensurate with commercial aviation cabin lay-out practice. And this is highly tailorable according to individual airline/ operator preferences.

### 3.4 Defining Safety and Services Profile

In Section 3-2 above, it was mentioned that the Commercial Operations Directive (COD) contains the different, constituent directives or drivers for the integrated maintenance operation.

Figure 3-4 illustrates four (4) different profiles, which are contained in the directive, with the following significance, i.e.

- Commercial Operations Profile Reference (COP-ref) shows the different Safety Objectives (SO1 to SO3) and the Commercial Services (CS1 to CS4), that are defined for the particular Cabin-Cargo configuration under consideration, together with their required status/ condition as "available"
- Commercial Operations Profile for Dispatch (COP-dis), which contains a selection of those SOs (SO1 to SO3) and CSs (CS1 to CS3), together with their status/ condition, that are required for a dispatch, which is airline/ operator tailorable/ customisable
- Commercial Operations Profile Actual (COP-act), which shows the current, actual status/ condition of the different SOs and CSs. Status/ condition can be any one of Available / Degraded / Disabled / Failed

- Commercial Operations Profile Delta for Dispatch (COP-del.dis), which simply shows the difference in status/ condition for the considered SOs and CSs between the dispatch and actual profiles.

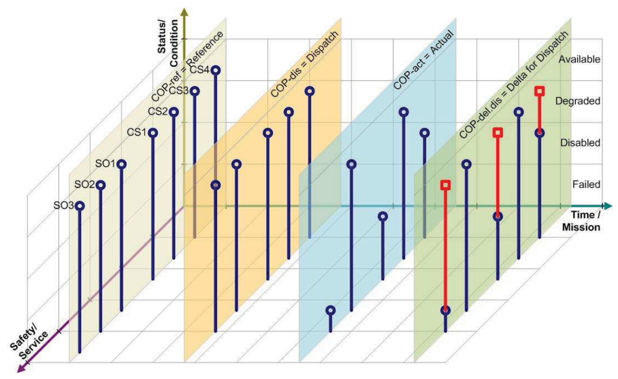


Figure 3-4 Illustrating the Different Commercial Operations Profiles (COPs)

This "delta profile" (red bars) indicates the maintenance effort required before a next dispatch is possible. As such it represents the driver for the maintenance crew regarding the prioritisation of maintenance work. And it is therefore also a very useful decision support as to what needs to be attended to immediately and what could be deferred to at a later point in time. In this way the maintenance crew has a clear indication on what to focus its attention and the maintenance action required before the next flight.

In essence it ensures restoring the CC Maintenance Capability to that required for delivery of CSs, while simultaneously attaining SOs required for certification purposes.

An outstanding useful feature of this approach lies in the customisation and/or tailoring of the different profiles. This allows a major measure of flexibility.

Under present day practice it would rather be the exception to change/ tailor a safety objective profile, because of certification reasons. However, in future it is conceivable that this would be possible under very well-defined conditions.

On the other hand it is very convenient to allow flexibility for changing/ tailoring commercial services profiles. And airlines want more flexibility with respect to future cabin-cargo utilisation to satisfy changing market/ customer needs.

## 3.5 Deriving a Basic Function and Element Architecture

Figure 3-5 shows a basic function architecture for the Cabin-Cargo Maintenance Capability that is required to perform the maintenance requirements outlined above. A functional representation outlines WHAT needs to be done.

The process to arrive at this architecture involves systems engineering and will not be further detailed in this short concept coverage.

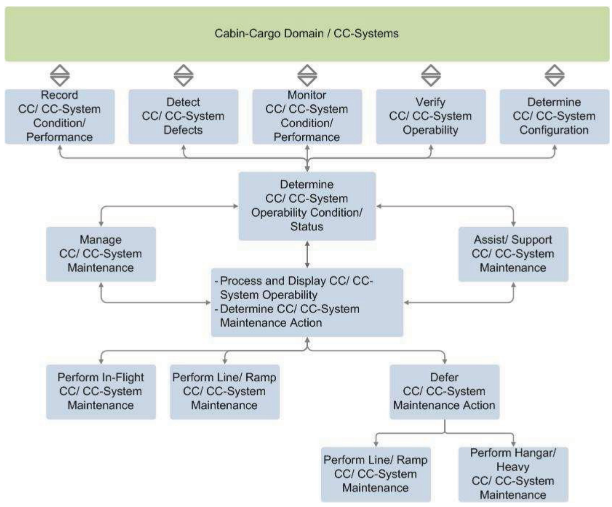


Figure 3-5 A Basic Cabin-Cargo Maintenance Capability Function Architecture

Figure 3-6 shows a basic element architecture for the Cabin-Cargo Maintenance Capability. Such an element architecture depicts HOW a function architecture can be realised/ enabled, i.e. it presents the corresponding enabler for the required functions. The particular element architecture shown could enable the corresponding function architecture shown in Figure 3-5 above. It depicts how the major role-players are involved, i.e.

