TITAN

turnaround integration in trajectory and network

The Book

Going beyond A-CDM

TABLE OF CONTENTS

TABLE OF FIGURES

Document Authors: Steve Zerkowitz and Ana C. Sáez Sánchez

Date of publication: February 2013

1. PREFACE

Perhaps it will sound like an over-simplification, but one way of describing air traffic management (ATM) is to say it is the sum total of a series of decisions made by various stakeholders, based on their operational and business priorities.

Although these decisions are arrived at with the best of intentions, in the traditional scheme of things little attention is paid to the effects of a given decision on the operation of other stakeholders, let alone the overall air traffic management operation.

Like in other areas of complex human activity, in air traffic management also everything is related to everything else and the effects of decisions, good or bad, ripple through the whole system, often leading to surprising, and not always welcome, results.

The situation becomes really critical when air traffic demand grows to the point where the available ATM capacity becomes a limitation on further expansion. When the system is bursting at the seams, there is no room for less than optimal decisions.

It was this realization that led a number of experts in the United States more than a decade ago to come up with a new concept of making decisions. Stakeholders became *partners* and decisions became *collaborative* decisions.

CDM, or Collaborative Decision Making, was born.

Although at the time of its invention CDM was a rather straightforward proposition, over time it was reinterpreted several times and some of those interpretations resulted in mental pictures of CDM that has little to do with the original concept that was elegant by its simplicity. For some people and some companies CDM became a hoped-for cash-cow and this, more than anything else, led to the concept being tarnished slightly and the drive to implement slowing.

The abbreviation CDM is, unfortunately, also often used as a buzzword to jack up claims that a project or proposal was in line with the latest thinking. Scratch the surface, though, and it quickly becomes apparent that those claims are based on vaporware... The authors know only one thing: CDM must appear in their documentation to be seen as credible but what it really means, they have little or no idea.

Many articles and studies have been written about Collaborative Decision Making (CDM) but this is probably the first time ever that an attempt is made to tell the story of Collaborative Decision Making from its inception to the successful completion of the TITAN project at the end of 2012. What is more, the story will be told on the pages of this book in what we hope is an easy to read style, accessible to all interested partners regardless of their background or position in the world of air traffic management. Who knows, a few aviation enthusiasts may also find it interesting and will want to add it to their home library.

The idea for this book actually came towards the end of the TITAN project, which, as we will see, is something that takes CDM to new levels in the airport environment. During the whole project the team had to deal with the problems caused by a certain lack of understanding out in the field of the basics of CDM as well as the principles of information management that is needed to support cooperative decisions. In the circumstances, getting the advanced ideas inherent in TITAN across was also a challenge. Creating a "book" on the subject seemed like the best way of summing up the most relevant information on the subject of CDM and ultimately TITAN. To understand TITAN, one must understand CDM. This is why the first two parts of this book are dedicated to CDM and we get to TITAN only in the third part. If you are already familiar with CDM and system wide information management (SWIM), go directly to Part 3 to read about TITAN only. But do come back to the first two parts also eventually. There are interesting bits and pieces you may not have been aware of after all...

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

2. PART 1 – THE CDM CONCEPT

2.1 Historical perspective

The concept of CDM was originally defined in the United States by a group of airlines, led by USAir as it was called back then, in response to what the airlines perceived as inadequate co-operation between airports, the Federal Aviation Administration (FAA) and the airlines themselves. They formed the so called CDM Group, members of which visited several airports with traffic flow problems and analyzed the reasons.

Significantly, they discovered that in many cases the reasons were in fact quite trivial. In one instance, a missing telephone connection between the FAA tower and the Delta Airlines ramp controller was found to be at the root of major departure delays; in another case the "secret" nature of cancelled flights was discovered as the cause of unused slots at an otherwise seriously congested airport.

The CDM Group in its original reports had actually established three of the most basic rules of CDM which remain valid to this day even if, unfortunately, in some cases they are being ignored.

The three rules are:

• Most problems have simple causes with simple solutions

• Better information sharing eliminates a very large proportion of the problems

• CDM can only be successful if trust is established between the partners as the first step

Although the CDM Group did at first address problems at airports (Atlanta and Philadelphia) when the FAA embraced the concept, they focused on applying it in the en-route environment. This was a natural consequence of the US scene where capacity constraints were present en-route while airports were almost all free flow at the time. Nevertheless, US airports got involved in CDM early as a result of the FAA's ground-delay concept. The value of information sharing was shown right from the start. Just by being better informed, airlines were able to respond to the restrictions in a much more efficient manner. The initiative in the early 1990s called FAA/Airline Data Exchange (FADE), supported among others by Northwest Airlines, can be seen as the direct forerunner of what evolved into the US CDM project of today.

The CDM concept was brought to Europe by experts of the International Air Transport Association (IATA) and at first it was treated as a research topic and as such, assigned to the EUROCONTROL Experimental Centre. Several years passed and the concept was stuck on the research agenda while the need for better decision making grew every day. At the time, also in Europe most of the delay problems had their origins in the en-route environment and of course the power of CDM could have brought the same level of relief as it did in the US if only States had gotten together and implemented CDM. But this did not happen in spite of repeated pleas by the airspace users.

The lack of progress did not go unnoticed by EUROCONTROL and following a suggestion by IATA they came up with a new idea. Even if it was proving very difficult to get European States to embrace CDM in the en-route context, the more independent and business minded airports, with their more or less closed systems and multiplicity of partners, could prove more receptive to improved decision making and hence introducing CDM on the airport level might prove to be actually feasible. This is how Airport CDM (A-CDM) was born.

In recent years of course airports in Europe have become a major source of delay and hence A-CDM was proven to be a good idea in more sense than one. But all development projects must keep in mind that A-CDM is not special at all, it is simply a pragmatic sub-set of CDM implementation forced by the initial failure of getting CDM on-board in the overall context.

In terms of terminology usage, when we say CDM, this usually indicates the concept of collaborative decision making while A-CDM refers to Airport CDM, in other words, CDM applied in the airport environment.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Not that A-CDM was an immediate hit. Although many airports created CDM teams, built systems and even booked some initial results, full, across the board exploitation of CDM remains the exception rather than the rule.

An important, relatively recent development of course is the realisation that individual airports forming “CDM islands” can only achieve limited benefits if the air traffic management network of which they are a part is not fully involved. Bringing the Central Flow Management Unit (CFMU) into the CDM picture was a major step in CDM implementation in Europe and the first one in realising what one may call “network CDM”.

Needless to say, CDM is an important element in the operational concept of both the European Single European Sky ATM Research (SESAR[1]) program and NextGen in the US. Under these initiatives, all decisions will be required to be collaborative to the maximum extent possible and hence the idea of CDM will be influencing the very core of air traffic management practice at every level.

2.2 The business case for CDM

In 2007-2008, EUROCONTROL had commissioned the production of CDM Cost-Benefit Analyses (CBA) for Barcelona, Zurich, Brussels and Munich. At the time, also a generic CBA was produced, taking a typical European airport as the baseline. In 2008, a CDM CBA was also ordered for Prague.

Originally it was the intention to show the benefits of CDM in general but also the specific benefits attributable to the different CDM applications, like information sharing, variable taxi time calculation and so on (see paragraph 2.4). This was meant to enable planners to set implementation priorities and find the best possible combination of applications for any given airport. At that time there was no airport where all the applications had been implemented and so some of the work had to be undertaken using projections and well reasoned assumptions based on interviews with operational experts.

The conclusions were predictable and not at all surprising as they lined up perfectly with the most basic tenets of the CDM concept. In excess of 90% of the benefits attributable to CDM were in fact generated by information sharing. Other applications added only small, incremental improvements and the order of implementation was also of little impact on the actual benefit picture. It was therefore not possible to really quantify the benefits of applications, or combinations of applications, beyond information sharing as the additional improvements were well within the error range of the calculations.

Although EUROCONTROL has started to promote a more prescriptive approach to CDM in recent years specifying the implementation order of CDM applications, the fundamental benefit balance of those applications has not changed.

A new feature of CDM of course is the network version where several airports start to collaborate with each other and the CFMU (now renamed Network Manager or NM) using information sharing and the other applications. This kind of network CDM forms the basis of the SESAR concept of operations also.

In this context we must remember that information sharing as defined for CDM is in fact an early instantiation of the System Wide Information Management (SWIM) concept (see paragraph 3.1.4) and at some point SWIM will overtake this aspect of CDM. The benefits will not diminish since support for decision making and the current and future CDM applications will of course continue.

Nice words and very promising, but of course your first question will be: what are the numbers? What did the cost-benefit analysis reveal about this concept when applied in the airport environment?

[1] SESAR programme website: http://www.sesarju.eu/

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

As we know, for most enterprises the payback period, that is the time it takes from spending the money until it is fully recovered, is one of the deciding considerations in any project they plan to participate in. In the case of A-CDM, the payback period is typically two years. This should be acceptable even to the most money conscious airline. However, the analysis has shown that for ground handlers in certain circumstances a payback period of even one year might be possible!

Another important parameter is the cost benefit ratio. For A-CDM this has been shown to potentially reach 9, again a figure that is considered very favourable. What is more, the positive result is there for each partner, even if not to the same extent.

Alongside the quantifiable benefits, several important qualitative benefits have also been identified. Among these the most important are a better Air Traffic Control (ATC) environment (more predictable operations), improved ground handler customer satisfaction and an improved overall image for the airport. Especially in areas where several airports are competing with each other and at airports where ground handling companies are in competition, these qualitative benefits count a lot even if they cannot be readily expressed in money-terms.

Of course airports do not operate in isolation. They are all part of the air traffic management network and the operational quality of each and every one of them has an influence on the others and hence on the network itself. It is easy to see that the more of those airports are involved in CDM, the more the overall benefits become apparent. Calculations made for the European environment indicate that these so-called network benefits manifest themselves in a number of important ways. When there is no CDM in the network, ATC sectors tend to use capacity buffers to protect themselves from overloads that happen in spite of the air traffic management efforts... simply because there is so much uncertainty in the network. We now know that one of the beneficial effects of CDM is to increase predictability, which of course results in the reduction of uncertainty. Capacity buffers can therefore be reduced or eliminated altogether and hence sector declared capacities can go up. This is of course not creating additional capacity, just enables the use of existing capacity (part of which was wasted as a result of the inherent uncertainty) to a much higher degree.

The calculations show that a 4% overall network capacity increase is possible with several airports using CDM. This translates to 1 - 2 additional flights per sector. In other words, with 16 airports the network benefits start to become significant and with 42 airports, air traffic management related delay minutes can be reduced by anything between 18 and 23%.

All right... so we are now convinced that CDM is a good thing... but before we can say we actually understand what this good thing is, we need to explore a few more things. Fasten your seat belt...

> Did you know... That you can find more information on the A-CDM CBA at:
>
> http://www.eurocontrol.int/ecosoc/public/standard_page/cba.html

2.3 Partners in A-CDM

In the usual texts about air traffic management, the term "stakeholder" appears repeatedly. Business dictionaries usually define this term as referring to a person, a group or organization that has interest or concern in an organization. It is said further that stakeholders can affect or be affected by the organization's actions, objectives and policies. If you look at this definition closely, you will recognize the legacy air traffic management environment... there are all those stakeholders who all impact each other, they all have an interest in the enterprise but it is not said anywhere that they work together or make decisions together.

Now, if we look at the term "partner", this refers to an individual who joins with other individuals in an arrangement where gains and losses, risks and rewards are shared among the partners. This

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

looks much better and we all feel intuitively that in CDM of ay kind we better talk about partners rather than stakeholders. After all, they come from the legacy world of stakeholders to create something new and more effective... collaboration in decision making or CDM. They will be partners much more than just stakeholders.

It is for this reason that we prefer to call CDM participants partners rather than stakeholders. What is in a name, you might ask. Well, in this case the difference in meaning is actually important. We must grab every opportunity to impress upon everyone the basic tenet of the CDM philosophy. Working together is the name of the game.

So, who are the partners that we want to come together under the A-CDM umbrella and improve their decision making?

The airport, handling agents, airlines and air traffic control are the obvious organizations that need to work closer together when it comes to decision making.

One might think that they are already so closely tied through the operation of the aircraft they all have something to do with that it further improvement is probably not realistic. But wait a second... think back of the origins of CDM... the missing telephone line for example. Things have not changed that much when it comes to making decisions together. Airlines with sophisticated operations control centers and airports with their own sophisticated set of tools still find themselves in situations where decisions made by one or the other fail to match up with each other's requirements, let alone preferences. Passengers experience this when their aircraft arrive on time only to find its assigned gate still occupied and similar hiccups that can be prevented with better collaboration. But we could mention the handling agent or the de-icing company which also often feel like they were operating in a vacuum when in fact there was loads of relevant information around except that they had no access to it and so their decisions continued to be of inferior quality.

So, all appearances to the contrary, these four partners are the basis of any A-CDM initiative. Of course they are not the only ones. In regions like Europe, the Network Manager (known in the past as the Central Flow Management Unit, CFMU) must also be involved. There are other partners to also consider, but we will come back to those in Part 2 - Extending A-CDM, discussing the extension of A-CDM.

A final thought here is probably in order. When thinking about partners, do not focus on any particular physical location. For example, the operations center of an airline concerned may be thousand of miles away or it may not even be that of a single airline in the case of a value added provider and may be located in a place that one would not at all associate with the airline in question. The main thing is, they are making decisions and have information to share that is relevant to the A-CDM project.

2.4 The things A-CDM is made of

We know now that CDM is first and foremost a new way of working together, making decisions in the full knowledge of the consequences of the decisions on the operations of our partners and arriving at decisions after proper coordination with the partners. Fine. But how does this happen in daily practice? In other words, once CDM is implemented, do we have to invent how to make decisions collaboratively every hour of the day? Luckily not.

EUROCONTROL has defined a number of concept elements[2], each describing specific functionalities that support the implementation of the concept. Some elements are basic and must be there before the others can be considered, while others add more advanced functions and are not necessarily needed everywhere.

[2] Airport CDM Concept Elements at: http://www.euro-cdm.org/concept_elements.php

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

The Concept Elements constitute the minimum common functionality to be implemented if we want to achieve a consistent, interoperable and cost-efficient CDM environment in Europe, fully integrated with the ATM network.

Of course, every airport is different and local needs may dictate additional or different functions to be considered. The CDM concept does not preclude this, however, such local extensions must be seamless and transparent to the total CDM environment and must not induce unnecessary extra costs or require the modification of the “standard” CDM environment.

The concept elements currently defined are the following:

- Airport CDM information sharing
- The milestone approach
- Variable taxi-time calculation
- Collaborative management of flight updates
- Collaborative pre-departure sequence
- CDM in adverse conditions

It is important to remember that this splitting of A-CDM into concept elements does not imply any particular physical system architecture. The concept elements may reside in any part of a physical system, the only requirement being that they must be able to receive and output information they need to function properly.

Of course not all concept elements are created equal. In the Chapter on the business case we have already mentioned that CDM Information Sharing is the single element that brings most of the benefits. Indeed, it is not an exaggeration to say that once Information Sharing has been implemented, some 90% of the potential benefits can be achieved at most airports.

Information Sharing is the glue that ties everything together and is also the communications interface locally as well as the rest of the world.

Each of the other concept elements concentrate on a specific aspect of decision making, processing specific information supplied via information sharing, and enabling better decisions in their particular area. For instance, Variable Taxi Time Calculation will ensure that precise taxi times are calculated and used in establishing when a given aircraft will be on the runway, ready for take off, or when it will arrive at the stand.

Information sharing is the basis of everything, and you can think of the other concept elements as plug-ins that add functionality, making full use of the information management capabilities provided by information sharing.

Let's now look at the concept elements in a bit more detail.

2.4.1 A-CDM Information Sharing

If ever there was a magic bullet in air traffic management, information sharing most certainly qualifies. Good decisions can only be arrived at if they are made on the basis of the right kind of information that is timely and accurate. Good decisions also need to take into account the effects of decisions on the operation of the partners the decision impacts. This too requires that information on the partner operation be available. Before A-CDM information sharing came along, all the information partners would ever need was already there... but it was not accessible across partner boundaries. In other words, the information was sitting there without being shared. Decision were of course being made but since they were not based on full information, the quality of decisions was often doubtful.

Why is Information Sharing so powerful? Well, in order to have better, harmonized decisions, partners need common situational awareness. In other words, they must be able to interpret the available clues in a way that creates the same reality framework for each one of them, even while they are looking at that reality from their particular operational perspective. This common situational awareness is created by sharing each other's information so that the reality presented to each partner has as its basis the same (shared) set of information. Partners will still be looking at the slice of reality important for their particular operation, but it will be like a piece of a puzzle, for which the solution (the finished picture) is known. When making a decision, they will have to figure out how to place that decision into the big picture but they will all be working towards creating the same picture. This is a very important change compared to the legacy way of working.

Here is a list of the most important information sharing benefits:

- Brings partners together
- Reveals process shortcomings and causes
- Better understanding of each other = motivation to go further
- Common situational awareness resulting in improved decisions and more efficient use of resources
- Improved predictability, resulting in better slot adherence
- Establishes the foundation of more advanced CDM functions
- The recording and analysis function enables permanent monitoring of performance, identification of shortcomings and determination of remedial actions.

2.4.2 The Milestones Approach

The evolution of a flight can be seen as a series of events, each of which has to take place before the next and if any event gets delayed, this automatically results in subsequent events also being delayed unless, of course, certain buffers are built into the times allocated to the completion of certain events. In this respect, not all events are created equal. Once the aircraft is airborne, it is either not possible or not economic to have buffers built into events that concern flights in the air. Events that relate to an aircraft on the ground can have buffers built into them so that a delay does not have to impact everything upstream. Not very efficient, working with buffers but usually it is still cheaper than knocking all upstream events out of place by some spurious delay.

Of course if we could follow all the events closely and be aware of looming problems, we could intervene and possibly avoid the problem before it resulted in the late completion of an event. Even if we cannot avoid all problems, at least being aware of the exact consequences of each gives us a chance to act early and notify everyone what is going to happen. Delay will still be there but things around it will become predictable.

Enter the Milestones!

Assign a Milestone (M) to each event and additional milestones between them... if there is no readily identifiable "event", think of something that needs to be complete at that point in time and not later... then assign completion times to each of the milestones. These completion times will of course change depending in the flights being the subject of our interest... Obviously, the unloading and loading of a Boeing 747 takes longer than a 737. Then have a clever application watch the completion of the milestones. If there is a delay or other disturbance, raise an warning.

This is what the Milestones Approach application does.

Obviously, everything depends on getting the milestones right. Some are obvious and tend to be identical everywhere. These are the ones that will support the common situational awareness. But there is no reason why additional milestones may not be defined locally if for some reason they prove to be required.

In the baseline A-CDM concept, the following generic milestones have been defined.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

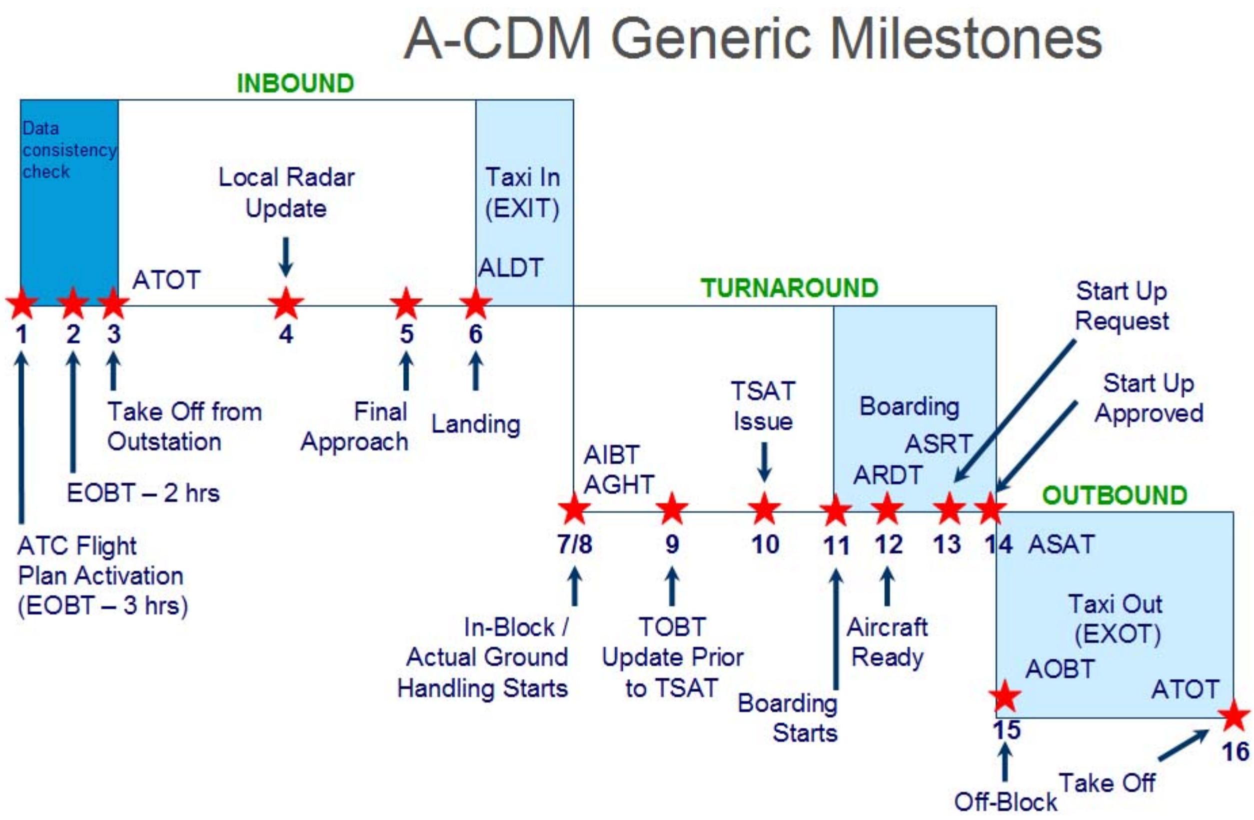

Figure 1: A-CDM Milestones

Lots of abbreviations there but you can find them in the list of abbreviations at the end of the book. Here it is enough to note that the 16 basic milestones cover the progress of the flight from as early as ATC flight plan activation (M1) through take-off from the outstation (M3) all the way to and through the destination airport (M6 - M11) until the aircraft takes off again (M16). Although at the time these milestones were first defined, Trajectory Based Operation (TBO) were not yet the order of the day, intuitively the designers came to a solution that more or less described what we today call the airport ground trajectory and the idling trajectory during turnaround. The milestones approach has, also for the first time in the history of ATM, firmly established the connection between a given airframe and the flights it was planned to carry out. If any of the incoming milestones gets delayed, there is a good chance that the outgoing ones will also be delayed. So, timely action can be taken to mitigate the adverse effects.

The planned and target times for a given flight are allocated to the milestones and the situation is then monitored to see how the flight actually evolves. If a planned or target time can no longer be met because the actual time for a previous milestone is later than the plan/target time had been, alarms go off and partners get together to find a solution to the problem.

From the diagram above it will also be clear why information sharing is essential for the Milestones Approach to work. The milestones span the domains of all partners from the airlines through the airport and handling agent and of course ATC and without the partners sharing their information, the milestones become meaningless except for the partner immediately concerned with it.

Let’s look at an example of how the milestones work.

The aircraft operator or the ground handler issues a Target Off-Block Time (TOBT) or confirms a TOBT calculated by their system This TOBT is shared among all the partners, telling them the time when the aircraft will be ready to push back. When ATC becomes aware of the TOBT, they issue and share the Target Start-up Approval Time (TSAT) which specify the time of the push-back clearance and confirms the position of the flight in the departure sequence. As both the TOBT and the TSAT are shared among all the partners, they will have common situational awareness to which they can work, adjusting their resources as required. If any one of them discovers that it is not longer possible to work to these targets, collaborative action is undertaken to resolve the situation.

Here is a summary of Milestones Approach benefits:

- Monitoring of milestone completion enables early identification of downstream problems, predictability improves
- All partners made aware of impending problems, time horizon of common situational awareness extended
- Flexibility of flow management process improves, Network Manager can optimise the slot allocation process
- Benefits of information sharing further enhanced

2.4.3 Variable taxi-time calculation[3]

At most airports today, the time taken by an aircraft to taxi from the runway to its stand, or from the stand or gate to the runway is represented by a default value which, at best, takes into account the runway in use but nothing else.

Yet, the taxi speed in fact depends on a number of factors that include aircraft type, pavement conditions, visibility, taxi route taken, location of the stand and even the prevailing traffic.

While it may be correct that the taxi out time to runway 25L is 9 minutes on a quiet, sunny Sunday afternoon, it may be considerably longer in pouring rain or when traffic is heavy.

If the taxi-in time used for calculating the Estimated In-Block Time (EIBT) is substantially different from the actual time the aircraft needs to get to the stand, the use of resources at the gate may be sub-optimal and the planning of apron traffic where movement may be constrained will become difficult.

A more serious problem occurs if the taxi-out time is different from the default value used. If the Calculated Take-Off Time (CTOT) was based on the default taxi-out time, adherence to the CTOT becomes very difficult when conditions result in an actual taxi-out time that is substantially different from the default value.

Clearly, default taxi time values result in inaccuracies for both arriving and departing flights reducing the efficiency of the ground handling process, possibly creating problems in the management of apron traffic, gates and stands and, most importantly, adversely affecting the flow management process.

The purpose of Variable Taxi Time Calculation is to provide fully automatic calculation of realistic taxi times of the required accuracy for both taxi-in and taxi-out. This then results in better predictability of Estimated In-Block Times and Estimated Take-off Time (ETOT).

The main objectives of Variable Taxi Time Calculation are:

- To achieve a fully automated taxi time calculation process, minimising additional workload for controllers
- To provide an accurate estimate of the inbound taxi time before the aircraft has landed, resulting in an improved Estimated In-Block Time which will
  - o enable ground handlers to make more efficient use of existing facilities and resources
  - o optimize stand and gate management

[3] A-CDM Implementation Manual and BluSky Services A-CDM course material.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

- To provide an accurate estimate of the outbound taxi time before taxiing starts, resulting in an improved Estimated Take-off Time for
  - more accurate en-route traffic demand calculations, subsequently reducing the number of regulations and optimizing en-route capacity
  - enabling ATC to optimize the pushback, taxi time and pre-departure sequence which in turn leads to a reduction in aircraft engine run time and fuel burn, saving aircraft operator costs and reducing emissions
  - improved departure slot allocation, producing slots more closely aligned to the desired and feasible take off time for each flight
  - optimizing ground handlers' resources (push back, de-icing etc.)
  - optimizing stand and gate management

In ATC the expression 'taxi time' is the period of time it takes for an aircraft to taxi rather than the actual moment in time that taxiing will commence. Therefore, although the phrase 'taxi period' is technically more accurate, the commonly understood phrase 'taxi time' has been used to refer to the length of time it takes to taxi.

Variable Taxi Time is the duration of time that an aircraft spends on the taxiways including some time spent on the runway when lining up and vacating.

For Airport CDM purposes, taxi time is considered to be:

- For arriving flights: the taxi-in time is the period between the Actual Landing Time (ALDT) and the Actual In Block Time (AIBT)
- For departing flights: the taxi-out time is the period between the Actual Off Block Time (AOBT) and the Actual Take Off Time (ATOT)

For planning purposes and for tactical management of time estimates, each movement must be considered individually. This is the reason why the taxi time is called variable. It is no longer a fixed default value for all flights. The notion 'variable' is used opposed to the default fixed taxi times, which are currently applied at most airports.

Variable Taxi Time Calculation is an automatic process that gets and provides its data via CDM Information Sharing. It is important to fully automate the process so that it does not impose additional work-load. Nevertheless, it must be possible to manually override the automatically generated values, should this be necessary.

While precise taxi times are important at every airport, calculating taxi times is more or less complex, depending on the size and complexity of the airport and the traffic levels.

In line with the cost-efficiency principles of CDM, several methods of calculating taxi times have been defined, each suitable for a different environment. The method best suited to the actual situation (and of course the short/medium term traffic and development plans) should be selected for implementation.

Several factors influence taxi times.

Some factors are static (e.g. airport layout) others change dynamically (e.g. weather or taxiway availability) and both static and dynamic factors have to be considered at all times.

Airport layout

The airport layout is an important factor that determines the minimum times required to taxi as well as, for instance, the number of runway crossings for a given taxi route, all of which affect taxi times. Many turns and bends slow down the process.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Infrastructure availability

Closed taxiways or aprons and other restrictions have a major impact on taxi times.

Runways in use

Determines the distance of the ground movement. The distance to/from the runway represents one of the most important factors determining taxi time.

Stands and parking positions

It is easier and quicker to taxi to/from some positions than others and the distance from the runway in use may also be substantially different. In order to simplify the calculations, stands and gates with similar characteristics may be grouped.

Aircraft type

The typical taxi speed of a fully loaded Boeing 747 and an Airbus 320 is obviously different.

Aircraft operator

Aircraft operators have different practices and procedures and this can impact taxi times.

Push-back method

Push-back may be affected with a tug and tow-bar on the nose-gear, or a remote control trolley attached to the main wheels and any number of variations thereon. Disengaging the equipment and clearing the aircraft perimeter takes time and this has a small, but still significant effect on taxi time.

Push-back approval delivery time and target start-up approval time

These times determine when the aircraft will be inserted into the "system" and consequently what traffic and other conditions are to be taken into account in the calculations.

Remote de-icing/anti-icing

When remote de-icing/anti-icing is required, the taxi route to be taken may be substantially different from the "summer" taxi route, as the aircraft must pass by the de-icing pad. The time required for the operation plus eventual queuing time must be added to the taxi time.

Traffic density

Traffic density refers to the total number of aircraft moving around on the airport surface at any given time. It represents a constraint, expressed as the congestion factor, on the free movement of aircraft, as they have to queue, give way at crossings, etc. The Variable Taxi Time Calculation function must have traffic demand figures to be able to calculate traffic density figures. Calculating the effects of traffic density is not an exact science and local experience is a valuable source of determining the actual extra taxi time that different densities, and corresponding congestion factors, impose. Except at the busiest, most complex airports, traffic density is usually not required to calculate precise taxi times.

Local operating procedures

Some airports may have local operating procedures, applicable in certain circumstances, to certain aircraft types, etc., which can affect taxi times. When such procedures are applied, their specific effects must be taken into account in the calculations.

Meteorological conditions

Precipitation, pavement conditions, high winds, visibility can all affect taxiing aircraft, usually slowing them down. The effects can be significant and must be taken into account.

Day/night

In certain circumstances there can be a substantial difference in taxi speeds between day and night time operations which must be taken into account.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Not all of these factors are applicable at all airports but those that are affect taxi times together. The generic algorithms need to be adapted to local circumstances, as the interaction between the applicable factors is not the same at all airports.

We will now look at the different methods for actually calculating taxi times. The following methods will be discussed, in order of increasing accuracy:

- Default taxi times
- Average taxi times based on historical data
- Specific taxi times based on operational conditions
- Complex taxi time calculation

Default Taxi Times

Default taxi times? Is this not what we want to avoid? Well, yes and no. Default taxi times at a complex, busy airport may be an anachronism and the source of inaccuracies, but there are other airports generating significant traffic yet with such a relatively simple layout that default taxi times do actually work.

At such airports, there is no need to use anything more sophisticated and this simple method can then be automated.

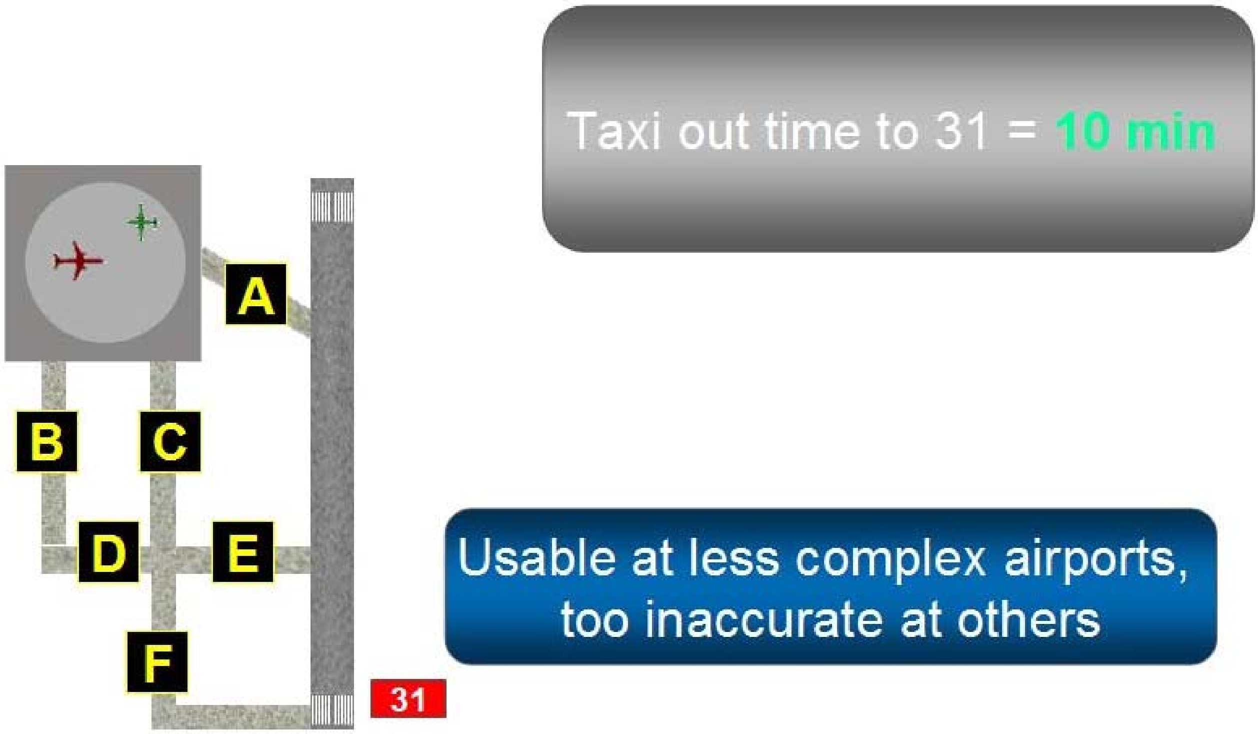

Figure 2: Default Taxi Times

It is of course good practice to take a good look at the default values to make sure they are still the right ones… Something established many years ago may no longer be the appropriate value.

The default taxi time method needs very little outside input to perform its calculations (usually, the runway in use is sufficient). As such, it can even act as a back up system at places where otherwise more sophisticated methods are needed. If the connection to the data sources required by the more sophisticated methods breaks down for any reason, this simple method can still continue to operate and feed data automatically into other calculations. The accuracy will be lower, but the workload reduction is maintained.

Average Taxi Times based on historical data

This is in fact a variation on the default taxi time method, where the accuracy of the calculation is increased by defining average taxi times (rather than a simple default value) based on experience and taking into account the date and time of day. Depending on the variability of the circumstances prevailing at the airport concerned, accuracy can be improved by defining averages for different weather conditions, holiday periods, recurring special events and the like.

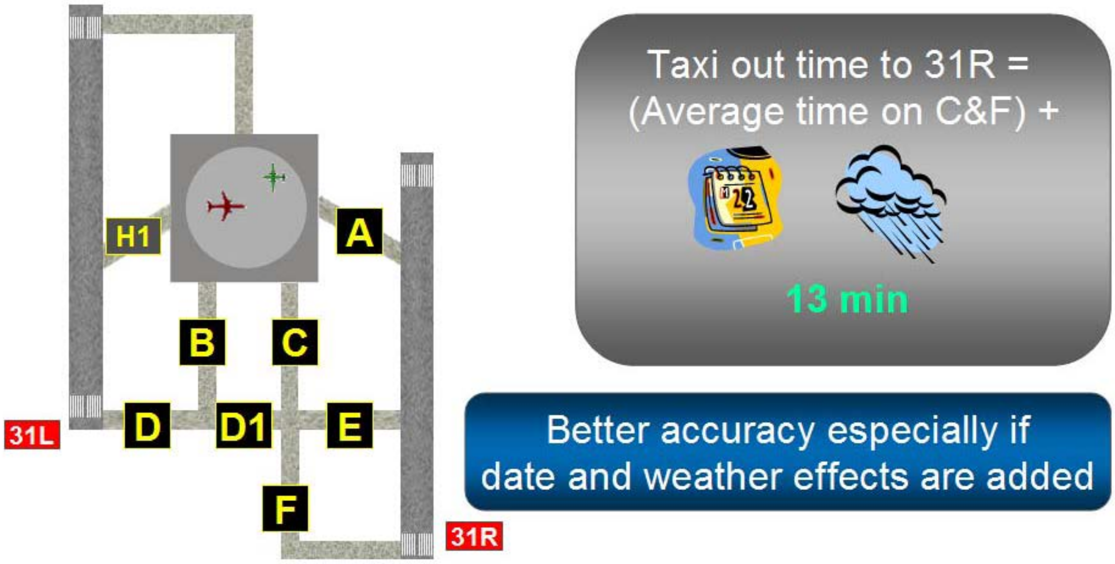

Figure 3: Average taxi times based on historical data

Specific Taxi Times based on operational conditions

In all of the previous methods, the taxi time was applied without regard to things like aircraft type or stand/gate used. Clearly, the accuracy that can be achieved with such rough methods is limited.

In the Specific Taxi Time calculation, at least the aircraft type, stand/gate, runway in use and weather is taken into account and the calculation is done specifically for each flight with the data applicable to that flight.

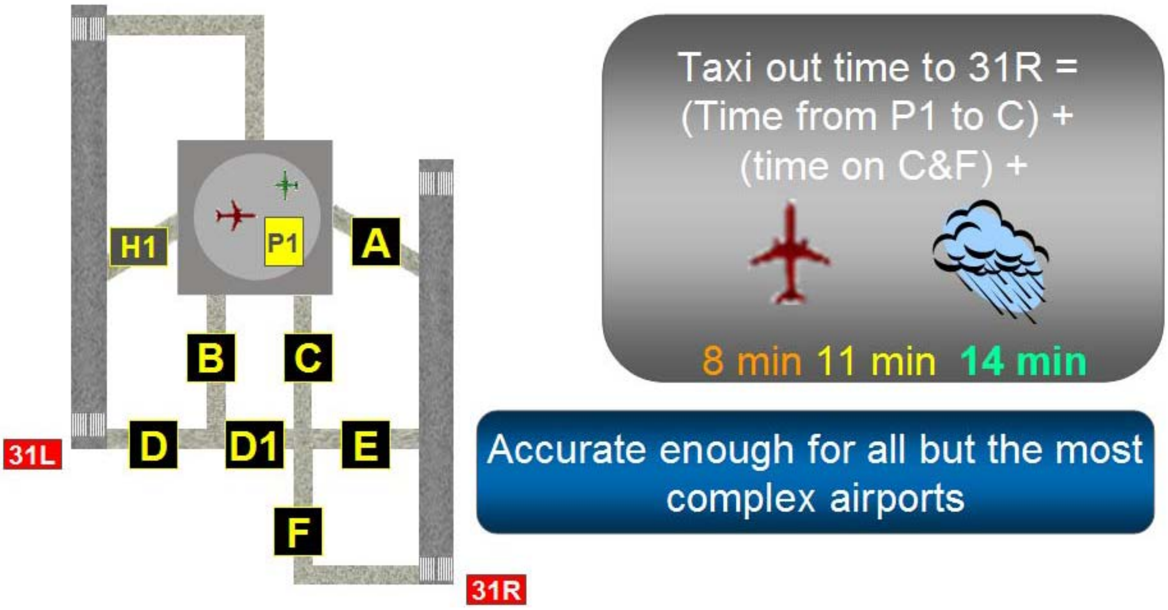

Figure 4: Specific taxi times based on operational conditions

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

> Did you know... That according to Department of Transportation (DOT) statistics, in the US weather accounts for more than 40 percent of all flight delays. A recent study commissioned by the Federal Aviation Administration (FAA) calculated that delays and cancellations from all causes cost passengers $16.7 billion a year. That puts the price tag on weather-related schedule disruptions at around $6.7 billion. (Weather and Flight Cancellations by Jim Glab, 2011 http://www.executivetravelmagazine.com/articles/weather-and-flight-cancellations)

Usually, the first calculation is done using a default or average time. Then, as more information on the flight and the various conditions become available (or something changes), the taxi time is recalculated, producing increasingly accurate values until the maximum accuracy achievable with this method is reached.

It should be noted that this method provides sufficient accuracy in all but the most complicated environments.

Complex Taxi Time calculation

This method is the most comprehensive yet defined for calculating taxi times. While the theory is straightforward, in practice it needs substantial tuning and balancing to ensure the maximum accuracy potentially available from this approach.

The calculation begins with determining the so called “unimpeded taxi time” between the gate and runway used by the flight. The taxi route may be a default one selected by the system based on local rules, or the taxi route actually assigned to the aircraft. In any case, the taxi route is considered in very high detail, taking the known length of straight sections, curves, turns, etc into account, with the most likely taxi speed on all parts for the given aircraft type used as the basis for the calculation.

Various modification factors are then applied to the unimpeded taxi time, to calculate the variable taxi time to be used for the flight.

The modification factors include aircraft operator, push-back method, weather conditions, pavement conditions, remote de-icing/anti-icing and possible manual input to take account of additional constraints.

At the same time, the traffic density at the airport is also continuously calculated. Traffic density is arrived at by subtracting the number of off-blocks from the number of take-offs and the number of in-blocks from the number of landings to arrive at the actual number of aircraft moving about the airport at any given time. This is the traffic density. At any given point in time, traffic density at a given airport can be assigned a congestion factor. The congestion factor is a value determined on the basis of experience, simulations, specific observation, etc. The congestion factor in the context of taxi time calculation gives a figure that indicates how the taxi time changes in function of the traffic density. Obviously, a given traffic density will result in different congestion factors from airport to airport.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

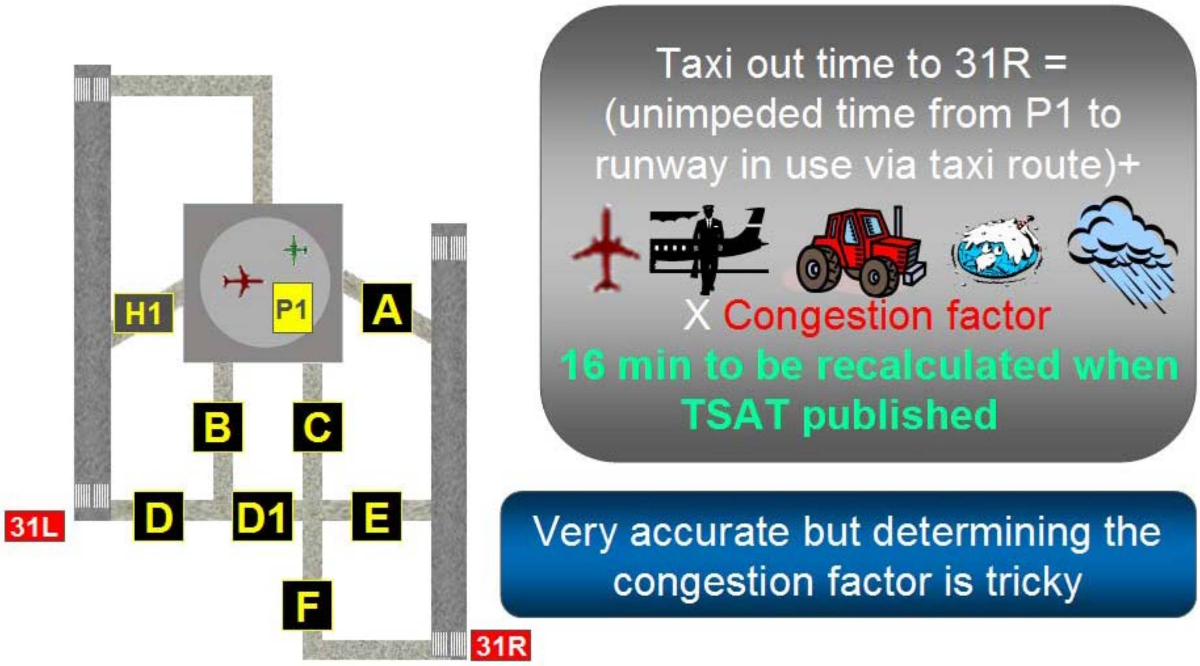

Figure 5: Complex taxi time calculation

For a given flight, the taxi time calculated originally without taking traffic conditions into account is modified with the congestion factor determined for the period in which taxi will effectively take place.

The complex taxi time calculation is repeated each time any of the input data changes significantly.

When the Target Start-up Approval Time is published by the aerodrome control tower, the taxi time module compares this time with the Target Off Block Time. If it finds a difference exceeding a pre-determined maximum, the taxi time is re-calculated.

Obviously, the accuracy available from this method is very high. At the same time, determining the local rules that define the congestion factor is not a trivial task and the figures need constant tuning as circumstances change.

This kind of high accuracy in taxi time calculation is probably not needed yet, but may become essential in the future.

Let's briefly summarize the benefits of Variable Taxi Time Calculation:

- Eliminates inaccuracies in taxi time calculations
- The accuracy of all calculations in which taxi time is used improves, enhancing predictability
- Enables a more accurate flow management process
- Different methods available to suit different circumstances

2.4.4 Collaborative Management of Flight Updates

Collaborative Management of Flight Updates was developed to improve the coordination between air traffic management and the Central Flow Management Unit (CFMU[4]), now renamed Network Manager or (NM).

[4] All CFMU documents available at: http://www.eurocontrol.int/network-operations

The role of the CFMU was to ensure that ATC sectors were not overloaded when demand exceeded capacity. To be able to do this, they needed pretty accurate data on departing traffic at the various airports so that they could calculate a flight profile and estimate the loading in the various sectors that traffic would fly through. Before the arrival of A-CDM, the estimated take-off times were anything but accurate and consequently the CFMU calculations also left a lot to be desired. This led to traffic bunching and occasional overloads. ATC reacted by declaring lower capacities to avoid the overloads and the result of this was that the actually available capacity was not fully used.

When A-CDM proved how predictability could be improved it was only natural that the CFMU became interested in making use of the more accurate information.

Since information sharing along more modern lines was only available locally at the CDM airports, a messaging solution was developed, comprising two times of new messages defined in the Air Traffic Services (ATS) Data Exchange Presentation (ADEXP) format: the Flight Update Message (FUM) and the Departure Planning Information Message (DPI). This latter has several sub-types.

The FUM is sent once for each flight by the CFMU to the A-CDM airport to enable the sharing of accurate arrival times. The DPIs are sent by the A-CDM airports to the CFMU, communicating accurate information on the evolution of the turnaround.

The procedures around the sending of DPI messages evolve all the time, so the information given here is for illustrative purposes only. There are six types of DPI messages, where each DPI message type giving a more accurate update on the flight it refers to. These are:

- E-DPI - Early DPI
- T-DPI-p - Target DPI - Provisional
- T-DPI-t - Target DPI - Target
- T-DPI-s - Target DPI - Sequenced
- A-DPI - ATC DPI
- C-DPI - Cancel DPI

The following diagram shows when the various types of DPI messages are sent.