- Engineering that provides the Cabin-Cargo entity
- Maintenance Capability that loads the reference profiles, and assess current performance profiles
- Maintenance that restores operational readiness
- Operations that define the reference profiles and directs operation

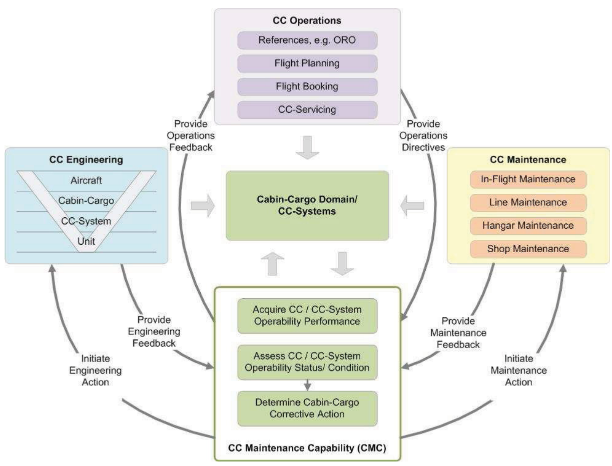


Figure 3-6 A Basic Cabin-Cargo Maintenance Capability Element Architecture

## 4. APPRAISAL

The relevance and novelty of the proposed integrated maintenance for an optimised commercial utilisation has been outline above. It is shown how this integrated maintenance approach is the common enabler for an optimised operation with respect to both the safety and the commercial drivers simultaneously. It is also shown that the proposed framework is of a generic nature, applicable to other similar operations such as rail, road and water transportation, industrial plants, and other similar operations, where different operational drivers have to be accommodated.

Application of the Commercial Dispatch Readiness (CDR) principle has already been demonstrated in a computer simulated model. This was reported in a paper presented at the previous DLRK 2010 in Hamburg [Reference R4].

An attractive feature of the approach is the flexibility, customisation and tailoring that it offers. Present day operations are increasingly under the pressure of economic viability while at the same time required to be adaptive to changing customer/ client and seasonal demands, as well as market trends. Adaptation to requirements is achieved through adapting, tailoring and customising the Operations Readiness Objective (ORO), which is accomplished mainly through defining different commercial services profiles and to a lesser extend also different safety objectives. The future potential of this approach is significant.

An interesting and relevant application example was considered for which the application of the concepts was illustrated. As a next step a representative demonstration would be required to elaborate and fine tune the approach.

## 5. REFERENCES

[R1] EASA, Annual Safety Review for 2010

[R2] ICAO, Safety Management Manual, 2009 Ed 2

[R3] IDEF0, Integrated Definition for Function Modelling, FIPS Publication 183, 1993

[R4] D Fischer, A380 Advanced cabin line maintenance - Highlights of modern Airbus line maintenance, DLRK-2010

Acknowledgement: The concepts presented in this paper have evolved over a considerable time span. Some of the concepts are original from the author, while others matured over time through various interactions and discussions with several experts and knowledgeable persons. And most certainly these ideas and concepts will further develop and mature as time goes by.

## 6. ABBREVIATIONS

| | |
|---|---|
| A/C | Aircraft |
| CC | Cabin-Cargo |
| CDR | Commercial Dispatch Readiness |
| COD | Commercial Operations Directive |
| COP | Commercial Operations Profile |
| COP-act | Commercial Operations Profile Actual |
| COP-del.dis | Commercial Operations Profile Delta for Dispatch |
| COP-ref | Commercial Operations Profile Reference |
| CS | Commercial Service / Services |
| CSP | Commercial Services Profile |
| CSR | Commercial Services Readiness |
| EASA | European Aviation Safety Agency |
| FIPS | Federal Information Processing Standard |
| ICAO | International Civil Aviation Organisation |
| IDEF0 | Integrated Definition for Function Modelling |
| LC | Life Cycle |
| LoA | Levels of Abstraction |
| ORO | Operations Readiness Objective |
| SDR | Safety Dispatch Readiness |
| SO | Safety Objective / Objectives |
| SOP | Safety Objectives Profile |
| SOR | Safety Objectives Readiness |