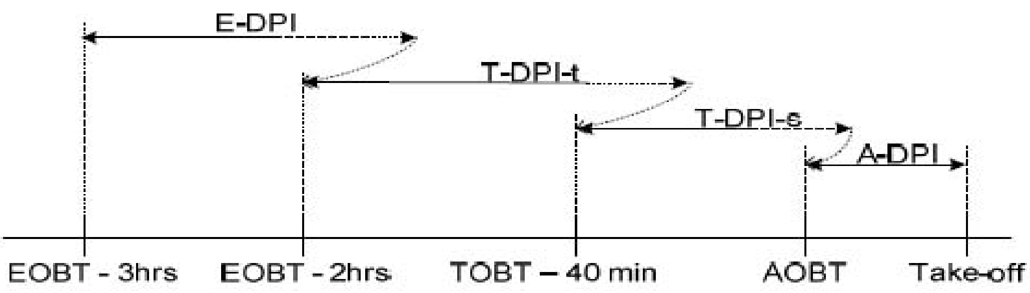

Figure 6: DPI messages

This all looks relatively simple but in fact there are several very strict rules governing the use and acceptance by the CFMU of the DPI messages. This is understandable if we consider that the expected sector loads are calculated on the basis of the information communicated in the DPI messages.

This message based solution reflects the legacy environment in which the DPI process was implemented. In a SWIM type environment (see paragraph 3.1.4) where information is shared across all the partners, separate messages are not required. Any change in the status of the flight is immediately available for all those interested in the flight.

2.4.5 Collaborative Pre-departure Sequence

Currently, as a general rule, aerodrome control applies the 'first come first served' principle in departure sequencing, taking into account only the optimization of the runway throughput. This principle is well out of date and this fact is more and more accepted. Where pre-notification of when the aircraft is ready to push back is available, optimized pre-sequencing of departures according to known constraints is possible. Collaborative Pre-departure Sequence defines processes where sequencing principles are applied for various reasons (such as slot compliance, aircraft operator preference, night curfew, stand and gate usage, etc). This process will result in a collaborative pre-departure list that ATC then takes into account while sequencing departing aircraft, as and when feasible. Of course, final sequencing will always remain the responsibility of aerodrome control, but taking the collaborative pre-departure list into account will increase overall efficiency.

Collaborative pre-departure sequencing allows ATC to arrange the Target Off Block Times obtained from the partners in a way that flights can depart from their stands in the optimum order, taking also the operational situation into account. The resulting list of sequenced TOBTs forms the basis of the Target Start-up Approval Time (TSAT) order that is then provided to the CDM partners and is significant since it takes into account the partners' preferences.

Collaborative Pre-departure Sequence uses information available in or from other CDM elements and hence to operate really efficiently, Information Sharing, Variable Taxi Time Calculation and the Collaborative Management of Flight Updates need to be present at the airport concerned.

Let's now have a quick look at how this works in practice.

ATC will initially sequence flights in the order in which the confirmed Target Off Block Times are received. Airlines and the airport operator may express certain preferences and ATC will try to take these into account to the extent possible. The sequence is then finalised, taking into account also other constraints such as Calculated Take-off Times.

Where two or more flights operated by the same aircraft operator will be ready at the same time (they have identical TOBT), the aircraft operator can express a preference for their order of departure. Such preferences can be made known via the Airport CDM Information Sharing functionality. Flights with identical TOBT but operated by different aircraft operators can be sorted on the basis of the existing delay they were allocated, giving priority in accordance with local agreements.

Ground handlers and other services satisfy requests according to the pre-departure sequence and hence are in a position to be both efficient and maximally service oriented, operating according to the client preferences.

We can summarize the benefits of Collaborative Pre-departure Sequence as follows:

- All partners have greater transparency of the operational situation regarding the position of departing flights, enabling them to rapidly respond to operational issues by making decisions that are driven by accurate and current information.
- Ground Handlers will be able to position their resources, e.g. push back tugs, more efficiently as they will know exactly in which order and when the flights will depart.
- Stand and Gate management will be able to plan stands with more precision and Aircraft Operators will be able to manage their flights according to their preferences and have a better overview of their aircraft movements.

2.4.6 CDM in Adverse Conditions

CDM in adverse conditions aims at collaborative capacity management during periods of reduced capacity (due to fog, strong winds, snow etc). CDM in adverse conditions disseminates relevant information to all partners in anticipation of disruptions and facilitates expeditious recovery

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

following disruptions. This is achieved by systematic strategies to deal with disruptions, allowing quicker recovery to normal operations.

There are many different events, both planned and unplanned, which disrupt the normal operation of an airport and reduce its capacity to levels substantially below that of normal operations.

Although every airport is different and it is not possible to develop uniform procedures for the handling of adverse conditions, there are sufficient similarities to enable the development of high level, generalised guidance that can serve as the basis of local procedures.

CDM in adverse conditions aims to enable the management of the reduced available capacity in the most optimal manner possible and to facilitate a swift return to normal capacity once adverse conditions no longer prevail.

Adverse conditions fall into two main categories. They can be predictable or unpredictable.

Making anticipatory arrangements for predictable adverse conditions are relatively straightforward, as both the scope and the likely effect of the condition is known, or can be estimated with high accuracy. Some of the predictable events (e.g. maintenance) are also regularly recurring and hence the procedures can be refined easily. It is important though to ensure that the procedures in normal and predictable adverse conditions differ only where it is really needed and provides added value. Acting in accordance with special and overly complicated procedures that are not required often can in fact negate the potential benefit of having anticipated the event.

Some unpredictable events can in fact be planned for while others are so unique that no amount of preparation can hope to cover its effects. A planable unpredictable event is, for instance, an extensive failure of the electric supply or a fire needing evacuation. Plans are usually in place to handle such events and these plans can be supplemented with CDM related steps and actions to make their effective scope larger. Some events are so remote that no contingency arrangements are considered necessary… yet when they happen anyway, if at least procedures are in place to share information and make decisions together (even if not on the basis of pre-arranged procedures), things can run much smoother than would otherwise be the case.

There must be agreed procedures and action plans for all predictable and at least in a generic sense for most unpredictable adverse conditions. The procedures must be as simple as possible; otherwise they will not be used. It is also essential that partners are familiar with the procedures and this applies to managers as well as simple workers.

When an adverse condition does occur, it is important to follow the procedures as this will ensure that others can anticipate what everyone else is going to do. Having a CDM Coordinator appointed and supervise the handling of the event is a good practice. But only if the CDM Coordinator has been agreed and installed in advance of the event…

In general, alarms are used to indicate the onset or anticipated onset of an adverse condition. Obviously, different alarms are used to announce a planned industrial action and sudden ice formation on the ramp. The important thing is to issue the alarms in good time whenever possible and that the alarms go (also) to the people who are in a position to make swift decisions appropriate to the situation and its timing.

Experience shows that often procedures developed for adverse conditions are too complex and hence are quickly ignored. This situation must be pre-empted by having straightforward, effective procedures in place. But even with good procedures it is possible that an event has aspects that the procedure has failed to anticipate. Creativity is called for on such occasions, but one should never forget that in CDM even creativity must be collaborative.

At airports where adverse conditions happen often, establishing a CDM Cell, managed by the CDM Coordinator may be an effective way of handling the situations. Such a cell may be virtual, where telephone conferencing and other modern means of communications replace face to face meetings whenever possible.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

A CDM Cell and coordinator can also be an effective tool for communicating between the partners and also outside parties.

When CDM is practiced in adverse conditions, a number of areas need special focus.

As many flights suffer delays and cancellations in such circumstances, managing these collaboratively is especially important. A good practice is to create a list of departing flights that will still operate and then share this list and any changes thereto to plan activities during the difficult period.

Resources (tugs, gates, buses, etc.) that are more than enough in normal situations may be stressed to their limits when the going gets tough. It is absolutely vital that all resources are managed efficiently to ensure that they do not in themselves become a limiting factor.

The Network Manager being such a strategic element of ATM, they must of course be informed of the changes in airport capacity. It is essential that the NM gets accurate data both in terms of capacity and duration of the change, so that the modification of traffic flows is done only as much and as long as necessary and not a moment longer.

De-icing companies and the de-icing process have a major impact on the operation of an airport whenever de-icing (on stand or at a remote location) is necessary. Both must be integrated into the CDM process to ensure that their influence is properly taken into account.

It is also essential that a performance evaluation take place after each adverse condition episode to check whether improvements are necessary.

The benefits of CDM in Adverse Conditions can be summarized as follows:

- Anticipating the occurrence and effects of adverse conditions has great benefits by enabling partners to prepare and then act in unison to mitigate those effects and ensure a swift recovery. The result is the best possible use of whatever capacity is still available during such conditions.
- The ability to return to normal operations faster than would otherwise be the case is an especially important benefit.
- Airports able to manage adverse conditions well have less of a negative impact on the ATM network as a whole and this has important and far reaching benefits well beyond the airports concerned.

2.5 A-CDM in Europe

Although the uptake of A-CDM in Europe has not been as fast as one would have hoped, at the beginning of 2013 it is fair to say that the idea has substantial traction all over the continent and that alongside the airports that have become true A-CDM airports with the functionality fully implemented, the other location where work has started will also catch up soon. With the SESAR program placing so much emphasis on CDM generally and A-CDM in particular, this unique pillar of the future ATM environment looks forward to a very bright future indeed.

Let's now cast a look at the situation as it was in Europe towards the end of 2012[5]

[5] Source http://www.eurocontrol.int/

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

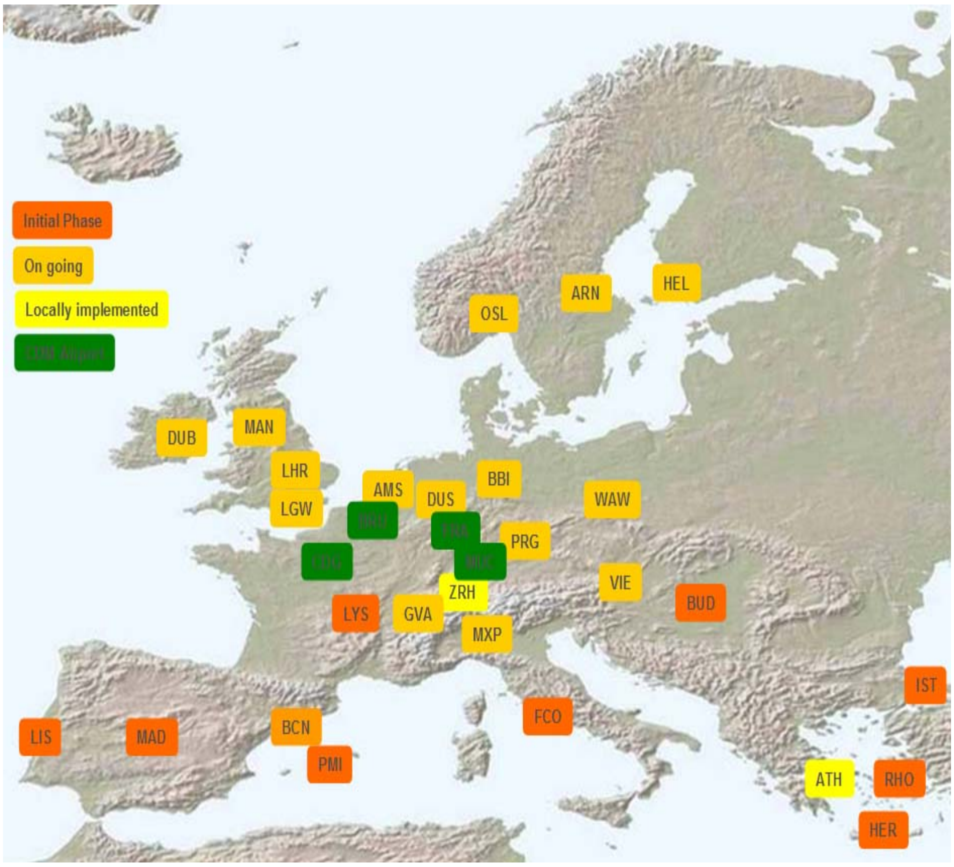

Figure 7: Current CDM implementation situation in 2012

It is clear that a lot of activity is ongoing even if only four airports have become fully A-CDM airports. "Fully A-CDM" means that they have implemented the A-CDM functionality in line with the EUROCONTROL guidelines and as such, they are also permitted to exchange FUM and DPI messages with the Network Manager (former CFMU). The results obtained at those airports speak for themselves.

For instance, Munich airport reported a 10% reduction of taxi times for departures, Air Traffic Flow Management (ATFM) slot adherence reaching 85% and the yearly fuel saving for aircraft operators around 2.63 million euros.

Brussels airport reported a 3 minute average decrease of taxi times, major environmental benefits via absorbing delays at the stand, improved capacity planning and improved slot monitoring and adherence.

Even those airports, like Zurich for instance, which have implemented A-CDM on the local level only, report that the expected A-CDM benefits are being realized. The improved punctuality was even identified as a factor that improves airport image. A good example of the qualitative benefits!

With more airports moving to the green color on the map, network benefits will also start to accrue in earnest. A-CDM is proving to be all it was expected to be.

Did you know... That you can find the latest information on A-CDM implementation on the EUROCONTROL A-CDM web-site at http://www.euro-cdm.org.

2.6 A-CDM, the basis for the future

In this part of the book, we have reviewed what CDM means, what A-CDM is and how it came about. With a little luck, you will have a better understanding of the concept underlying collaborative decision making and its specific application in the airport environment.

We have also seen that A-CDM is in fact delivering the benefits expected, clearly showing that improvements in decision making have a major impact on the operation of the ATM network.

Of particular importance is the proven benefit of information sharing. The common situational awareness made possible by information sharing is of tremendous value in all areas of ATM, well beyond the airport environment. This is one of the most important legacies of A-CDM, beyond the obvious local airport and network benefits, that it has shown how by simply making better and common use of information already available we can create a completely new air traffic management paradigm. It has shown that efforts aimed at improving information management in general are well worth the investment in time and money.

So, what is the future of A-CDM? Will it sit there and generate benefits or is there potential in the concept to adapt to the changing ATM environment and become even more useful in the future?

In the next part of the book we will look into the drivers and changes that require A-CDM to evolve further and then we will also discover in some detail how the TITAN project builds on what A-CDM has laid down as the basis.

3. PART 2 – EXTENDING A-CDM

3.1 The new ATM environment

When the CDM concept was first defined and subsequently, when A-CDM as a specific application of CDM in the airport environment was first put together, we only had a very rough idea of what the next generation of air traffic management systems would look like. The concept was therefore described taking into account the existing, largely legacy, environment. The solutions introduced were also meant first and foremost to address the problems as they manifested themselves in that environment.

As the years passed, the concept details of the new ATM environment came into increasing focus and were finally firmed up in projects like SESAR in Europe and NextGen in the USA.

> Did you know... That you can find more information on SESAR and NextGen at the following links: http://www.sesarju.eu and http://www.faa.gov/nextgen/ respectively.

What has not changed is the need for common situational awareness for all partners and decision making that is collaborative. With the fine-tuned nature of the new ATM Concept Of Operations (CONOPS), the need for predictability is as high as ever and hence the importance of CDM is not going to diminish. On the contrary. Both SESAR and NextGen have clear statements in their respective CONOPS indicating that all decision making will have to take place taking the collaborative principles into account.

At the same time, the new ATM environment will bring certain new elements that have a direct impact on A-CDM as currently defined. If improved decision making is to remain enabled also in the future, A-CDM will have to evolve to take these new elements on board. Let's now have a look at the pertinent new features of that new environment to gain the knowledge we will need to understand the rationale for extending A-CDM and ultimately bring in novelties like TITAN.

3.1.1 Trajectory based operations (TBO)

In order to explain what TBO is all about, we need to take a step backwards and consider how the legacy ATM environment works. We have several kinds of airspace defined that serve aircraft flying en-route, near airports in the terminal area and even nearer in the control zone. They each have air traffic services units allocated to them which provide the required services, like air traffic control, flight information and so on.

Aircraft fly within the confines of the airspace and their trajectories are modified in real time by air traffic controllers to provide separation between them and to set up metering onto the runways on arrival.

Airspace users submit a flight plan that is a fairly rough description of their intentions which is then interpreted by ground systems and clearances are issued to achieve the aims mentioned above. Controllers focus on the portion of the trajectory within their own piece of airspace and their main concern after having separated conflicting aircraft is to pass them to the neighboring sector or control centre without there being a new conflict as a result of their intervention. They do not much care about the effects of their actions further down the line. Their local focus means that even large distortions to the original trajectory further down the line will be invisible to the upstream controller.

Clearly, the airspace user's intentions, which were communicated in a rather summary way to begin with, often bear only a remote similarity to what the aircraft is actually made to fly. If we now realize that the original trajectory had already taken into account the airspace-imposed restriction and this trajectory was further distorted by tactical actions, it is easy to see that what the aircraft flies is a far cry from the most optimal trajectory the aircraft in the given day could have flown.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Trajectory based operations or TBO aim to remedy this situation. How will that be done?

We will move from the airspace based paradigm for a trajectory based paradigm. The totality of the airspace is seen as a single continuum and aircraft trajectories are not distorted by airspace constraints except where this is unavoidable.

Airspace users will submit their so called business trajectories which express their intentions, the way they want to fly so that the given flight may be conducted in the most cost efficient way possible.

The following diagram illustrates the life-cycle of the business trajectory mapped onto a commonly used division of the ATM planning phases. It is for illustration purposes only, in actual implementation in SESAR for instance, slight differences may be seen.

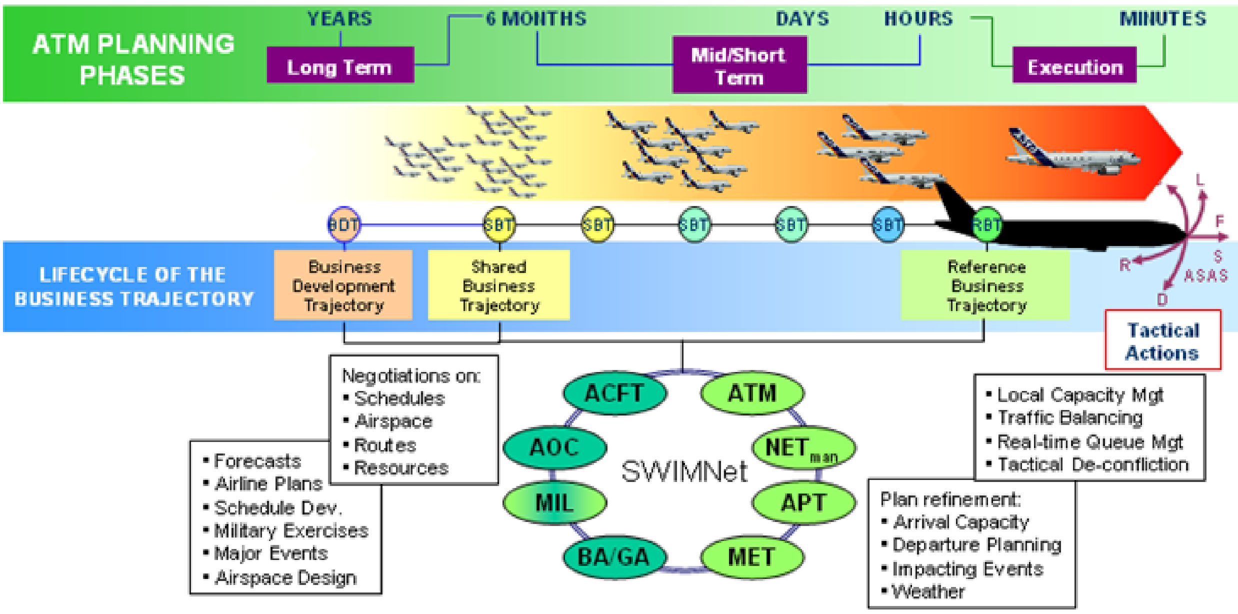

Figure 8: Business trajectory Lifecycle and ATM Planning phases

The airspace users develop the first version of the trajectory of a proposed flight, possibly even some years ahead of the actual flight. This is just a plan but it takes account of what can be foreseen at that point of time including absolute limiting factors. This version of the trajectory is called the Business Development Trajectory (BDT).

Some six month before the actual flight the trajectory is shared via SWIM (which we will discuss later in this chapter) and it becomes the Shared Business Trajectory (SBT). All partners concerned now see the proposed trajectory and collaborative coordination takes place to ensure that eventual unavoidable constraints can be worked into the SBT. The purpose of the coordination is to ensure the best overall result, i.e. the situation where all the SBTs together end up with the least amount of individual distortion. Obviously this ensures ultimately that all the airspace users will operate as close to their original intentions as possible.

Hours before the flight is to take place, air traffic management looks at the SBT and confirms its acceptance as the actual business intentions of the airline concerned. At this point ATM may add constraints if necessary but here again the overriding consideration is to have the least overall distortion. The ATM approved trajectory becomes the Reference Business Trajectory (RBT) which is defined as "the trajectory the airspace user undertakes to fly and ATM undertakes to facilitate". Obviously, controllers have the possibility to intervene should this be required to resolve a conflict, but the aircraft is returned to the RBT as soon as possible following the intervention.

In this concept, the RBT is something that is shared in its totality between all partners concerned and hence any sector controller and his/her decision making aids can check for each intervention

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

the action resulting in the least overall distortion. So, we can finally forget the limitations imposed by the short sector horizon while at the same time being able to work with solutions that fully comply with the TBO requirement of maintaining the least overall distortion of trajectories when an intervention is required. Obviously this is a two way street: airspace users are obliged to stick closely to their RBT and avoid last minute changes as much as possible. This is a logical precondition for ATM to be able to accept the trajectory with minimum distortion.

The diagram above contains references to Airborne Separation Assiatance System (ASAS) also, where the responsibility for providing separation is transferred to the pilot. ASAS is a complex subject that deserves a book of its own and we will not go into the details here.

Did you know... That you can find more information on ASAS at the following link: http://www.asas-tn.org/library/asassworksdonesbysrdsbod/nlr

The focus on trajectories creates a very clean and easy to understand overall picture of the traffic, much clearer and easier to predict than the current method of slicing the trajectories into airspace delimited sections.

TBO is interesting also because by not looking primarily at individual aircraft but the trajectories the aircraft will fly, the connection is suddenly made between the individual flights a given aircraft will perform on a certain day. This makes the knock-on effects of distortions of a part of a trajectory clearly visible.

With TBO it is also easy to bring the airports into the ATM network in a clear and unambiguous manner.

When we mention the word "trajectory", we tend to think of it as the Four Dimensional (4D) something an aircraft will fly on when in the air. However, an aircraft has a trajectory also when it is moving on the ground and even when it is parked at the gate or a remote stand and overnight stop. Just think about this. In the air, the trajectory is 4D: three spatial dimensions and the time dimension. By definition, all four dimensions are constantly evolving. When moving on the ground, the trajectory is Three Dimensional (3D): two spatial dimensions and the time. If the aircraft stops at the gate, the trajectory becomes Two Dimensional (2D): only the time dimension continues to evolve, the two spatial dimensions in which the aircraft's position is defined stop changing.

Irrespective of the number of dimensions a given trajectory has at any given moment, resources will be consumed and it costs money. Even during an overnight stop, costs accumulate from amortization to guarding the aircraft... there is no free lunch.

Going to the extreme, we may even say that a given airframe has a trajectory from the moment it is built to the time when it is withdrawn from service or fate overtakes it in some other way. Anything that happens to the trajectory will have a ripple effect downstream on that airframe. Just think of the Boeing 787, which was expected by airlines almost three years earlier than it was finally handed over. If we go back to the picture of the trajectory life-cycle it is easy to see that the airlines concerned will have been in the process of building the Business Development Trajectory for their new 787s... only to find that those trajectories would not become reality until much later. This was a typical distortion of the time dimension of those trajectories.

In this concept of trajectory based operations we can also say that the trajectory will have different names attached to it at different times. These names are of course the flight numbers the airframe is called to carry out. It is the trajectory of the airframe that connects everything together. In the past the best we could hope for was a view of the individual flights but very rarely did we have visibility of how the airframes and flight numbers over a longer period of time were connected with each other. Of course the airlines have been working in this basis for a long time now but, pre-CDM, it was not thought necessary to share this information. Predictability for the other partners suffered as a consequence.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

When an aircraft is scheduled for several rotations on a given day, the "names" of the trajectory sections are back-to-back. When the aircraft is parked for the night, there is a period when the trajectory has no name as such... but it is still important to know where it is idling until it is time to start another day's work. The position of the idling trajectory will determine the kind of resources that will be needed to bring it to a gate or to take passengers to the aircraft, the ground traffic it will generate, etc.

By common agreement, the airport ground trajectory is considered to be the taxi following touch-down till in-block and from off-block taxi until take-off.

However, this definition leaves the turnaround out of the picture. This would of course be a mistake since many influences act on the trajectory while it is idling at the gate... The time dimension can be distorted in many different ways and they all have an impact on the rest of the trajectory. In this document, we will consider the idling trajectory as an integral part of the airport ground trajectory in order to gain an insight into the turnaround also.

From the CDM perspective, what we want is to have the earliest possible indication of anomalies affecting the trajectory and then use collaborative decision making to avoid the anomalies or at least mitigate their effects.

3.1.2 Service Orientation (SO)

During the drive to make the SESAR project service oriented, the following definition was put on the table as one of the arguments in favor of SO: "Service orientation is an approach to organizing distributed resources into an integrated solution that breaks down information silos and maximizes business agility. Service orientation modularizes Information Technology (IT) resources, creating loosely coupled business processes that integrate information across business systems. Critical to a well-designed service-oriented architecture is producing business process solutions that are relatively free from the constraints of the underlying IT infrastructure, because this enables the greater agility that businesses are seeking.

Service Oriented Architecture (SOA) ultimately enables the delivery of a new generation of dynamic applications. These applications provide end users with more accurate and comprehensive information and insight into processes, as well as the flexibility to access it in the most suitable form and presentation factor, whether through the Web or through a rich client or mobile device. Dynamic applications are what enable businesses to improve and automate manual tasks, to realize a consistent view of customers and partner relations, and to orchestrate business processes that comply with internal mandates and external regulations. The net result is that these businesses are able to gain the agility necessary for superior marketplace performance.

Service orientation is a means for integration across diverse systems. Each IT resource whether an application, system or trading partner can be accessed as a service. These capabilities are available through interfaces; complexity arises when service providers differ in their operating system or communication protocols, resulting in interoperability problems. Service orientation uses standard protocols and conventional interfaces—usually Web services—to facilitate access to business logic and information among diverse services. Specifically, SOA allows the underlying service capabilities and interfaces to be composed into processes. Each process is itself a service, one that now offers up a new, aggregated capability. Because each new process is exposed through a standardized interface, the underlying implementation of the individual service providers is free to change without impacting how the service is consumed.

NextGen in the US is being developed in an environment where both “net-centric” and “enterprise services” have been either made mandatory or are being leveraged to create an agile air transport system (NextGen, as opposed to SESAR, encompasses the complete air transport system not only ATM and is not only a technology pillar, like SESAR).

In particular, the Department of Defence (DoD) Global Information Grid (GIG) material, DoD 8320-G Implementing Net-Centric Data Sharing, Net-Centric Enterprise Services Service Discovery Core Enterprise Services Concept of Operations (Defense Information System Agency – DISA) and the Capability Development Document (CDD) for Net-Centric Enterprise Services (NCES) are being made use of as examples of non-ATM related but completely applicable products."

If we now consider how easily we fall into the trap of discussing CDM in terms of IT solutions it is easy to see why the insistence on separating the business and IT layers in the enterprise is so important. Especially when we add the fact that CDM is being implemented in an environment with many legacy systems and solutions, the push to adapt the business needs to the IT capabilities, rather than vice versa, tends to become overwhelming. However, this is nothing less than trying to force a new concept into a legacy environment that inevitably ends up with the new concept failing to deliver its full potential.

Certainly when it comes to CDM in the future ATM environment envisaged by SESAR, service orientation becomes an absolute must.

As mentioned already, service orientation and the Service Oriented Architecture creates an environment where business services and the IT services required to support them are clearly divided from each other, for the former driving the latter. This is a very business oriented approach which fits well with the airspace user drive to accurately price everything they need to pay for and to have complete transparency of what they are paying for. Services in this context have a clear content, composition, price, performance and delivery schedule. This clarity and transparency forces everyone to focus on the business aspects first and consider the IT aspects in second place only, as the means for realizing the business objectives.

In practice many organizations planning to switch to service orientation have found that there are relatively few experts in the field who can help in defining the services applicable in a given environment. This is particularly true for air traffic management and CDM since without a thorough knowledge of what ATM and CDM is all about, even just talking about services tends to bog down in circular discussions. Of course as time passes by, the required expertise will also grow and at the end of the day the problem will resolve itself.

In any case, the TITAN project we will be discussing in Part 3 - Welcome to titan is a good example of how a part of CDM can actually be written up in a service oriented manner. At the time of writing (Spring 2013) this is the only CDM related project that has used a full service oriented approach.

Did you know... That Service Oriented Architecture principles have been the foundation for the evolution of transactional systems to e-business and end-to-end business process integration. In the next decade, the same SOA principles will be at the core of a new era of business engagements that transact at internet scale across locations, devices, people, processes and information - says IBM.

3.1.3 Net-centric

As discussed earlier, air traffic management can be considered as a complex, world-wide decision making machine and this is why collaboration in decision making and the provision of common situational awareness has such a huge impact. By making decisions better the operation of the whole "machine" becomes better.

In order for the decisions to be not only good in themselves but also to be effective it is necessary to make the environment in which they are made net-centric.

If you look up the definition of "net-centric" in, for instance, Wikipedia[6], you will find that it refers to participating as a part of a continuously-evolving, complex community of people, devices,

[6] http://en.wikipedia.org/wiki/Net-centric

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

information and services interconnected by a communications network to optimize resource management and provide superior information on events and conditions needed to empower decision makers.

The above definition fits so nicely with our mental picture of air traffic management that it is probably hard to imagine that the concept of net-centricity was originally developed in the US Department of Defense in the late 1990s. They were of course talking about net-centric warfare, a far cry from ATM. But, over time, it was realized in more and more non-military areas that the idea of net-centric operations could be applied to great effect in all kinds of peaceful activities also.

Did you know... That many experts believe the terms "information-centric" or "knowledge-centric" would capture the concepts more aptly because the objective is to find and exploit information, the network itself is only one of several enabling factors. (Wikipedia)

The partners in air traffic management are producing and consuming a huge amount of information which can be shared in a net-centric environment to support decision making and to promulgate decisions as well as provide feedback on the actual effects of the decisions. The aim is to maximize safety and efficiency. If you compare this to the above definition of net-centric operation, the similarity is striking. It is no accident that net-centricity is such a prominent feature of all new ATM initiatives.

Net-centric in the ATM context means that each information generator or consumer partner is a node on the global network, directly addressable by all the other partners, with everybody sharing a common virtual information space.

Another important feature is the generalised access to information. Limited only by legitimate security considerations expressed in powerfully protected and enforced access rights, all partners may contribute and/or access the shared information. Obviously, this raises the need to ensure the quality of information going into the system on the one hand and satisfying the expectations of the partners using the information for quality and timeliness, on the other.

In the next paragraph we will look at how all the information in a net-centric environment can be managed.

3.1.4 System Wide Information Management (SWIM)

A few thoughts up front

We will dwell on this subject a bit longer than the others, mainly because it is such a fundamental new feature and because it addresses an issue in air traffic management that has been a limiting factor in realizing the full potential of many new initiatives for decades.

It is not by accident that a survey of user requirements some 15 years ago identified issues more than half of which related to information management shortcomings.

We have already seen that information sharing is the most powerful concept element in A-CDM and the net-centric approach to the future is also built on the premise that the available information must be shared between all partners to maximize the benefits. Clearly, without properly managing all that information the already identified problems will only get worse.

The solution is System Wide Information Management or SWIM, which is not a standard feature in the plans for all new ATM environments and has been formalized also in the ICAO (International Civil Aviation Organization) ATM System Block Upgrade (ASBU) concept.

In order to understand what SWIM is all about, we need to be aware of a number of basic facts.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

What is information management?

We will answer this question by stating what information management is not:

- Not the same as CDM - Information management is an enabler for CDM. CDM information sharing is realized using information management (SWIM) techniques.
- Not the same as communications - Communications is one of the enablers for information management.
- Not the same as information modeling and standardization - These activities are part of information management which in itself has a much wider scope.
- Not a technical issue - System-wide Information Management addresses the lifecycle and use of information, primarily from an operational (decision making), organisational, spatial, economic, institutional etc. point of view. Therefore SWIM should not be confused with (or equated to) the technical solutions (information and communication technology) underpinning automated SWIM support.
- Not part of the system architecture - SWIM drives architecture: depending on the adopted SWIM concepts and performance requirements, the system architecture may need to look different

So what is SWIM? As we will see, there are a few more common misconceptions that we need to dispel to arrive at the correct picture.

SWIM is the external (from an ATM point of view) enabler entity that brings benefits by allowing end-user applications from the simple to the most complicated to make full use of the complete ATM data set and which can start on existing infrastructures. Institutional issues will need to be addressed, but for a simple start, no great changes are needed.

In many of the SWIM descriptions circulating at the time of writing, SWIM as the data management "entity", ATM end-user applications and even institutional aspects are mixed up in a way that projects a flawed picture. The most important misconception is that SWIM should be under the purview of air traffic management, that it is a function integral to the air traffic management systems. One of the consequences is that the date for SWIM implementation is often pushed to the right since SWIM is seen as belonging to a more advanced state of ATM and hence cannot be done earlier than the date those advanced functions become available.

In fact, SWIM is NOT an ATM category, it is simply the enabler of information sharing and indirectly the enabler of advanced end-user applications (which are ATM categories) which will be introduced in different phases of advanced ATM implementation projects.

Actually, the common ATM information model is the only aspect of SWIM which is really air traffic management specific.

SWIM can bring benefits even in a legacy environment and hence it is wrong to make its implementation dependent on the availability of a more advanced ATM situation. Witness the limited information sharing being practiced by Airport CDM today in Europe or the similar activities in the USA and it is clear that certain aspects of SWIM can be implemented now to enable immediate benefits. It can then grow as required to meet the demands of the more advanced ATM features.

Did you know... That the name SWIM was invented at 3 a.m. in a Luxemburg hotel room while experts from EUROCONTROL and IATA were drafting the report of the information management sub-group of the ATM2000+ workshop? It was prompted by an IATA presentation that said "aircraft were flying in a sea of information".

Another misconception that can result in huge costs is the premise that SWIM needs dedicated highly secure networks under the stewardship of ATM organisations. Most of the information in ATM can be safely put on existing networks and even with the more sensitive information, costly and cumbersome security overkills must and can be avoided.

It is important to remember also that the benefits of SWIM arise from the end-user applications that make use of it and not SWIM itself.

Finally it is essential to realise that there is no such thing as ground/ground and air/ground SWIM. SWIM is about information and how it is shared and managed. The complete network may be built in segments and air/ground may come later than ground/ground, but this is a connection issue and not a SWIM issue. An aircraft may not be able to use certain applications if the air/ground network segment is not yet available but conversely, this does not prevent other applications from using information that might come via the air/ground segment but which is also available from other sources (e.g. Airline Operations Center (AOC)). This however does not mean that SWIM has different characteristics in the ground/ground and the air/ground context and hence SWIM implementation must reflect this universal nature of information management.

The SWIM figures provided later in this paragraph are not meant to show a particular architecture or technical solution. They are designed to illustrate the elements that need to be enabled to achieve information sharing and common situational awareness in ATM and all areas of concern to ATM, via the SWIM concept.

The relationship between SWIM and ATM Performance[7]

From a generalised "command and control" perspective, the ATM system can be seen as a complex, distributed real-time information processing community populated by a large number of humans and automated systems in the role of sensors, information providers, information users and decision makers, all collaborating to ensure a safe, expeditious and efficient flow of air traffic.

The following figure illustrates the interaction between information providers, decision makers and information users.

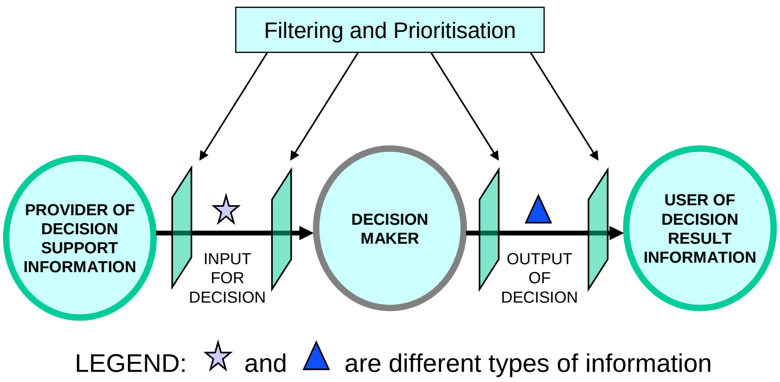

Figure 9: Information interactions

As is illustrated in the figure, the performance of ATM depends on six factors:

1. Existence of airborne and ground-based suppliers (systems and service providers) for the various types of ATM decision support information;
2. Availability, quality and timeliness of the provided decision support information (quality includes integrity, accuracy, completeness, legibility, trustworthiness etc.);

[7] Implementing SWIM as the external enabler of ATM end-user applications - BluSky Services 2008 with input from EUROCONTROL.

3. Ability of airborne and ground-based ATM decision makers to receive, absorb and use available information;
4. Quality and timeliness of the airborne and ground-based decision making itself;
5. Effectiveness and timeliness of making the resulting ATM decision information available to (potential) airborne and ground-based consumers of that information (those who have to act on it);
6. Effective information filtering and prioritisation along the way.

In order to improve overall ATM performance, al six factors need to be improved.

Historically, the focus of attention has primarily been on item 4 — how to improve (algorithms, automated tools and procedures for) decision making in the various functional categories e.g. airspace management, flow and capacity management, separation assurance, sequencing and metering etc. — whereas the purpose of the *information management* perspective is complementary. It focuses (exclusively) on improving the other five factors which are equally determining how well ATM performs at the end of the day.

System Wide Information Management (SWIM) introduces a number of changes which are specifically designed to improve these other five factors. The final effect of the evolution towards SWIM is illustrated in the Table below, which contrasts the information management situation before and after deployment of SWIM.

ATM information management prior to SWIM	Target situation after SWIM deployment
Has roots in the traditional ATM environment where CNS limitations were the main determinant for what was possible	Applicable to a fully networked information-rich ATM environment
Focus on “micro-management” of information	Challenge: how to deal with large quantities of information
Interaction between decision makers is through communication (mainly point-to-point information flows)	Interaction between decision makers is through information sharing, i.e. via a distributed "virtual" information pool which uses concepts such as information replication, information caching, etc.
Real-time event propagation amongst ATM stakeholders occurs through message exchanges (send/receive) generated at decision making level, not at information management level	Real-time event propagation amongst ATM stakeholders is managed by a separate information management layer: triggered by information filters (publish/subscribe) and the dynamics of the information web, i.e. by synchronisation of information state & relationship changes in the various copies of the information)
Emphasis is on interface definition and standardisation in a static environment (development and acceptance of information architecture standards takes years)	Emphasis is on information standardisation in a rapidly evolving environment (advanced systems know how to adapt to new meta-information — this is the key to quick responses to changing information needs)
Most meta-information is embedded (hidden) in system designs and information architecture standards	Extensive amounts of explicit meta-information are circulating in the ATM system
Systems follow a classic design which enforces a rigid structure of information flows (functional architecture with "hardwired" data flow diagrams, i.e. static view of inputs and outputs of a function)	Systems are designed to support flexible information flows (not based on pre-defined data flow diagrams, but on predictive, dynamic information demand/supply balancing — capable of adaptation to the "information market")
Information management principles are applied at the local (system) level only (leads to islands of information)	ATM network characterised by the existence of common processes explicitly responsible for system-wide information management (leads to a coherent system-wide integrated web of distributed information: the ATM virtual information pool)
ATM is characterised by integration and interoperability problems	Integration and interoperability problems in ATM are solved by efficient information sharing capabilities
Information ownership, licensing, pricing and security are poorly addressed	Information has become a commodity: information ownership, licensing, pricing & security mechanisms have matured (for static as well as real-time information)

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

The notion of the "virtual information pool"

The concept of SWIM is in fact much more than just switching from a point-to-point data communications model to network centric communications. SWIM is not the same as being able to send messages to any desired destination. SWIM is an information broker which resides between the originators of information and the users of information. It manages processes (which run outside of ATM applications) which manage standardization, data discovery, access rights, etc. and safeguard the overall quality and consistency of the total body of ATM decision support information. The net-centric communications method is of course an enabler of SWIM, but it is not SWIM.

SWIM is a “store and forward” layer between the applications. All aeronautical information provided by data sources can reside for an indeterminate length of time (from a millisecond to a year or more) somewhere in the “virtual information pool” before being picked up by those systems/applications needing it.

The “virtual information pool” notion symbolizes both the persistence (availability as long as needed) and accessibility (access as quickly as needed) of every bit of aeronautical information produced.

Some essential characteristics of SWIM that depend on the “virtual information pool” notion:

- primary focus changes from information exchange to distributed information storage (persistency aspect) and synchronized replication of information copies, making a distinction between "master copy" and "secondary copies" of information.
- searchable "virtual information pool" (through data discovery) represents the "unified market place" for ATM decision support information, appropriately protected by access and update rights (security management) with appropriate ownership, licensing, liability, charging, information archiving, disposal etc.
- fastest possible event propagation by information supplier: the "virtual information pool" is updated without delay after each (validated) change
- user-dependent speed of event propagation to information user: updates of the "virtual information pool" not necessarily propagated immediately to the information user, but based on individual timeliness needs

SWIM is the ultimate distributed information environment, the elements of which are tied together by the notion of the “virtual information pool.

The scope of SWIM

Information has always played a vital role in aviation. “Knowing” and “being informed” has been synonymous with safety in the early days and having timely and accurate information is as important today as it was then.

It is both interesting and educating to cast a view backwards to bring into focus where we have come from before considering the present and even more importantly the future, from the specific view point of information.

The provision of aeronautical information was originally conceived to ensure that individual aircraft are given all the information necessary to conduct their flight safely. When the business aspects of aviation attained a more pronounced importance, becoming second only to safety, aeronautical information had to be enhanced to cater also for the requirements of efficient operations.

Although meteorological information is essential for safe and economic operations, for historical reasons the rules applicable to Meteorology (MET) and its provision have evolved in a way that is parallel to, but not integrated with, the rest of aeronautical information.

With air traffic demand growing year after year and the world’s busiest areas getting saturated both in the air and on the airports in those areas, the need to look at the air traffic management infrastructure as a network was increasingly recognised and with it the need for new types of

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

information, including increased coverage both in the geographical and the temporal aspects. Since these new developments came at a time when electronic information processing and exchange was already well established, such methods were readily adopted also in the air traffic management context.

Very quickly the situation evolved to the point where the fragmentation (traditional Aeronautical Information Service (AIS), MET, new types of information and services delivered in numerous different contexts) started to become a limitation to growth and in some cases even led to safety concerns (e.g. presence of multiple, slightly different flight plans, for the same flight).

A further complication was identified in the way information was/is being promulgated. Many point to point connections, a not always reliable addressing scheme, a push-type distribution which quite often missed the target users, difficulties in accessing important information, etc. all combined to help arrive at the realization that a new approach to managing information was needed.

The most important characteristics visible from plans for new ATM systems is the trajectory based operations on the one hand and a shared information environment which is the main underpinning of all the air traffic management functions on the other. This shared information environment extends to include aircraft on the ground and in the air. The traditional flight plan filing as we know it today will be replaced by the managed sharing of flight data and associated trajectories, demonstrating the depth to which the new way of handling information will reach. It is clear that this net-centric approach can only exist if the information generated and consumed by the various partners in the ATM network is managed in a safe, cost-efficient and quality assured manner without limitations on the type and quantity of information or the number of users. The system must also be agile, flexibly and cost efficiently adapting to new requirements, be it new information types or new users or providers.

The information shared environment also requires that fragmentation in terms if what is available and how, is eliminated and also that information must be provided in the form of data, which can then be processed into usable output on the client side.

The importance of meteorological data will also increase substantially since the precise flying of trajectories and making precise predictions (essential to reduce uncertainty and hence increase capacity) all depend on improved meteorological information, especially wind aloft data. With the expectation that aircraft platforms will increasingly communicate such data, to be then shared via the new environment, it is clear that meteorological data will have to be part of the information sharing environment, just like all other information that is of concern to ATM.

As mentioned earlier, information has always been one of the cornerstones of aviation safety. Traditionally, the information was provided by the Aeronautical Information Service, one of the few, truly global services in aviation. Over the years the means used to deliver information have evolved and the scope of information has expanded. By necessity, international standardisation was one of the chief goals of all concerned, resulting in a product oriented output that served most needs but was rarely perfect for any specific need.

With the quantum leap in information use and the requirements for more information described above as well as the introduction by airspace users and other partners of a digital, data oriented paradigm in their operations, the gap between the requirements and the ability of the product oriented AIS system to deliver what was needed was becoming more and more apparent. The product oriented system is not really flexible and it is difficult and expensive to add new features and/or information and hence closing the requirements gap has proven impossible.

The difficulty was duly recognised by the AIS community as was the fundamental truth that the aeronautical information service is an essential service to aviation that must rise to the challenge through developing into the service that fully supports the future information sharing environment.

This evolution is taking place via the transformation of traditional, product based AIS into data oriented System Wide Information Management that has been discussed and agreed in numerous forums world wide.

The main drivers determining the scope of aeronautical information, and hence SWIM, are:

- Air traffic management is evolving into a net-centric, trajectory managed environment which is based in all its aspects on shared information and collaborative processes using the shared information
- A shared information environment implemented in a net-centric manner requires that there should not be fragmentation of the available information set. In other words, the shared space encompasses all types of information, be that meteorological, environment, traffic, flight or any other category
- An agile system means that it is easy to add new information and providers/users of information, in effect meaning that there is no predetermined limit on the scope

Only standardised information may be included.

While in the past aeronautical information had been defined in a rather narrow manner, the shared information environment of the future, and in particular the collaborative processes envisaged, require that aeronautical information not be limited to a set of data that is pre-determined based on expectations. The new definition should also be net-centric and focus on the overall needs of air traffic management, recognising the propensity of these needs to change over time.

Based on the above, the best definition appears to be: Aeronautical information is any information of concern to air traffic management, without pre-defined limitation.

A system built to cater for this premise has no problem in accommodating an expansion of the information set or of the users/providers and hence can fully support the evolution of the net centric environment as it embraces new processes, both in the air and on the ground.

It is clear from the above that SWIM must have a scope that is open and which enables additions without difficulties or high cost. Obviously, this open scope is a characteristic that will be taken into increasing use as time passes, filling in the “space” with information in line with the evolving requirements and the pace of standardisation.

This latter is a critical issue. Only information the characteristics of which have been agreed can be shared in the ATM network and hence only such information can be considered for inclusion in the actual SWIM scope. This is a limitation that will have to be handled carefully.

Standardisation can be a very slow affair. If an ATM requirement appears asking for an as yet un-standardised information element, if the process is too long, if too much time elapses before the given element is included in SWIM, the users of that information may default to an alternative path, creating a degree of fragmentation that can lead to unnecessary complications. It is essential that data level standardisation be put in a regime that works with the required speed to keep pace with ATM developments.

The elements of SWIM

The following figure shows a simple, high level description of the main conceptual elements of SWIM.

The blue Institutional background signals the fact that SWIM is as much a set of roles, rules and responsibilities that apply to SWIM itself and to its users, as it is a technical facility. It also shows that the users of SWIM, like for example Air Navigation Service Providers (ANSP) and airspace users, are in part under the SWIM institutional background as users and providers of information. Clearly, SWIM is external to ATM, however it supports ATM as the enabler of the end-user applications implemented in the various user systems. Airspace users, airports and all other partners communicate via the Information Services, just like ANSPs do.

Of course there is more to SWIM than what is shown on this simplified diagram. Have a look at the next diagram.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

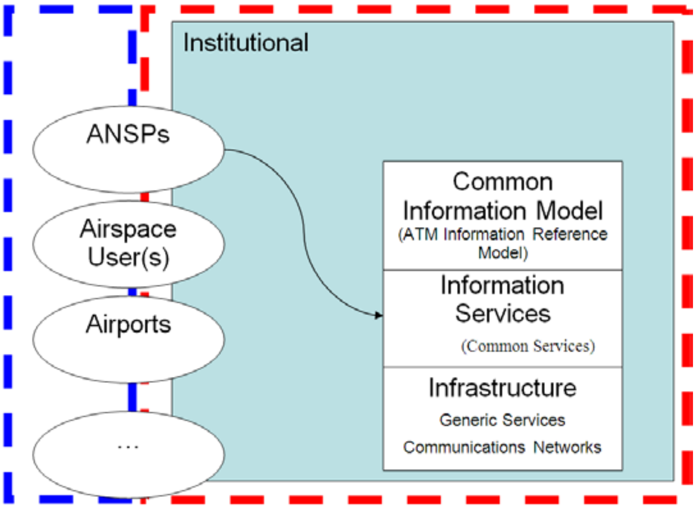

Figure 10: SWIM information providers and users

This diagram represents the same SWIM concept as the previous, however, with more detail on the information providers and users as well as the management and provision of SWIM specific services. In the following, a detailed explanation of the different elements shown in this more detailed depiction is given.

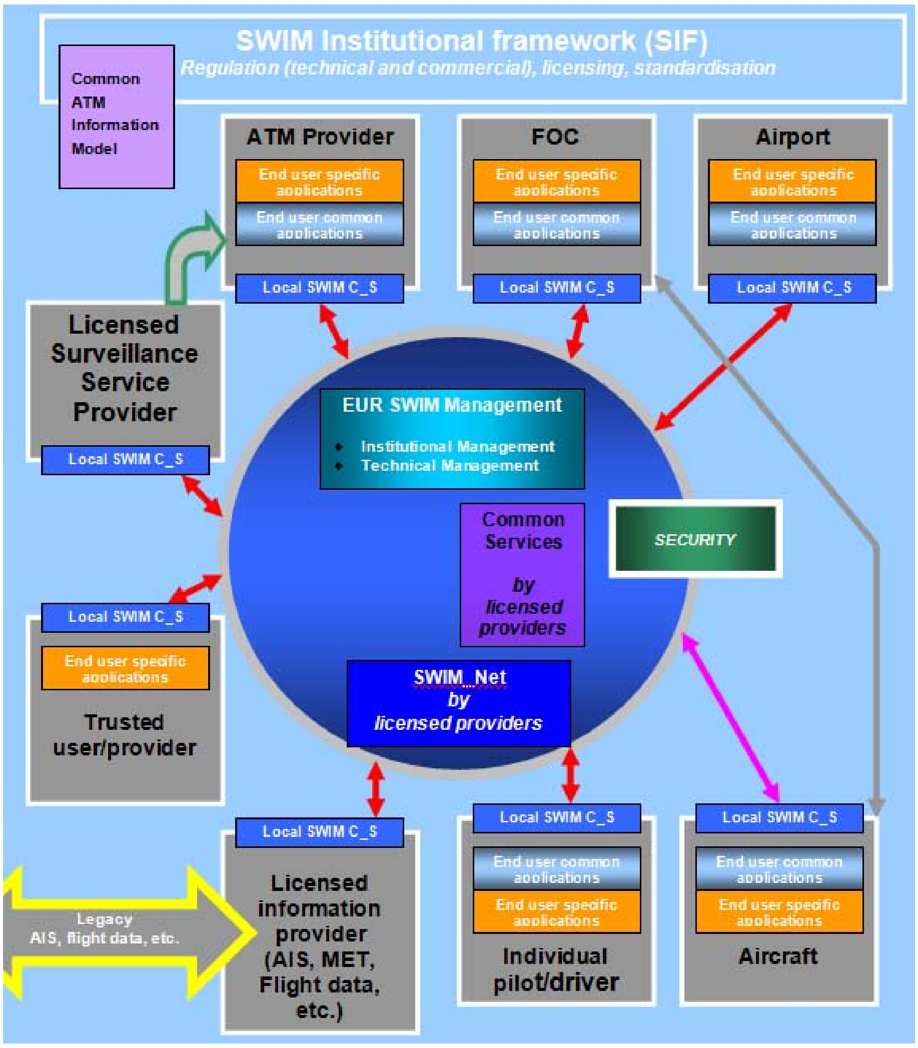

Figure 11: Elements of SWIM

SWIM Institutional Framework

The Institutional Framework encompasses all enabling activities required to create the technical and commercial regulatory environment in which cost efficient, safe and secure information sharing for ATM purposes can be practiced. This includes also the necessary standardisation and the rules for licensing on the European regional level. This framework serves also as the high level regulatory interface to the rest of the world.

It is in this framework that necessary amendments to ICAO and European provisions (e.g. Annex 11, 3, 15, 10, Doc. 4444, 7030 etc.) on which SWIM has an impact are initiated and carried to approval. This includes extending the scope of aeronautical information and integrating MET information in the extended scope. The Common ATM Information Model is also developed under the stewardship of this framework.

It should be noted that the framework as shown here is for illustration only and its functions may be assumed by any appropriate organization agreed by the industry.

The concept of SWIM recognizes the ownership of the data managed in it, but there is no "owner" of SWIM itself. It is also against the SWIM principles to allow any particular organisation or group of organisations to become a monopoly for providing any service on any level in the SWIM environment. Service provision on all levels in SWIM is open to competing providers as long as they meet the published requirements (and are duly licensed if applicable).

It is also against the SWIM concept to prescribe to any ATM partner which provider to use for any service on any level.

SWIM_Net by licensed providers

SWIM_Net is the underlying network infrastructure supporting system wide information management in all its network aspects. It is NOT a dedicated network but an industry standard networking capability without proprietary solutions, run by cost-efficient providers, meeting the requirements posed by ATM and appropriate to the different kinds of data being exchanged.

It is important to note that different ATM data have different needs and SWIM_Net enables this differentiated service. This reduces overall costs on the one hand and enables the early implementation of services and applications that do not pose the highest requirements which will only be possible to satisfy in later phases of SWIM implementation.

Common Services by licensed providers

Common services encompass those network services that are required for the data services on the network (directory, discovery, security, etc.). These common services also ensure the interoperability with other SWIM-type environments (e.g. USA). These services are provided by providers licensed according to the applicable rules defined under the institutional framework.

SWIM Management

SWIM Management is the entity (i.e. not under an ANSP or other user) charged with the daily supervision of all aspects of the SWIM operation. This entity is responsible for the evaluation of license requests, issuing and withdrawing licenses, dealing with details of the security arrangements, quality issues, etc. It operates in accordance with the applicable rules defined under the institutional framework. SWIM Management could possibly take the form of a not-for-profit consortium looking after the interests of all users of the system. Although on the figure SWIM Management is shown with an EUR prefix, in the concept this is not specific to Europe and in some cases the entity may be charged to manage SWIM for more than just one region.

Traditional users and providers of information (ATM, Flight/Airline Operations Centre (FOC/AOC), Airport)

These are the traditional ATM users and providers of information. Using their systems, they publish their information into SWIM_Net and obtain necessary information from SWIM_Net in a number of different ways (subscription, direct query, etc.).

Local SWIM Connectivity Service

The Local SWIM Connectivity Service represents those changes required in local systems (including aircraft systems) that enable them to exchange data (publish, receive) via SWIM_Net. Local SWIM Service is NOT a set of people or local supervisors, it is purely a system provision. There is no need to supervise any aspect of SWIM locally!

End-user common applications

End user common applications are NOT in fact part of SWIM as such. They only make use of the information sharing capability. They are called common applications because they fulfil certain functions common to several ATM partners.

Note that these applications are specified in accordance with a performance based approach to their design. This means that they request data of the required quality without specifying the source. This ensures early benefits since data of the required quality from ANY source can be used (e.g. if trajectory data is available from the Flight Operations Center (FOC)/AOC only, it is accepted the same way as that from the Flight Management System (FMS) via air ground digital link, if the quality is otherwise identical. This is an example of the early benefits of SWIM based information sharing that can bridge the gap until air/ground digital link is more widely available.

An example of a common application is the arrival manager. While the core algorithm may differ from location to location, the data it needs and the data it outputs is subject to all the information sharing rules. Another examples could be Variable Taxi Time Calculation or in fact any other A-CDM application or TITAN itself.

End-user specific applications

End-user specific applications are NOT in fact part of SWIM as such. Different end-users may have different and even unique needs in respect of their particular operation. End-user specific applications are built to cater for such needs in as much as they are able to use information available in SWIM_Net and can also be charged for chargeable services/information. The output of such an application is not necessarily shared. If it is, it is subject to all the information sharing rules.

An example of such an application is a local trajectory modelling tool, which may or may not feed a trajectory submission tool where this latter is an end-user common application (used to share the various forms of the business trajectory).

These applications are also performance based, as described above. They would typically be developed by value-added suppliers.

The aircraft

The aircraft are data users and providers, with applications of similar characteristics to all other users/providers. It should be noted that MET observations made by an aircraft will be published into SWIM_Net like any other information and there is no need for any special interface between aircraft/AOC/FOC and the MET providers.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

On the SWIM figure, a direct link is shown between the aircraft and the AOC/FOC. This signifies the possible desire of airspace users to retain such a direct link for their own purposes. This is not contrary to the SWIM principles as long as the SWIM defined rules, roles and responsibilities assigned to the AOC/FOC and the aircraft are duly observed.

Connection between an aircraft and SWIM_Net can take several forms and this is also specified on a performance basis. Hence a General Aviation (GA) aircraft will be required to possess a link appropriate for their needs only.

Note that air/air information exchange is not shown separately here. While such exchange will happen directly between the aircraft concerned, information of ATM relevance will be published into SWIM_Net by the aircraft concerned and hence from a logical perspective, there is no difference between this kind of data exchange and that via SWIM_Net.

Individual pilots, vehicle drivers, etc.

These entities are typically people or ground vehicles accessing information via mobile devices. Examples would be a private pilot submitting a trajectory and other flight data from a smart-phone or tablet, or the operator of a de-icing truck consulting the pre-departure sequence on a mobile device in the truck. Applications on such devices will be optimised for the more limited capability but otherwise the performance based approach applies.

It is also envisaged that under this category data may be sold/made available to enthusiasts, researchers, etc., eventually with a time lapse to protect real time operations. The eventually ensuing revenue can be used for various agreed purposes.

Licensed information providers (AIS, MET, flight data, etc.)

Licensed information providers are the entities duly authorised under the provisions of the institutional framework, as shown by the license issued by SWIM management, to provide essential data into SWIM_Net. They are responsible for the quality of the information they provide.

Such providers include State organisations (formerly known as AIS) fulfilling an obligation of the State to provide aeronautical information, MET information providers, value-added providers like Jeppesen today, etc. Such an entity will be charged with the reception of aeronautical and flight data from non-SWIM areas as well as the provision of legacy information to non-SWIM areas. Note that “entity” here does not mean a single, centralised entity per-se.

Trusted user/provider

Trusted users are entities who are not appropriate for licensing or are not required to be licensed as they will only ever use data from SWIM_Net, never supplying data into it. They need to be registered only to ensure charging, if applicable. An airport taxi company wishing to purchase arrival information would be an example of this.

A trusted user/provider would be the FAA for instance, with privileges to use and submit information, being trusted on the basis of its recognised status in the industry.

Licensed Surveillance Service Provider

With the advent of new technologies like Automatic Dependent Surveillance, Broadcast (ADS-B) and multilateration, surveillance is likely to be increasingly outsourced for reasons of cost efficiency. Such providers will have to be properly licensed of course. However, on this illustration the important element is the direct connection between the surveillance service provider and the ATM provider. This is in recognition of the fact that initially SWIM_Net may not be suitable for handling all the surveillance information available in a given region. With the optimisation of the surveillance infrastructure, however, SWIM based operation should be possible.

It is important to note that abbreviated/limited surveillance information should nevertheless be provided into SWIM_Net right from the start to support applications requiring it.

High-speed network connections

Red arrows represent high-speed connections into the network with sufficient bandwidth to cater for the needs of the applications being use.

Link between aircraft and SWIM_net

A pink arrow represents the connection between an aircraft and SWIM_Net. This being a performance based system, the link to be used is specified from a SWIM point of view in terms of performance only.

The grey arrow is shown only as a reminder that airspace users may retain legacy links for their own use.

Security

The SWIM security concept is based on the fact that not all data and the information that can be deduced from it is equally sensitive and hence the level of security to be provided must be carefully calibrated to the actual need and not some perceived “importance” to certain interest groups.

This approach ensures that costs and system complications are kept low, information availability and accessibility is not adversely impacted by security overkills while the legitimate protection needs are fully catered for.

A system similar to that developed by the US National Security Agency called Multiple Independent Levels of Security (MILS) could be envisaged. MILS specifies how information should be partitioned and protected while running on the same server. Levels are from 1 to 7, where 7 is the most secure.

3.1.5 Airports integrated into the ATM network

Perhaps it is a surprise to read that integrating the airports into the ATM network should figure as a new feature in air traffic management development. However, if we look at how things developed over time, the situation becomes more understandable.

At the dawn of civil aviation, airlines and airports tended to be State or municipality owned and operated outfits with little attention to costs and with "profit" almost being a four letter word that was not usually mentioned in civilized discussions about aviation.

As State budgets the world over started to dwindle and priorities shifted, many of the largest airports found themselves being transformed into enterprises that were expected to break even as the minimum but with a reasonable profit also being put firmly on the horizon. The ownership of the airports did not always change at the same time but specialized airport operating companies sprung up almost overnight and they were given the concession of operating the airports for set periods of time. Airports became commodities, some of them changing hands repeatedly in a relatively short period of time. They were now firmly established as companies that had to earn their own keep and turn a healthy profit if possible. One consequence was that airports started to look for revenue in all possible form and they were rather successful. Some airports turned themselves into a kind of shopping mall where passengers sometimes have difficulty in figuring out where their aircraft is actually waiting.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Did you know... That in 1990, only about 30% of airport revenues were from non-aeronautical sources. In recent years, the global figure is closer to 50%, with a number of large airports deriving over 60 percent of gross revenues from non-aeronautical sources. Airport Council International (ACI) http://www.aci.aero/aci/aci/file/Position%20Briefs/position%20brief_AIRPORT%20BUSINESS.pdf

In time, deregulation of the airline industry also started, first in the US and then also in Europe. Airlines used to the comfortable life of "flag carriers" where there was little competition had to adapt to being companies that had to stand on their own two feet while also having to face competition not only from other legacy airlines but also the new crop of low-fare companies which had a definite take-no-prisoners approach to the market.

All this time, air traffic management remained a State monopoly where the terms "business" and "profit" were banned from the vocabulary. Of course the problem was not that they themselves were not supposed to earn a profit but that they did not much care about the profitability of their clients, the airspace users either. Setting up a safe air traffic management system was their goal, which they did achieve admirably but efficiency took a poor second place... if it was on the agenda at all.

As traffic demand grew, so did delays and after a time the built-in inefficiencies were no longer acceptable. The airspace users were becoming ever more vocal about their dissatisfaction with the worsening situation.

The implementation of the Central Flow Management Unit in Europe was a major step forward. Later, several EUROCONTROL projects were started (EATCHIP, ATM2000+) aimed at bringing much needed ATM reform. Since initially the delays were caused mainly by en-route capacity shortfalls, the projects tended to focus on finding solutions for those. Airports were not really tackled, although a program called APATSI did look at airport related issues.

The picture that emerged was a lopsided one. With the CFMU up and running and efforts on the part of air navigation service providers to generate additional en-route capacity combined with the drop of demand following the 9/11 terrorist attacks in the US resulted in delays dropping to historic lows. But this situation highlighted a new fact: most of the shortcomings still in the system were related to airport operations. The very place which had been left out of the equation for more than a decade!

At first, airports were not too keen to let projects like SESAR start meddling in their integral kitchen. They felt that the rest of the ATM community was not really familiar with what they were doing and were worried that interference with an air traffic management hat on would impact their competitive position. Of course Airport CDM had already penetrated their domain and the benefits were clear. But full integration into the ATM network?

In time the airports also realized that they had to contribute to the overall improvement efforts and since the remaining delay sources were clearly mostly in their back-yard, they too came on board. But they tend to maintain a kind of fierce independence, cooperating in the work but making clear where their home turf begins. This is all right of course. With the airport ground trajectory now firmly recognised as part of the overall trajectory and efforts like TITAN to further enhance the turnaround, integration of the airports into the ATM network is becoming reality.

It is trajectory based operations and hence the trajectory, that will ensure this integration. The magic of TBO at work here again. Perhaps a bit late, but we now know why there was this delay.

3.2 The rationale for extending A-CDM

As described earlier, CDM, the concept, was not limited to airports only. Collaborative decision making is a way of working, a way of improving decisions by ensuring that decision makers have all the available information on which to base their decisions as well as being aware of the consequences of their decisions on the operations of their partners. Common situational awareness is the name of the game.

Airport CDM in Europe came about as a pragmatic way to speed up CDM implementation. The idea was simple: if moving ATM in its totality towards reforming its decision making practices was too big a task, focusing things on the airport environment might make things more manageable with benefits also showing up sooner. This than can be used as a catalyst for more widespread implementation. It worked.

Reducing the CDM scope to just Airport CDM required also to set the limits of what A-CDM should deal with. In this respect another pragmatic decision was made: A-CDM should look only at things that happen on the air-side of the airport. Air-side was interpreted as meaning "things down on the tarmac"... As it turned out, this limitation enabled the work to catch most of the major issues that arose in airport operations and hence the aim of showing quick benefits was achieved.

Having been more than satisfied with the results of the A-CDM implementation, experts started to look at how the momentum of the improvements could be maintained. It was generally recognised that full-scale CDM implementation was still too ambitious an aim and that it was best left to projects like SESAR. So, a solution had to be found while staying more or less within the original limitations but still extending the A-CDM scope where possible.

EUROCONTROL had commissioned a study in 2008 with the aim of looking into what could be done with A-CDM to further increase its effectiveness. The study, entitled Level 4 CDM or L4CDM came up with a number of interesting conclusions. In the following, we will look at these, quoted from the L4CDM Concept of Operations, as they are in fact the forerunners of what TITAN has in the end realized, in a much enhanced and expanded form, in actual practice.

Process based, service oriented solutions

Purpose: To create a complete and un-fragmented picture of the environment in which L4CDM is used and to define the actions, the sources and destinations of the actions which are the subject of the collaborative decisions in the L4CDM context.

From the perspective of L4CDM, two main operational processes can be identified. One process is the management of the trajectory, the other the management of the passenger and baggage flow. Of course there are other processes relevant for the turn-round (e.g. crew to aircraft, fuel and catering to aircraft, etc.) but their effects are considered in A-CDM and only their effects are visible in L4CDM in the form of eventual distortions to the ground trajectory.

In order to be executed, the operational processes require various services. They also fall into several categories, related to one or the other (or several) of the processes described above.

The L4CDM concept of operations is expressed in terms of those two processes and the services required to support them, with L4CDM being the element that facilitates the decisions forming part of the services themselves. The L4CDM concept describes a number of services specific to this enhanced form of A-CDM. However, there are other service that exist already (though not always described as services in the legacy environment) while still more services may be defined in the future. L4CDM is able to seamlessly incorporate also those types of services.

Conceptually, the services in turn support end-user applications which are the operational interface to the outside world (for humans) or other systems, as appropriate. Decision making and two-way access to information is realized via the end-user applications enabled by the services.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

No airside/landside division from the CDM perspective

Purpose: To remove a source of fragmentation of the L4CDM environment.

The concept of L4CDM is process-based and service-oriented as described above. As such, it aims to eliminate subdivisions and organisational boundaries that are not relevant for the processes in L4CDM and the inclusion of which could potentially impact the efficiency of the concept.

Airports have traditionally been divided into “airside” and “landside”. The definition of these terms varies from airport to airport the same was as the physical boundary between airside and landside does.

Of the two main processes recognised by L4CDM, passenger and baggage flow extends on both sides of the airside/landside boundary, irrespective of its actual location at any particular airport. The processes require various services and L4CDM is concerned with the decisions associated with the delivery of those services. The sequence in which the services are delivered does depend on local circumstances (e.g. the Passenger Screening service may be applied to the passenger flow just after check in or shortly before boarding) but the sequence is not necessarily affected by the location of the airside/landside boundary.

The conditions and restrictions applicable to those delivering services may be different depending on where the service is delivered but this does not affect the service itself.

The L4CDM concept is built on the premise that the existence of a designated airside and landside on any airport is of no consequence for the processes recognised by the concept. Under L4CDM and from its specific perspective, the airport is considered a single continuum in which the processes are executed through the application of the required services, without the processes and services being divided by an airside/landside boundary.

This “single airport continuum” approach of L4CDM does not preclude the existence of an airside/landside boundary if maintaining or establishing one is found necessary for other purposes.

Inclusion of new (formerly landside) partners and events

Purpose: To include the impact of the activities of partners and events formerly ignored, both on the airport premises and beyond, in order to create new opportunities to positively influence that impact.

As described above, L4CDM recognises two main processes, one related to the management of the trajectory supporting TBO and the other related to passenger and baggage flow. It has already been shown that extending the range in which a given trajectory is considered improves the picture L4CDM can build of the state of the ATM Network, especially in terms of the future.

L4CDM treats the passenger and baggage (and eventually freight and mail) flow process on a similar basis. A large number of passengers and their baggage start their journey away from the airport and their progress towards the airport is subject to many influences (e.g. road and rail delays). Once on the airport premises, passenger and baggage flow towards the aircraft is once again subject to various influences, some related to the services being applied to the flow (e.g. identity and/or Passenger Screening service) others to the results of passenger behaviour (desired as well as incidental) and practices (e.g. shopping, eating). L4CDM recognizes the impact of these influences and commences the consideration of the passenger and baggage flow away from the airport, continuing with it through the airport until passengers are on board the aircraft.

This approach requires the recognition of several new CDM partners, who will be both information providers and information consumers. Road condition information from a traffic watch agency (from which delayed passenger arrivals can be deduced) or information on the length of the Passenger Screening queue from the company providing Passenger Screening services are examples of new information sources while the taxi company using arrival information to dispatch its vehicles is an example of a new information consumer partner.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

By incorporating the effects of these influences on the passenger and baggage flow process and determining the knock-on effects on the trajectory, L4CDM is able to maintain a much more accurate picture of the future state of the ATM Network.

The net-centric environment is very friendly towards extending the horizon even away from the airport, focusing on passenger and baggage flow. Most of the information needed is already available and the extension means only the intelligent use of the data as it applies to the process to be managed.

Did you know... That in the L4CDM project a 5th dimension was also given to the trajectory. This was called the economic value of the trajectory based on which a further collaborative prioritization could be undertaken when asked for by an airspace user. The economic value of the trajectory evolves from a hypothetical figure when it is first published, to one that can be expressed in actual money terms by the time the trajectory becomes the so called reference business trajectory. The overall value accrues from a number of different elements which include the other flights a given aircraft is scheduled to carry out, the number of high-yield passengers on a flight, the number of transfer passengers and the kind of transfers, etc. For instance, major distortions to a high value trajectory are likely to trigger mitigating actions sooner than in the case of a trajectory of lower value. Although airlines consulted on this subject saw merit in it, the idea was not pursued further.

It became clear in the course of the study that further enhancement of A-CDM was possible only if influences on the trajectory arising from activities and events previously considered off-limits were also included.

3.3 Focus on the turnaround

We have discussed in Part 2 - Extending A-CDM how the CDM concept works and how collaborative decision making improves the overall working of the ATM network. In Part 3 - Welcome to titan we have discussed how trajectory based operations brings every aspect of air traffic management together, how the trajectory acts as the common denominator around which common situational awareness can be built by sharing information.

When thinking about ways to leverage benefits from going beyond the A-CDM baseline implementation, we also agreed that, for practical reasons, this should be done keeping the original airport orientation of A-CDM intact. We have however also said that the extension should consider also influences on the trajectory that come from beyond the airside of the airport.

The basic A-CDM implementation covered most of the operational aspects from variable taxi time calculation through collaborative pre-departure sequence to collaborative flight updates. The milestones approach provides a good handle on the progress of the turnaround process. So, how can we improve on what A-CDM has already done?

Let's take an imaginary magnifying glass and hold it over the turnaround with its A-CDM milestones and other concept elements all implemented. Looking closely we will see that the idling trajectory, with its time dimension ticking away, will occasionally twitch slightly, a milestone or two turn red as a warning showing that something is amiss with the turnaround. Every so often it will be clear that the distortions come from events that A-CDM has no knowledge about or influences that are too subtle for the milestones to pick up individually but added together, they suddenly add up to a major distortion that could have been avoided if only the evolving problem had been visible earlier.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Conclusion? If we increase the granularity of the turnaround picture, if make it High Definition instead of being just good, if we extend the horizon to include hitherto unnoticed signs, we can arrive at a completely new understanding of the various effects on the turnaround and by managing them properly, we can improve predictability even further. This is A-CDM on steroids. This is TITAN.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

4. PART 3 – WELCOME TO TITAN

4.1 What is TITAN?

The abbreviation TITAN stands for Turnaround Integration in Trajectory and Network and it refers to a European Union (EU) Seventh Framework Program that ran for a little over three years and ended on 28 February 2013. Eleven companies took part in the work which was led by INECO of Spain[8].

Figure 12: TITAN Consortium

It was set up to analyze the aircraft turnaround process with a view to identifying opportunities for improvements as well as to identify the potential influence of processes traditionally external to CDM like passenger flow and baggage handling (including cargo). The improved turnaround concept was modelled and validated and a decision support tool developed suitable for use by different partners, enabling them to manage the turnaround process more efficiently. This was achieved primarily by providing predictive, common awareness of all the relevant influences, including those coming from the airport land-side.

The results from the TITAN project are complementary to the Collaborative Decision Making related activities of SESAR and feed directly into the relevant work packages there. This complementarily was seen as particularly important since CDM in SESAR was not looking beyond the traditional A-CDM boundaries.

[8] You can find all the project information at: http://www.titan-project.eu (available until the end of 2013). For additional information after the web-site is no longer available, please contact the authors at steve@bluskyservices.com and anacsaez@gmail.com.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

The following diagram shows how TITAN fits on the SESAR time-line and the three Implementation Packages (IP) that project has defined.

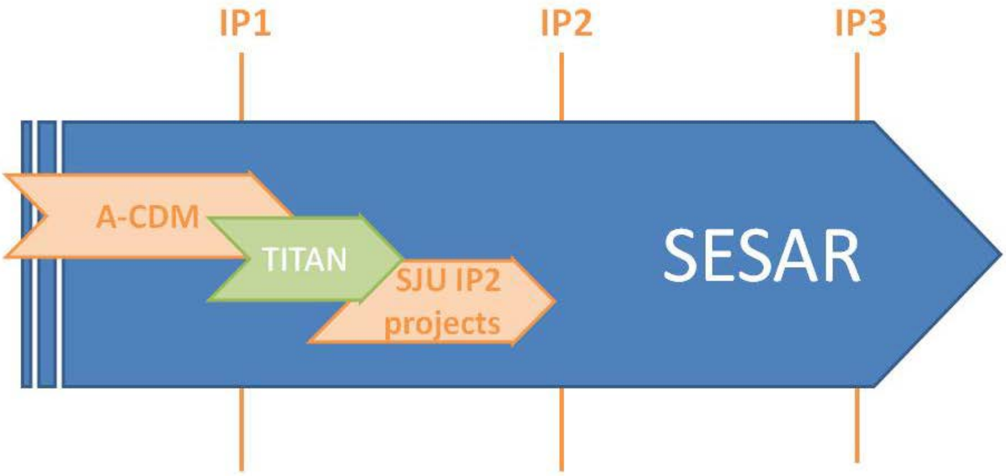

Figure 13: SESAR Implementation Packages

TITAN builds on the assumption that A-CDM has been implemented at the airports where partners wish to introduce this advanced A-CDM functionality. TITAN was built to be able to seamlessly integrate into a SWIM environment, however, it is also able to exchange information in a legacy environment and as such it can be implemented whether or not SWIM is available.

When the TITAN partners met for the kick-off meeting of the project in Madrid, Spain, the task to be carried out was pretty clear. Create something that takes A-CDM into the future, something that preserves all the benefits of A-CDM but it goes to the next step of refinement enhancing benefits to all partners even further. What is more, TITAN had to fit into the future ATM environment and as such, had to be compatible with trajectory based operations, System Wide Information Management and of course had to be compatible also with the legacy ATM environment. Last but least, although TITAN was focusing on the turnaround, it had to look at things way beyond the air-side to find the influences that can possibly have an impact on the turnaround and which had not been covered in A-CDM. In part, it was these additional influences that the project felt would have to be analysed if the "CDM on steroids" effect was to become reality.

Did you know... That the first proposal for a project to develop something akin to what in the end became TITAN had not been successful. The evaluators felt that more preparatory work was needed before money could be released for such a project. The second try went through with flying colours.

The proposal was also on the table: TITAN had to have a service oriented approach. Easy to say but this has never been attempted before. Other than in the L4CDM study mentioned earlier, CDM has never been the subject of an analysis to determine what kind of business services should be defined which would then drive the underlying IT solutions. Since TITAN was created to be an input to the CDM related work-packages of SESAR, and with SESAR itself being service-oriented, expectations were high: the way TITAN handled service orientation would be an important piece of information for SESAR itself.

4.2 Realizing service orientation

When the work started, the TITAN consortium faced the same problem many other have faced before them: defining business services for any new area is not a trivial task. What is more, a new type of thinking is required. Thinking in terms of services rather than pieces of hardware and software is hard enough but when these services need to be on the level of the business processes, our training from the pre-service orientation world shows up more as a handicap than anything else.

Of course the first order of the day is to accept that "services" here do not refer to IT services at all. The services here refer to those that are needed to support the processes running during and in connection with the turnaround and which are needed to accomplish the business objectives of the various partners. Note the fact that the term "business" has been introduced here... It echoes nicely with the concept of "business trajectory" we know already from earlier in this book. So, to find the services needed, we have to find the processes that are needed to realize the business objectives.

TITAN defined “process” as a sequence of interdependent and linked procedures which, at every stage, consume one or more resources (employee time, energy, machines, money) to convert inputs (data, material, parts, etc.) into outputs. These outputs then serve as inputs for the next stage until a previously established goal or end result is reached.

Processes are therefore fixed, step-by-step sequences of activities or courses of actions (with definite start and end times) that must be followed in the same order to correctly perform a task.

TITAN considers turnaround as a process composed of several sub-processes. Its final objective is to prepare the aircraft and achieve the target times agreed in the 4D trajectory. Each process feeds into or uses one or more service, which in turn may be inputs for other sub-processes. Consequently, a service is something that is needed for a sub-process to proceed, the subsequent delivery of services contributes to the overall aircraft turnaround process completion.

In order to define a process a number of steps need to be undertaken in order to identify the specific parameters of that process:

- *Identify process boundaries*: in other words to establish the start- and end-times. The start is usually triggered by a specific action while the end-time implies that the expected output or the service goal has been achieved;
- *Identify the inputs* needed that usually trigger the process (e.g. data, resources or services);
- *Identify the TITAN milestones* linked to the process. A milestone is defined as a significant event that occurs during the evolution of the aircraft trajectory;
- *List and describe the activities* included within each process and the role of the actors assigned to them. The activities to be performed within any process or sub-process are usually linked to a specific actor and to a specific goal;
- *Identify the outputs* regarding to data (information) and services.

To get a clear picture of the processes to be identified, it is necessary to know where they occur.

As you will remember from the story of L4CDM, the definition of air-side and land-side is contentious issue and in L4CDM it was even decided to discard this legacy division as it represented an unnecessary complication in describing the processes involved in the turnaround. TITAN did not cast away the division, mainly to remain compatible with SESAR. However, an additional complication arose when it was discovered that the traditional definition of air-side and land-side was different from current usage. Traditionally, the "sterile" area of the airport (basically everything beyond the first exit control/security control) was considered as the air-side, extending all the way to the aprons and taxiways/runway. Everything else was considered to be the land-side. SESAR on the other hand considers air-side as being limited to where aircraft move around

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

or are parked, everything else is land-side. We will not go into the logic of this here, let it suffice to say that this kind of division reflects thinking that is not process based. Anyway, in order to remain compatible with SESAR, TITAN has stayed with the new definitions, as follows:

Air-side: The continuous area within and extending to the airport perimeter, prepared, intended and set aside for the movement, servicing and loading of aircraft, or where aircraft can otherwise be situated.

Land-side: The portion of the airport that is not considered as airside is considered as landside. It consists primarily of passenger and cargo terminals, including appurtenances that may extend onto the airside, and those other facilities not located within the area defined by the term airside.

If you look at the above definitions, it is clear that the division is totally arbitrary and their existence from the CDM perspective makes little sense. This fact is highlighted especially when we start looking at the processes for which we want to identify the services needed. While some processes can be seen as remaining on one or the other side of the division, many others are oblivious to this artificial division. They stretch right through it and in fact need to be considered as such or else they lose their meaning. Air-side and land-side may be meaningful for security and the authorization to move around the airport but from a process view of airport operations, it is meaningless.

Anyway, staying within the limits of existing thinking, TITAN identified the following main air-side processes:

- Passenger embarking/disembarking (including disabled passengers and unaccompanied minors)
- Loading/unloading of baggage
- Loading/unloading of cargo/mail
- Positioning of air bridge and stairs
- Refuelling
- Aircraft cleaning
- Catering replenishment
- Maintenance
- Start-up and push-back
- De-icing at stand
- Stand allocation

The land-side processes considered by TITAN are the following:

- Check-in
- Assistance to disabled passengers and unaccompanied minors
- Passenger security control
- Passenger passport control (if applicable)
- Passenger boarding/de-boarding
- Baggage security process
- (Boarding) gate allocation

Several so called common-processes have also been identified, which stretch across the artificial boundary and hence cannot be classified under air-side or land-side. Putting them into both would not work either as this would create the impression that we were dealing with two separate entities when in fact they are one continuous stream.

Common processes are:

- Passenger tracking: scanning the boarding passes at check-in, security control, passport control (if applicable) and at the entrance of all major concessions and generating an immediate warning to the passenger if flight departure is within a set time period.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Note: Permanent monitoring of passengers, while technically feasible, cannot realistically be implemented in the TITAN time frame. However, having a check-point based solution would not prevent permanent monitoring from being implemented at a later date, as the two would be compatible on the system level and once permanent monitoring is in place, the checkpoint system could be deactivated.

- Baggage tracking: similar to passenger tracking, but related to baggage.
  This process will imply the scanning of baggage thanks, for instance, to individual tagging by Radio Frequency Identification (RFID) or the current tags through several check-points both in landside and airside (including the aircraft deck).
- Cargo/mail tracking.

In keeping with the TITAN concept that recognizes the effects of processes that are firmly off-airport yet can have a major impact on the evolution of the turnaround, TITAN introduced the idea of off-airport processes. For the sake of simplicity, only the airport access facilities (train, taxi, roads, underground) were included, on the understanding that there may be several more that need to be taken into account in a real life implementation.

Effects coming from the ATM network were also included, mainly the slot allocation process from the Network Manager as this has a fundamental influence on the turnaround.

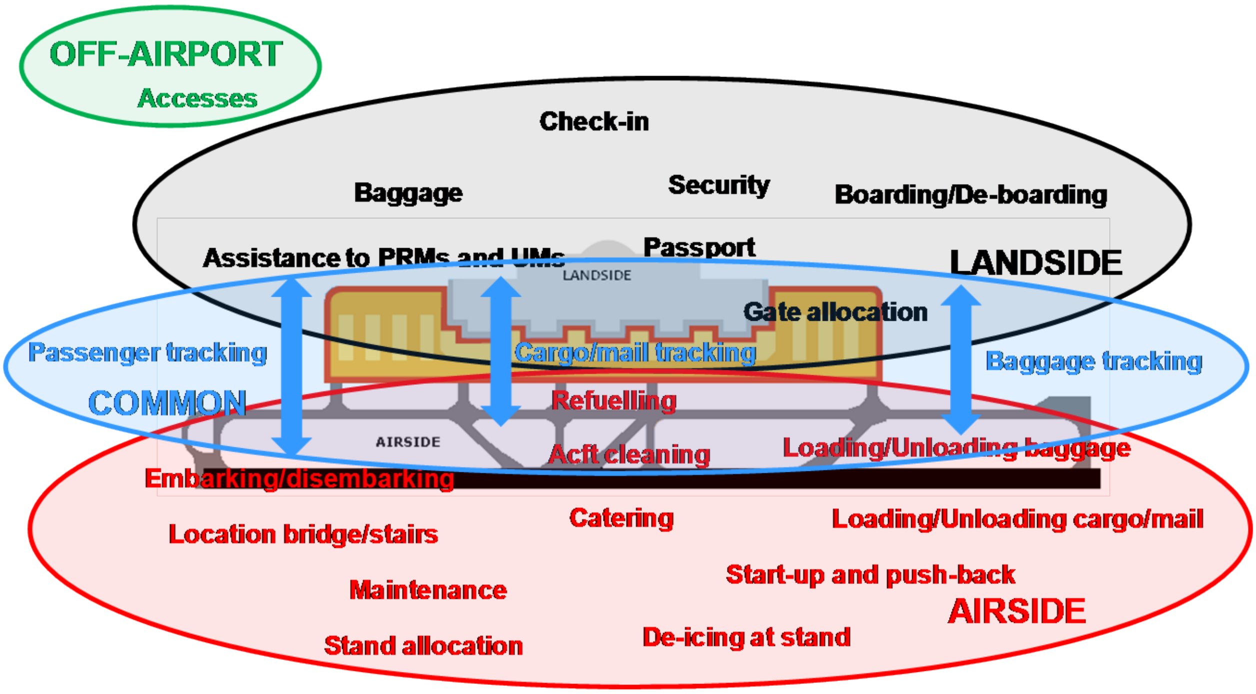

Figure 14: TITAN processes distribution

> Did you know... That by going for a service oriented approach, the TITAN Concept of Operations document provided one of the clearest descriptions of the business processes and related services of the turnaround ever created from an ATM perspective?

Having obtained some clarity on the processes involved, the next step was defining the services that will be needed to support the processes. It needs to be said right here that the services

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

eventually identified and tried out by TITAN are not at all the final word on the kind of services that the turnaround process needs. They are the most essential, for sure, but others may be identified depending on local circumstances or in case developments in other areas require the introduction of new services. If you recall what we said about the information sharing principles in the description of SWIM, it is easy to see that adding new services should not be difficult in an environment where everything, the services included, are using the same shared information space and are thus integrated while at the same time also being open to the addition of new elements without having to change the existing service set up.

The "shared information space" mentioned above is being referred to in TITAN as "TITAN Information Sharing" or TIS. If a SWIM type environment is available, TITAN will use that as its information space. If A-CDM Information Sharing is available, this can also be used by TITAN. TIS was defined only to ensure that it remains usable also in environments where its specific needs are not met by the existing environment.

But what is the definition of services in TITAN?

Services are supporting the processes identified in TITAN. In order for a process to run and complete properly, information is needed. Processes themselves also generate information which in turn is needed by other processes... or humans for decision making. It is the services that ensure that processes have access to the information they need and that their information is shared properly.

The time-scale of TITAN did not allow for a complete breakdown of all the possible services that may be needed, however, the most important ones were identified and described, on the understanding that they cover most of the processes listed as part of the TITAN scope... which we know is larger than that of A-CDM since it takes also land-side and off-airport processes into account.

The selection was made on the basis of the information needed and provided by each of the processes by allocating an appropriate service to each of the information elements concerned. This resulted in the following services[9]:

Passenger Flow Information Service (PFIS)

The passenger flow process is subject to several possible disturbances at different points of the flow. The effects of a disturbance depend to a large extent on the organisation of the process which determines where the source of the disturbance is located along the process. Tightened security or a scanner failure will impact the process differently if the passenger screening is centralised or boarding gate based.

With the expanded scope of TITAN, influences as diverse as airport access road conditions and train driver industrial action can be included to generate a good picture of the evolution of the passenger flow process. The time scope is not limited to the present or immediate future. Planned industrial action several weeks or even months in the future are also considered by the service.

PFIS follows the passenger flow and identifies possible or actual disturbances. The information generated by PFIS is published into the shared information space to be made use of by different end-user applications. These may be as simple as a warning displayed at a working position or they may take the form of more advanced, intelligent applications that are able to interpret the state information and initiate defined, context sensitive actions. The actions concerned will be mainly those aimed at mitigating the effect of the distortion (e.g. opening additional Passenger Screening lanes, hiring alternative transport, etc.) or, if that is not possible, start action aimed at

[9] TITAN services were defined in the TITAN Concept of operations. Available at: http://www.titan-project.eu/library/titan/TITAN_WP1_INE_DEL_04_v1.0_TITAN_Operational_Concept_Issue1.pdf

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

minimising the effects of trajectory distortion that may potentially be caused by the disturbance. The users of PFIS may be systems which support other operational processes.

Following this rationale, the purpose of this service is to provide real-time information on the passenger flow on and beyond the airport as an enabler for warnings (when comparing the actual and the planned information) and intelligent applications that can react to disturbances in the passenger flow with a view to mitigating their effect.

In terms of granularity, the service aims primarily to generate state (current and future) information based on the global aspects of the passenger flow process. This means that the basic PFIS does not differentiate between the effects on the operation of individual partners.

PFIS will require the implementation of facilities that can monitor the passenger flow at different, required points, correlating the movement data and trends to generate the appropriate conclusions. It is important to remember that passenger tracking may involve issues related to the need for protecting personal data. Such issues were out of scope for TITAN but will have to be addressed and properly resolved in any real-world implementation.

Baggage Flow Information Service (BFIS)

BFIS works in a way similar to PFIS, except that it is applied to the flow of baggage. In this case, tracking does not raise any privacy issues and hence can be realized to the degree required by the operation without undue limitations.

Cargo/Mail Flow Information Service (CMFIS)

CMFIS is similar to PFIS, except that it is applied to the flow of cargo and mail carried in the hold of passenger aircraft. With the increasing importance of hold cargo for many airlines and the substantial capacity offered in this regard by many aircraft types, the importance of CMFIS will only grow in the future. Disturbances in the flow of cargo and mail will increasingly impact the turnaround and the need for collaborative decisions will also increase as a consequence.

Aircraft Status Report Service (ASRS)

A notification about the status of the aircraft during the turnaround activity is crucial for all of the actors of the process. A delay in one of the turnaround activities may affect other ones and can influence the scheduled departure of the flight. The actors of the turnaround process need to have reliable information about the flow of the process.

ASRS gives information about the status and the position of the aircraft e.g. allocated stand, end of de-icing time, etc. It can alert users if a delay is foreseen or some other disturbance is noticed.

Airport Information Report Service (AIRS)

This service provides information about the availability and allocation of the airport facilities (boarding gates, baggage belts…) and can serve as the primary trigger for users of the airport to consider eventual modifications to their trajectories taking into account present and future considerations, such as meteorological conditions, runway usage, etc.

Services are applied at the appropriate points of the processes they support, taking varying lengths of time. The services are provided by different partners at different times as required.

A particular process may be provided with a given service by only one provider of such a service at any given time. In all other aspects the relationship between providers of services and the processes is unlimited.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Providers of services may be present locally where the process is being executed or may be remote, as appropriate.

The providers of the services are normally organizations specialized in the support of one or several processes. They are all tied together and have the same, common situational awareness through the shared information space.

The users of the services are the processes that need to be executed as part of the turnaround. Use may be direct (when the service feeds into a process element running in software for instance) or indirect when e.g. a service feeds into an end-user application that in turn supports a human operator.

What are the services used for?

Well, here we go back to the roots. The information gathered and delivered by the services is shared and partners use it to feed their end-user applications that support collaborative planning and decision making. In fact, the TITAN tool (one of the products of the project we will talk about later) is an example of such an end-user application that supports decision making.

4.3 Information sharing in TITAN

As mentioned earlier, TITAN was designed to be completely in line with the information sharing principles of the future SWIM environment. But it can also operate in legacy environments. Where A-CDM Information Sharing is available, TITAN joins the sharing environment in a seamless manner. Where this is not possible for some reason, TITAN will use its own definition of information sharing which in fact creates a mini-SWIM island, geared to the information sharing needs of the TITAN tool. Of course a pre-requisite for this to work is the availability of the required input information.

4.4 The TITAN milestones

As we know from the description of the A-CDM Milestones Approach, using milestones to track the evolution of a process helps in discovering looming problems early, giving more time to agree remedial measures. What is more, the A-CDM milestones had helped, for the first time ever, to connect subsequent flights allocated to the same airframe also from an ATM perspective.

In a way we can consider TITAN as a magnifying glass that is put on top of A-CDM. The aim is to generate more detail in the common pictures partners share and hence make even the small ripples immediately visible so that they can be caught and eliminated before they escalate into bigger problems. If this is not possible, at least to provide as much advance notice as possible so that partners have more time to come up with remedial action.

One way of adding more detail to the picture is of course the addition of more milestones. So, while TITAN knows about and uses all the A-CDM milestones, a bunch of new ones have also been defined and these make all the difference.

> Did you know... That even the airport garage and the car rental companies can supply important additional information to the Passenger Flow Information Service? A peak in garage entries or in rental car returns means a peak at security in 30 minutes or so...

What is more, the TITAN milestones now connect the air-side and land-side processes, making their interactions visible on a timely basis, again for the first time in CDM history.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Here are the TITAN milestones as specified in the project:

TITAN Milestones	Rationale
M17. Close check in	Boarding can start. Passengers and baggage list closed.
M18. Last passenger crossing security control	Passengers monitoring. Means to know whether a passenger arrives to boarding gate on time or not.
M19. Last passenger crossing passport control	Passengers monitoring. Means to check whether a passenger has been rejected at passport control.
M20. End of deboarding	Ground handling activities on passenger cabin can start.
M21. Last baggage delivery to hold baggage bay	Baggage monitoring.
M22. End of baggage unloading	Baggage loading can start.
M23. Close cargo doors	Baggage monitoring.
M24. Start of fuelling	Inform firemen if needed. Specific processes have to be ready to start fuelling.
M25. Remove push back	Stand and gate available. Aircraft can move by itself.
M26. End of de-icing	Time for take off is limited.

The numbering is sequential to the numbering of the basic A-CDM milestones but in fact these milestones sit in-between the elements of the original set. Like in A-CDM, the selection of milestones is a matter of professional judgment and common sense.

The advantages of the service oriented approach, where IT services and business services are firmly separated from each other, with the latter driving the former, are immediately apparent here also. Additional milestones may be identified as required and the underlying IT infrastructure will have to ensure that the required information is made available in the shared information space.

4.5 Integration with the SESAR ground trajectory

The Business Trajectory concept contains both the air and ground segments of the trajectory. Originally, however, the turnaround was excluded from the ground segment which looked only at processes between landing and take-off but not the turnaround (the idling trajectory). Once the turnaround is integrated into the ground segment, we get the so called Airport Business Trajectory (ABT) which of course covers all the processes that impact the trajectory in any way.

TITAN follows this setup. The milestones cover the ABT to the required detail and it is easy to add more milestones as necessary, with the ABT forming the common thread.

4.6 Validating the TITAN concept

Although one could think of TITAN as a refined version of A-CDM focusing in even more detail on the turnaround, the fact that TITAN brings in land-side and off-airport processes and partners as well as the service oriented approach chosen meant that the concept had to be validated in its own right.

Right from the start, TITAN embraced the European Operational Concept Validation Methodology (E-OCVM[10]). The E-OCVM was originally launched in response to the requirement to have a coordinated and harmonized approach to research and development across the aviation industry, R&D organizations, Air Navigation Service Providers and EUROCONTROL. E-OCVM was also endorsed by the European Commission and its use was made mandatory for all ATM projects dealing with research and development.

The TITAN consortium placed particular importance on setting up a validation exercise that would result in credible information on the power of the concept. This was felt essential since new approaches, new solutions inevitably raise questions about their usefulness and it is always better to have good answers to such legitimate questions right from the start.

Several methods are available to validate a concept, their suitability depending on the maturity of the concept to be validated. Modelling, expert groups, gaming, fast time simulation, real time simulation and live trials are all available, though their price impact differs widely.

Taking all relevant considerations, including cost, into account, TITAN decided to use expert groups and gaming and later fast time simulation using a model developed within the project to validate the concept. This was based also on the E-OCVM V1 maturity level at the beginning and the V2 maturity level later on, by which time the model based simulation became appropriate.

The gaming exercise was set up with a view to assessing the feasibility and usability of the information exchange envisaged in the TITAN concept. Qualitative results were obtained in respect of the information available in TITAN, the TITAN services themselves and the impact of the implementation of TITAN in a representative ATM environment.

A web tool was developed to present the information delivered by the TITAN services. The tool also included a chat facility so that the game participants could communicate with each other while the game was running. This facilitated the task and helped in everyone working to the same standards and the post analysis of the gaming sessions.

Here is an example of the web tool interface used in the gaming exercise:

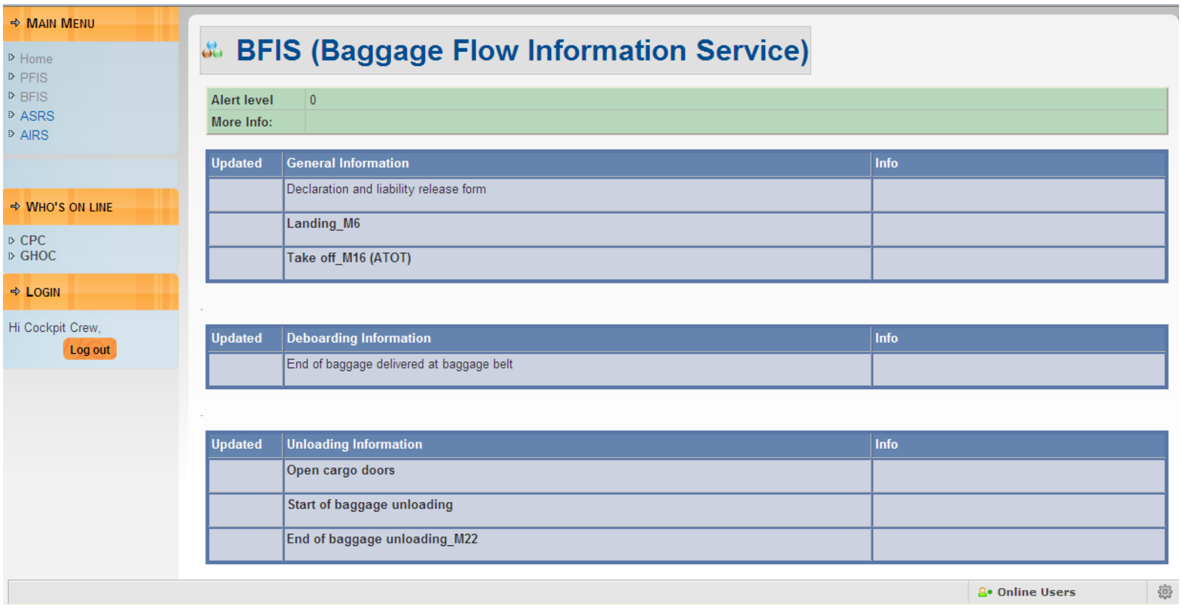

Figure 15: Gaming web tool interface screenshot

[10] E-OCVM Document and Support Material at:

http://www.eurocontrol.int/valfor/public/standard_page/OCVMSupport.html

The gaming exercises had shown clearly that the concept was feasible. Only minor changes were made to the concept of operations as a result of the gaming runs, mainly to clarify some aspects.

The TITAN model[11] was a gem. It made it possible to set up any desired airport scenario with complete flexibility in adding resources, facilities, outside conditions as well as limitations affecting the operation. It was also possible to design in operational conflicts, like occupied gates. A lot of effort went into designing and programming the model but this was understandable. After all, the credibility of the fast-time simulation in which the model would star was dependent to a very large extent on the credibility of the underlying model.

Here is a sample of the model's user interface to give you a feel for its multitude of functions.

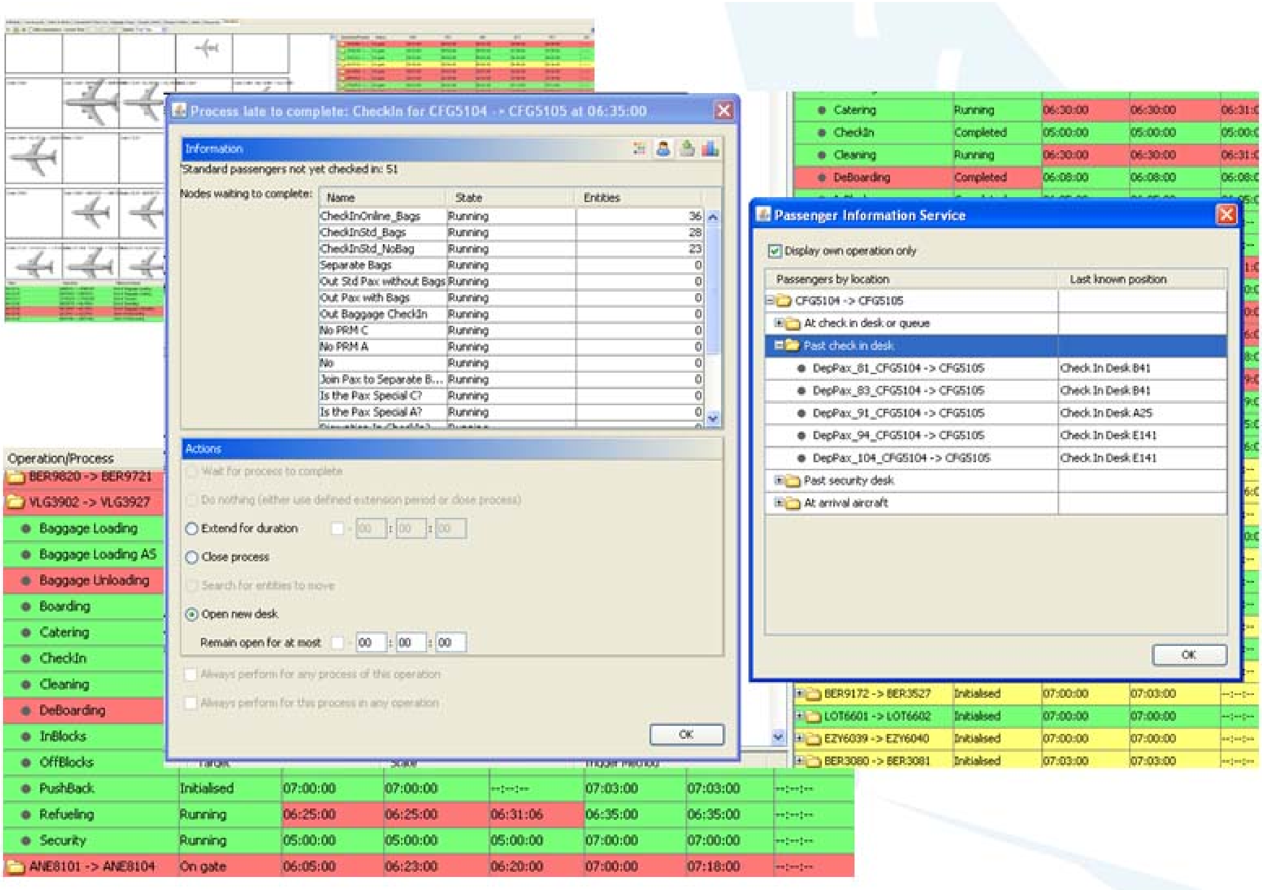

Figure 16: TITAN Validation Model Screenshots

The framework of the (V2) validation exercises was a generic large airport, corresponding to the EU community airport category. The validation traffic sample was a 24 hours traffic sample, corresponding to a representative day in the airport, consisting of 339 operations. The scenarios defined had various combinations of Schengen and non-Schengen flights and disruptions introduced artificially into the normal operation using the process editor.

A total of 330 simulation scenarios were run to validate the Concept in which passengers arrive late to different sub-process check-points, the amount of delayed flights varies, the demand is gradually increased or different levels of availability of resources are considered. Moreover, disruptions in different turnaround sub-processes were introduced to analyze the knock-on effect and measure the recovery delay factor. To analyze the benefits of service orientation, the model was programmed with the TITAN services, passenger walking distances within the airport, the

[11] TITAN Model is available at: http://www.titan-project.eu/library/titan/TITAN_WP2_ISA_DEL_07_v1.0_TITAN_Executable_Model_READMe.pdf

traffic sample, the available resources, the sequence of the various processes and the constraints between the different processes. Finally, pre-determined disruptions were added. It was here that the insistence of the model designers on having a lot of flexibility built in brought immense benefits. Setting up the simulation runs was much easier than it would have been with a less comprehensive model.

The results[12] spoke for themselves. When the operation without TITAN was compared with the operation with TITAN, the improvement was striking. The percentage of delayed[13] sub-processes with TITAN dropped substantially.

These results, in a comparison of TITAN and Non-TITAN scenarios are graphically illustrated in the following figures. With respect to the turnaround process and sub-process (boarding, catering, cleaning, refuelling, etc.) delays, the percentage of flights with a difference between actual and planned Off Block Time (OBT) or between actual and planned (sub-process) completion time greater than 15 minutes is reduced after TITAN implementation (Figure 13 and Figure 14). Standard deviation of the OBT difference values is always reduced when comparing a TITAN scenario to the corresponding Non-TITAN scenario (Figure 15)

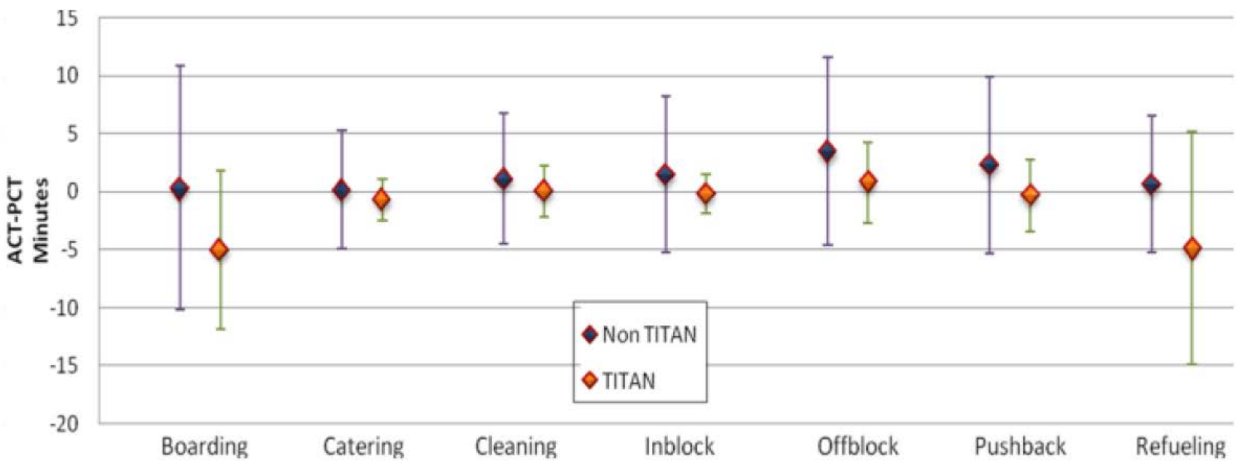

Figure 17: Delay turnaround sub-process

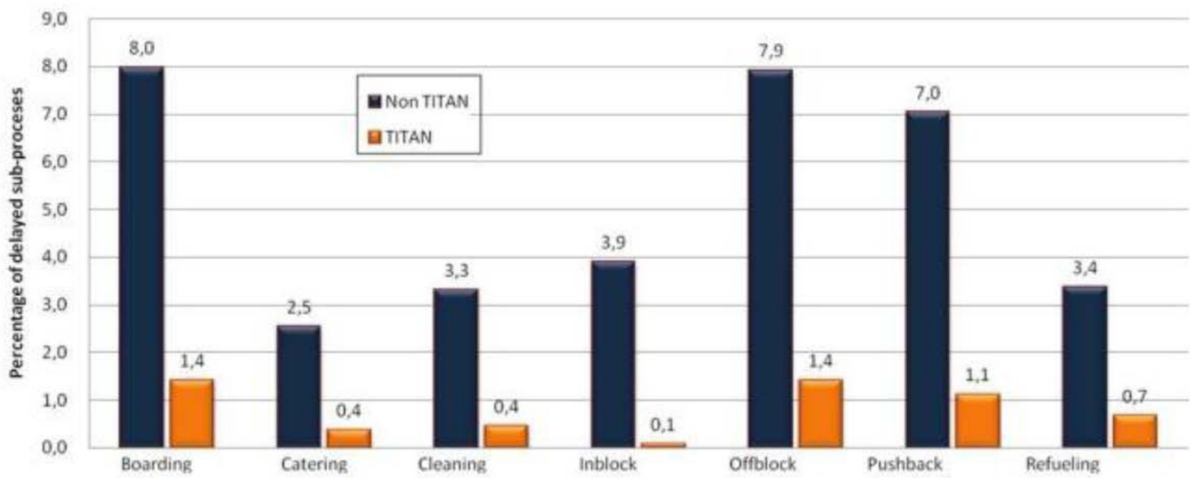

Figure 18: Percentage of delayed turnaround subprocesses

---

12 TITAN Validation results are available at: http://www.titan-project.eu/library/titan/TITAN_WP3_AEN_DEL_04_v1.0_Validation_Report.pdf

13 TITAN Project is considering as delayed those flights, processes or sub-processes with a delay higher than 15 minutes.

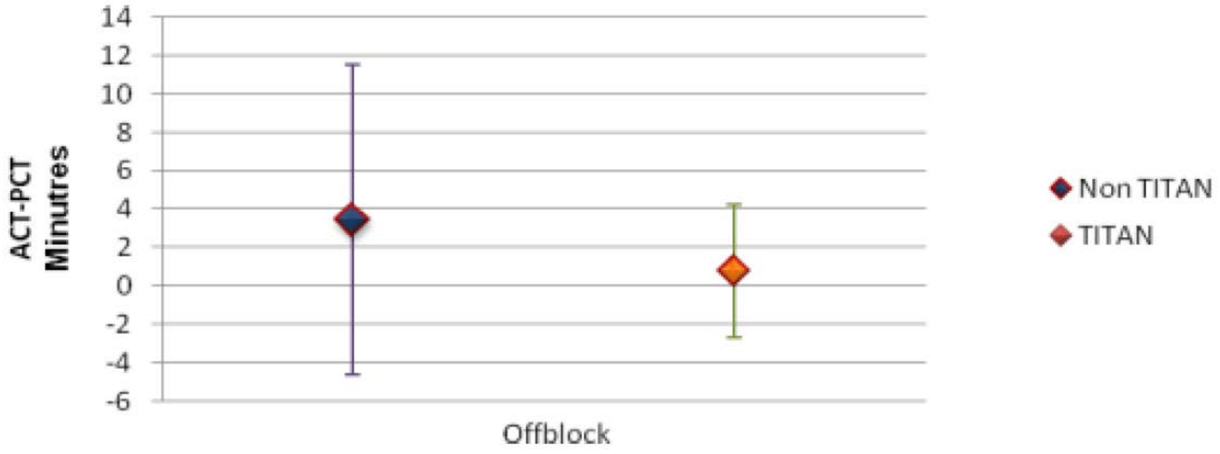

Figure 19: OBT Standard Deviation

4.7 The TITAN tool

Perhaps the most exciting development inside the TITAN project was the creation of the TITAN tool[14]. Its name is rather pedestrian especially when we consider that it was the TOOL in which the results of all the concept and validation work culminated, where paper became reality. At least to a large extent.

One of the high-level TITAN objectives had been to develop a decision support tool for airlines to achieve a more efficient turnaround process by implementing the TITAN concept. The TITAN Tool is in fact a non-commercial demonstrator composed of a sub-set of the eventual commercial TITAN tool. Enough of the requirements have been implemented in this demonstrator to effectively execute the restricted scenarios.

Here is the context of the TITAN Tool (next page):

[14] TITAN Tool available at: http://www.titan-project.eu/library/titan/TITAN_WP4_JEP_DEL_04_v1.0_Turnaround_Tool_Demonstrator.pdf

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

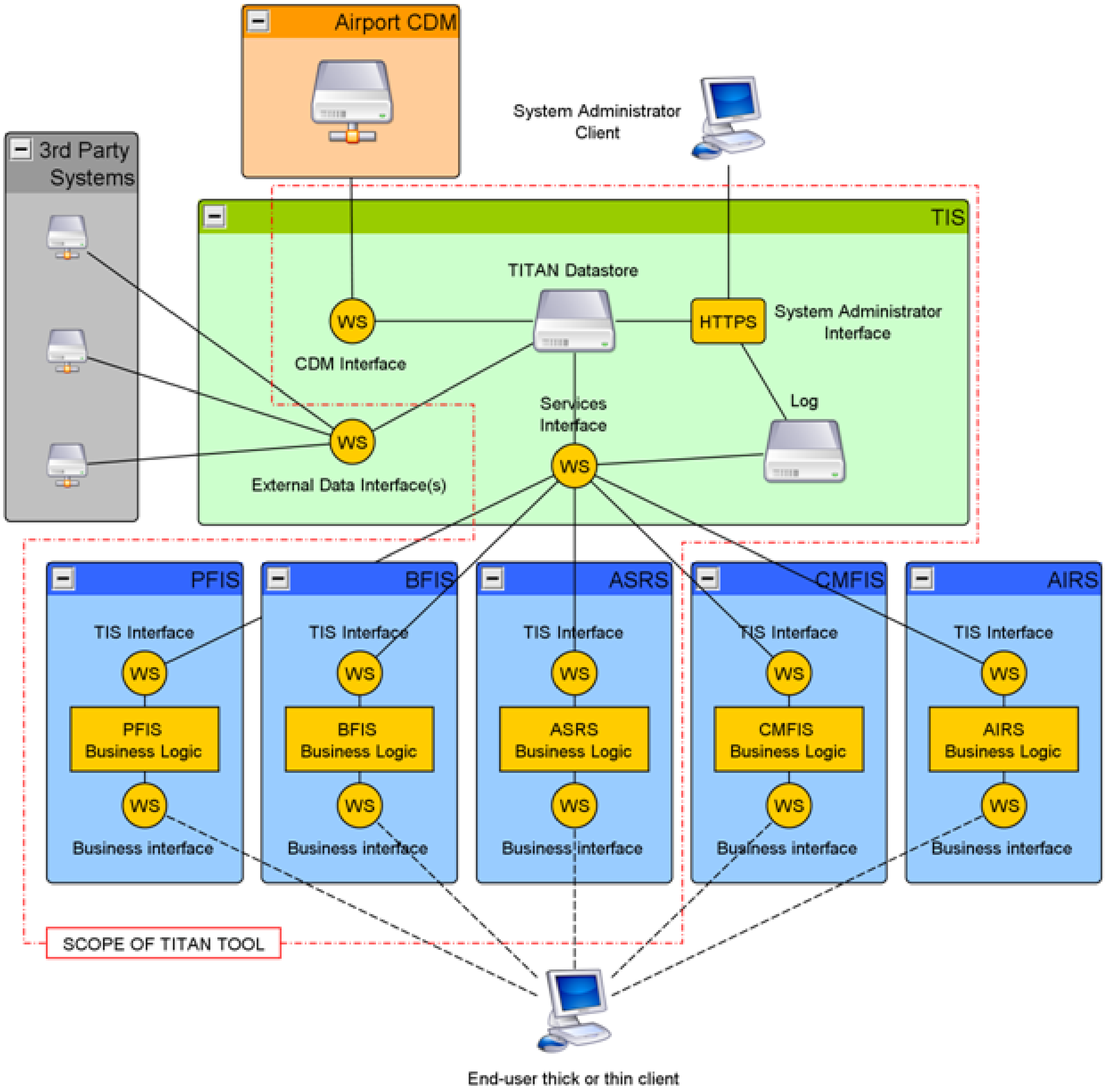

Figure 20: TITAN Tool architecture

The tool has a service oriented architecture and when it was tested, the A-CDM environment was only emulated. The tool was verified against the TITAN operational concept and passed with flying colors. What was the significance of all this?

If you recall the nice drawing we had about SWIM in 3.1.4, you will remember that the end-user applications were mentioned repeatedly. We have also said that the benefits of SWIM will not come necessarily from SWIM itself, but from the end-user applications it enables. TITAN is a shiny example of an end-user application!

It builds on the availability of information sharing and brings added functionality to an end-user, in this case an airline. However, similar end-user applications could be envisaged for other partners also, in each case applying the TITAN concept but with the application customized for the given partner.

This kind of environment opens up almost endless possibilities for the partners as well as value-added resellers who can come up with ever more ideas for exploiting the new information sharing environment and benefitting all concerned in all kinds of novel ways.

The TITAN Tool as implemented in the project was a limited demonstrator, but even then it had some impressive decision support capabilities. Just look at the sample user interface to see the wealth of information it offers for a missing passenger.

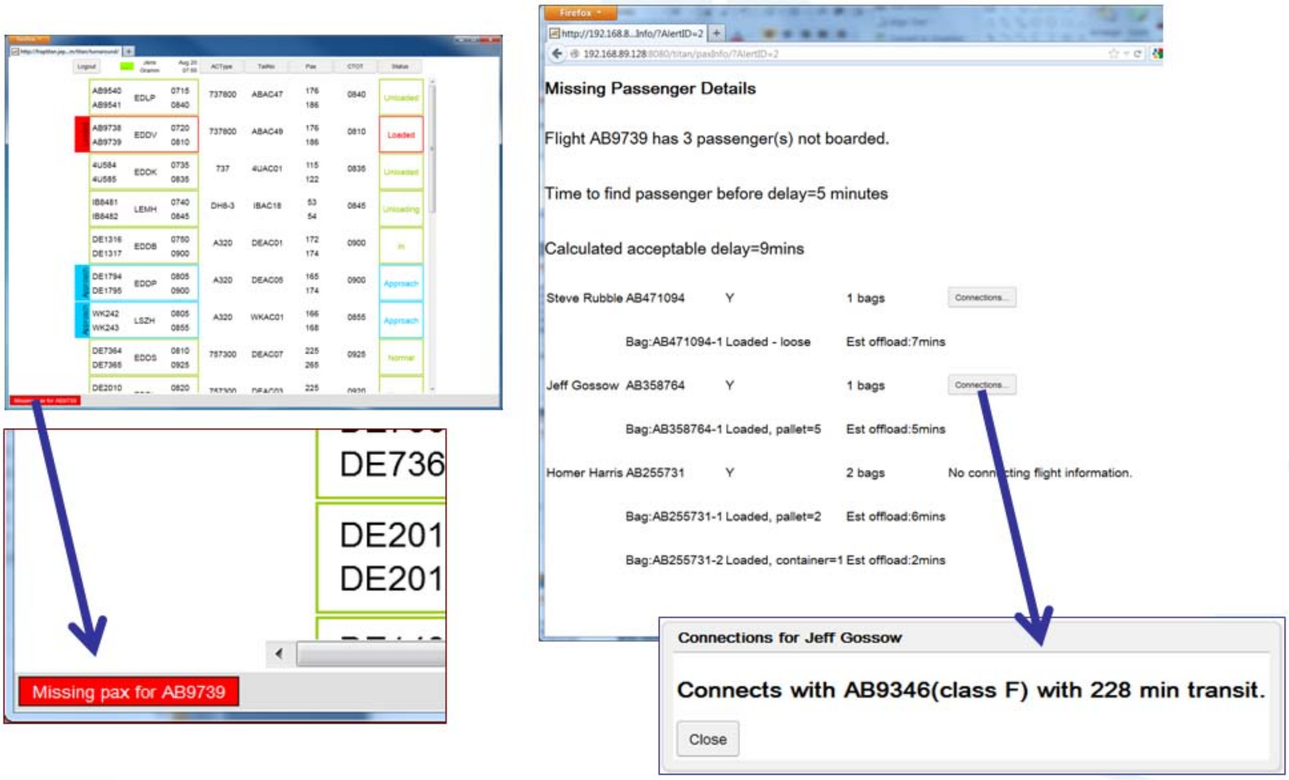

Figure 21: TITAN Tool sreenshots

Perhaps not unique in the sense that big airline systems may have similar functions but in the context of A-CDM TITAN was the first to realize this on the basis of a shared information space.

4.8 The TITAN cost-benefit analysis (CBA)

Having shown the TITAN works and delivers the promised benefits is of course only one side of the equation. The first question asked by the decision makers after a presentation extolling the virtues of TITAN is: yes, but how much does it cost?

With TITAN being a follow on to A-CDM, one could assume that its cost/benefit ratio may be similar to that of the original concept. On the other hand, we are talking about enhanced functionality and the enhancements will not necessarily generate benefits at the same rate to all the partners. In A-CDM after all, most of the benefits came from information sharing and they applied at roughly the same rate to all partners. TITAN makes use of information sharing but it cannot take credit for the benefits this brings in itself... TITAN must have something else up its sleeve that generates its own benefits and which can then be set off against the incremental costs TITAN implementation represents.

The TITAN CBA[15] activity covered two important tasks. First, a methodology appropriate for the TITAN tool was defined. Then this methodology was applied to the TITAN tool, basically comparing the "do nothing" alternative with the "tool in place" alternative, both considered in the context of a generic operational scenario.

The methodology adopted paid special attention to the need to avoid a number of common mistakes in CBA's. The most important of these are double counting, overlooked or under estimated costs, inconsistent cash-flow data and missing dependencies between variables. Like the validation of the concept, the CBA also needs to be totally credible if the project results are to be accepted and actually used in decision making.

The TITAN CBA uses a conservative approach to both costs and benefits and has validated the input data in a number of ways, including workshops with the partners.

Avoiding mistakes, valid input data and a conservative approach to costs and benefits coupled with a clear methodology ensures that the results are credible and will be accepted.

But what do the numbers say?

In the CBA calculations the assumption was made that any partner using the TITAN tool will have to pay for it at equal level. This cost manifests itself as a one-off acquisition cost and recurring costs involved in the operation of the tool.

As we already know, the main benefit of TITAN is a further increase of predictability of the turnaround. This benefit can be translated into monetary terms through delay reduction savings for the airlines and operational cost reduction for all the other stakeholders.

In the CBA it was assumed that the TITAN tool will bring as a minimum a 1% operational cost reduction for all partners. Accordingly, all statements in the CBA must be understood to mean that they are true if the TITAN tool actually generates a 1% operating cost reduction.

Net Present Value (NPV) is one of the important figures coming out of a CBA. NPV is the difference between the present value of cash inflows and he present value of cash outflows. In other words, NPV compares the value of a euro today to the value of that same euro in the future, taking inflation and the return into account. If the NPV of a prospective project is positive, it should go ahead. If the NPV is negative, this means the cash flows will also be negative. Time to think about the wisdom of investing in the project.

The TITAN CBA has shown that the NPV for airlines and airports is positive at 5.261.007,20 and 783.455,65 respectively.

The NPV for ground handlers and ANSPs is negative at -46.153.19 and -126.966,00 respectively.

This negative result is due to the relatively modest benefits ground handlers and ANSPs will see from the TITAN tool while still being required to pay for it (the problem comes mainly from the recurring costs). It is obvious that by adjusting the amount to be paid by the different partners to better match the benefits they obtain, positive NPVs for both ground handlers and ANSPs will become possible and hence a business case can be made for all four of the major partners.

So, in summary, the CBA analysis shows that on an aggregate level for all four partners on a generic airport the implementation of the TITAN tool is positive, under the assumptions applied including the assumption that it would lead to a 1%[16] operational costs reduction for all partners.

[15] TITAN CBA results available at: http://www.titan-project.eu/library/titan/TITAN_WP5_BRT_DEL_02_v1.0_CBA_for_TITAN_Tool.pdf

[16] Some stakeholders indicated that implementing TITAN will reduce their operational costs up to 5%. TITAN took this assumption as it was the most conservative one.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

The analysis shows that on partner level, the CBA is:

- very positive for airlines
- positive for airports
- negative for ground handlers and ANSPs

The following conclusions can be drawn from the complete CBA exercise:

- Recurrent costs drive the total costs for each partner. Recurrent costs are assumed to be the same for each partner type, but do not vary with the number of actors in a partner category in the current set of assumptions.
- There is an uneven distribution of costs and benefits among the four partner types. Airlines benefit significantly more while their costs are roughly at the same level as for the other ground handlers.
- The assumptions regarding the number of ground handlers, three, on the generic airport under study influence the results. Each ground handler incurs the full costs, while it receives only one-third of the ground handling benefits.
- The CBA results for each partner are very sensitive to the assumption adopted on the operational costs. If the reduction of the operational costs would be 1.5%, there would be a CBA for each of the four partner types. The interview conducted with partners indicated that for airlines this percentage is deemed an underestimation. The ground handlers that have been interviewed indicated a range from 0% (no impact) to 5% (only when the delays are the responsibility of the ground handling agent).

Based on the analysis and conclusions, the following recommendations were formulated:

- The analysis shows that the TITAN tool may become a merit if the operational costs would reduce by 1.5%. It is recommended to partners to refine the analysis of the potential operational costs reduction for their own company cost structure to assess whether such target costs reduction may be achieved.
- The distribution of benefits among partner categories is uneven and on an aggregate level the benefits significantly outweigh the costs. It is recommended to a future supplier of the tool to structure its pricing strategy taking this into account.

Clearly, with a bit of extra preparatory work and good cooperation in implementing TITAN a very beneficial additional layer can be built on the already impressive results of A-CDM that will improve the results of all partners in CDM.

4.9 Integrating TITAN into the air transport environment[17]

Had we been a decade or so further down the road, with System Wide Information Management implemented across Europe and most of the legacy systems replaced by new ones, designed and

[17] There have been produced four documents regarding the integration, all of them available at:

http://www.titan-project.eu/library/titan/TITAN_WP6_BLU_DEL_01_v1.0_Integration_plan_AOC.pdf

http://www.titan-project.eu/library/titan/TITAN_WP6_BLU_DEL_02_v1.0_Integration_plan_airport_operations.pdf

http://www.titan-project.eu/library/titan/TITAN_WP6_BLU_DEL_03_v1.0_Integration_plan_reference_business_trajectory.pdf

http://www.titan-project.eu/library/titan/TITAN_WP6_BLU_DEL_04_v1.0_TITAN_related_transition_considerations.pdf

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

built along modern principles and the various data models to describe the air traffic management network agreed and in use... the task of integrating TITAN anywhere would be easy.

However, we are still some time away from that happy scenario. TITAN needs to fit into a largely legacy environment. This is particularly true when it comes to airline systems. They do incorporate some of the most advanced functions in the industry but when it comes to communicating with an outside agent like TITAN, the interfacing becomes a challenge.

Information sharing in itself is also an issue. Even at airports where A-CDM has been implemented, things tend to work on a legacy, messaging type of basis and the "shared information space" is little more than lots of messages being exchanged between the partners. Of course this is better than nothing but for a tool like TITAN, which was designed primarily to work in a SWIM type environment, this is one more area that requires adaptation.

Recognizing the above hurdles, the TITAN tool has been designed to have its own "shared information space" if there is no outside shared space to work with. Furthermore, the TITAN tool can share information also in the legacy way and understands all the various message formats and protocols used by the industry, also generating its own messages in whatever format is required.

Of course integration in the technical sense is only one side of the coin.

We know (it was said many times in this book) that CDM is first and foremost a new way of working, a change in decision making culture, something that needs to be learned and hence need to be taught. It does not matter how wide the new information set being shared is, if partners do not know how to make best use of it or if they continue to make decisions on their own with little or no reference to the available information. If the trust required to accept and use information available from other partners is not there, if the need for collaborative decisions is not understood or accepted, if in daily practice everything defaults back to the old way of working, no CDM benefit will be realized.

During the various A-CDM implementation projects it was clearly shown that the biggest challenge is indeed not technical. The biggest challenge is getting partners to change their thinking and recognize the need for change. In some cases even the evident potential for major benefits was not sufficient to move things forward.

When it comes to TITAN, the problems are similar. A culture change is not easy to engineer and if we add the fact that TITAN involves new, land-side partners for the first time ever, the job becomes even more complicated.

The none-technical side of the integration task requires a carefully planned education campaign targeting decision makers and users alike. The traditional CDM partners like airlines, airports, air traffic management and the handling agents usually do not like being told what is best for them and hence the aim must be to build a partnership where they themselves come to the conclusion that the functionality inherent in TITAN is important for their work. Of course the ground-breaking work already performed in the context of A-CDM will be of enormous help but also a bit of a hindrance too. Proving that there are additional benefits possible beyond those already brought by A-CDM is not always easy. Carefully structured presentations and credible arguments are needed. It is also important to show the decision makers that those promoting TITAN are fully conversant with A-CDM and that they know why they are proposing an addition like TITAN.

Approaching the new partners needs even more preparation and tact. Let's face it, the company keeping the airport access road clean, the garage operators, the car rental companies or the municipal transport company has never been approached in the past to share their real-time information with air traffic management. When asked, their first reaction is usually an expression of concern about liability. A special awareness-raising campaign is needed for the new partners that addresses their concerns. They also need to understand what CDM and TITAN is all about, what the benefits are... in particular for themselves. They need to be reassured that if the sign on, at worst it will be a zero-sum game for them and very probably they will have benefits in their own operation too. It is important to show them how the shared information environment will open up new possibilities for their businesses, free or for a fee that is proportional to the benefits. Talking to

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

such land-side partners often reveals that they have all kinds of ideas about how they could improve their operations and most of these ideas are related to the need for new information. If it can be shown to them that CDM and TITAN will deliver this information in exchange for them granting access to their information, the project will be a winner.

Of course the integration exercise needs to present a realistic financing proposal also. Traditional partners will in most cases already have some kind of cost-sharing arrangement in place coming from the A-CDM implementation agreement. This can usually extend also into the TITAN implementation although some of the cost sharing may need to be amended to reflect the TITAN benefit potential for the different partners. New partners will typically be reluctant to consider co-funding the implementation, unless of course they see one of their "dream" improvements suddenly becoming reality through a TITAN implementation project. If this is not the case, traditional partners should give serious consideration to contributing to the costs of involving the new partners in some kind of arrangement that jump starts things and then aims to recover the investment when things take off in earnest.

Integration should always start with education. Engineering is important but only as a second step.

4.10 TITAN at work - a high level operational scenario

<u>A few words up front</u>

Well, if you have read "The Book" to this point, you will belong to one of two groups of people. Either you now have a very good understanding of what CDM and TITAN is all about or you feel completely confused by what we have put on paper... or your tab's or laptop's screen. Of course there is also a third group of people and I suspect they belong to the majority. Those who usually turn to the last chapter of any book they pick up to start with the crescendo of the conclusions of the story... Well, we would like to give you something really special here!

The following paragraphs contain an operational scenario that shows in all glorious detail how TITAN works! What is more, the scenario description is in a form that will be readable for anyone interested in the subject. If the story sounds a bit futuristic here and there, it is because we are talking about the future. A-CDM and TITAN on top of it is meant to eliminate the very problems we, professionals and passengers alike, experience every day. Some of the problems can be solved by applying a bit more common sense to how parts of the air transport environment is run, others need a bit of creative thinking and novel solutions. It is those novel solutions, part and parcel of the TITAN concept, that will make you feel like walking in the future.

That is exactly what we will be doing... Follow a passenger and his bags from home to the aircraft, taking little side-trips also to discover the subtle magic TITAN services will perform to make everything smoother and more efficient.

<u>Checking in... at home of course</u>

Passengers these days have a range of options to check in and obtain their boarding pass. You can check in at home, use a mobile device, use one of the check in kiosks at the airport or go to a check-in counter... increasingly though the possibility to check in using a traditional agent is becoming something of the past.

In this story, our passenger is using his home computer to check in. Though he is unlikely to watch the address line at the top of his browser while he is going through the various steps, had he taken a look he would have spotted the changes in the address... As part of his check in process, he will have gone to "Seat-selection" and very often these functions are hosted on different systems within, for instance, an airline alliance. Fact is, the airspace users have realized System Wide Information Management for their own purposes quite some time ago and this is what makes the check in and seat selection process, as well as all the other steps, appear to be seamless when looked at from the user perspective even though several distinct systems are actually involved.

Normally, check in is permitted a maximum of 24 hours before the planned departure time. Our passenger is interacting with the airline system but once TITAN is implemented, an important new

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

element, the Passenger Flow Information Service will also be quietly watching in the background. This service is responsible for watching the flow of passengers from their homes or hotels all the way to the gate. Mind you, this is not a big brother is watching you type of scenario. The service is interested in global passenger flows and not necessarily individual passengers. So, when we say watching, this means tracking the passage of important milestones, like checking in, dropping bags and so on. The information is then aggregated into a flow-picture that tells the airline that their passengers are coming and there are no problems... or that there are problems and action is needed.

The airline check in function shares all information of relevance to TITAN and the Passenger Flow Information Service, as a subscriber to this information is made aware of the fact that this passenger has now taken this first important step toward starting his journey.

At the time of check in the passenger has the option of choosing what level of interaction he or she wants to have with "system". He can opt out or go for full service or pick and chose if he feels like it.

Our passenger opts for full service. Why not? It is free...

This is where the Airport Information Report Service also comes into play. Although this service is meant primarily to serve the airlines and pilots in getting the latest information about the airport they are planning to use but of course it is eminently suitable also for informing passengers about what is cooking. No, the service will not tell passengers the runway visual range... but when access to the airport is a problem, or rather will be when the passenger is likely to be travelling to the airport, he gets advance warning at check in and (if he accepted this) also updates as time progresses. This is similar to what some airlines are already doing in the form of sending text messages to their passengers about the status of their flight but the range of information is much wider and because of the general sharing of information by all partners (airlines, airport, handling agent, ground transport companies, meteorology, etc.), the information provided is also more "intelligent", i.e. it can contain advice, alternatives and so on in case, for instance, the airport access road is blocked or there is industrial action planned by the engineers of the railway serving the airport in question.

The aim is to make the passenger aware of the best way to reach the airport and avoid problems and bottlenecks.

Getting to the airport

The tracking system of the transport companies involved in getting passengers to the airport also publish their findings and the Passenger Flow Information Service, as a subscriber if this information, knows whether there is a problem somewhere in the flow. With the Airport Information Report Service keeping an eye on conditions that may affect the airport and the access to it, a fairly comprehensive picture is built and shared among all partners. This does not mean that human operators at the airline or the handling company have to watch this picture... they can of course if they want but as long as the flow of passengers towards the airport is not disturbed, as long as transit times are within pre-determined limits, the "picture" exists mainly only in the minds of computers running CDM and TITAN. Should delays run up, or be forecast to run up, appropriate warnings are published and humans then take remedial action as necessary. This arrangement can be coupled also with third-party functionality like passenger numbers forecasting which then works together with the services to check whether the forecast numbers are being realized and if not, why...

At the airport and on to security

When we alight from the cab or train at the airport, we hardly give a thought to the wealth of information that is all around us and which can be harvested to feed the Passenger Flow Information Service that in turn can collate the information to deduce important conclusions. For instance, the barrier gate of the parking garage, the rate of returns at the car rental companies... they all say something about the number of passengers that will be presenting themselves at the baggage drop-off points and then at security in x minutes' time where the x depends on the airport.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

Once the Passenger Flow Information Service is there, the data not really used for anything much in the past suddenly has a home and can generate important forecasts about the likely passenger flows in the next few minutes.

With the Passenger Flow Information Service sharing information on the ebb and tide of passengers for the various flights, all the partners concerned can now benefit from this information.

The number of security lanes and passport control windows to be opened can now be geared to the real demand and be ready when the people actually arrive.

Our passenger has now also arrived and drops of his bag... this is a milestone noted by the Passenger Flow Information Service. From this point onwards his progress through the terminal will be monitored more closely. Not his every move of course but the passing of important milestones will always be compared to the time needed to reach his boarding gate. He will not be bothered personally unless there is something wrong, like the danger of his not being at the gate on time.

Monitoring takes the form of scanning the boarding pass at carefully selected points. Of course Radio Frequency Identification would be an even better option but it raises both privacy and logistics issues. If he has no bags to drop off, how does the radio frequency tag get attached to the boarding pass? But the feeling is, having fixed control points is probably enough in the overwhelming majority of cases.

So, scan the boarding pass when entering the sterile area of the airport, scan when passing security... At some airports this is already being done but only for opening a turnstile or checking the identity. The fact of the passage is not registered. When TITAN comes in, it will be. Two control points and the passenger will not feel anything from it... he will not have to do anything differently from before, the control action happens under the surface.

If passage of any of the control points indicates a likely problem in terms of reaching the gate on time, a warning goes to the airline/handling agent and they can decide what to do about the lagging passenger. In an extreme case, if there is no hope of his arriving at the gate on time, early action can be taken to unload his baggage or to call his name on the public address system... The key word here is that information on a possible problem is generated and shared early.

The winding road of baggage

The road of baggage from the drop off point to the aircraft hold is a convoluted affair. Especially now that full screening of hold baggage is becoming the norm, bags can get delayed, misdirected, dropped from the cart... However, the Baggage Flow Information Service tracks the baggage and makes the connection between passenger, bags and the aircraft. The Baggage Flow and the Passenger Flow Information Service also interact with each other and any problem signaled by one potentially modifies the reaction of the other. The passenger and his or her baggage has been coupled also in the past but their progress towards the aircraft cabin and hold respectively has not been monitored. With the services dedicated to this monitoring any kink in the process can be smoothed out before it escalates into a problem or at least timely remedial action can be taken if the problem cannot be avoided completely.

Beyond security

Most airports these days are constructed such that passengers have to go through a shopping area before setting out on the, sometimes, long trek to the boarding gate. What is more, the boards listing departures tend to show the departure gate only about 30 minutes before boarding time... All this is meant to keep passengers in the shopping are for as long as possible. This is understandable from the airport's point of view. After all, they earn a lot of money from the concession and will, in turn, make sure that people spend money to keep the concessions happy. Of course this is not something the airlines care about... for them passengers should be at the gate as soon as practicable to avoid having to deal with people who get lost in the shopping plaza...

Anyway, our passenger is now in this big no-mans-land and short of Radio Frequency Identification Device (RFID) tracking devices, it is not easy to see where he is. With public address announcements having disappeared at many airports of he world, it is easy for the unwary to lose track of time and not realize that he or she has become a delay factor for the flight concerned. Of course there are ways for the Passenger Flow Information Service to intervene even in such situations. Assuming the passenger buys something. A souvenir, food, whatever.

It is common practice to ask for the passengers' boarding pass when they purchase some item in any of the many shops. The concession holders use the information from the boarding pass to build buying habits information and of course also to screen out none-eligible customers. But by making a connection to the Passenger Flow Information Service and adding a small screen to the check-out lanes, it is possible to send a warning to the passenger who is late going to the gate. Although food vendors do not ask for the boarding pass, it should be possible to insert a scanning operation during the ordering process... If the passenger is already late or likely to become late by staying in the restaurant, a message can be sent to him or her asking them to hurry. Since this happens before they order, no problem would arise with customers leaving without having paid.

Other innovative ways may be developed to keep track of the whereabouts of the passengers and for ensuring their steady movement towards the boarding gate for a timely arrival there.

Finally at the gate and boarding

Once boarding starts, the Passenger Flow Information Service ceases to be active for this passenger and the Baggage Flow Information Service stops also once the baggage has been loaded in the aircraft hold.

The important thing to note here is the process view of the world inherent in the working of the services. They monitor and carry information on the evolution or flow of passengers and baggage towards the aircraft and this view allows impending problems to be seen well in advance with remedial action to minimize the impact possible early on.

All this time another service, the Aircraft Status Report Service was monitoring the turnaround. This service, like the others already mentioned, interacts with all the others and the information it shares influences the behavior of the other services. For instance, if the Estimated Off-blocks Time is modified (in effect the aircraft is late for instance), the margin of when to urge passengers to hurry to the gate may be modified. Similarly, instead of a warning, a passenger may get a message saying that he is now not expected at the gate until an xx time.

The idea is that if all the information already available and some more that can be extracted from the existing environment by the addition of a few more sensors or new procedures is bundled and shared, a few very useful ideas already exist on how to use the information for good effect but! There will be a multitude of innovative ideas showing yet newer ways of using the information. Experience has shown that the best catalyst for innovation is the availability of new types of information or just making existing information usable by better management and sharing of that information.

Life around the gate - the turnaround and the services

For a long time, the aircraft turnaround had been a kind of black box, at least from the air traffic management perspective. The arriving aircraft, once clear of the runway and taxiway system, dropped off from the air traffic management horizon and in spite of the furious activity around the parked aircraft and the multitude of things that could potentially impact its planned departure time, it did not reappear until either it was ready on time or a delay was announced. This latter usually too late to do anything about the effects of the late completion of the turnaround. Passengers experience such events for instance when their incoming flight stops somewhere on the apron, apparently unsure where to go... since its assigned gate is still occupied. Of course with Airport Collaborative Decision Making these kinds of problems have been eliminated to a certain degree. TITAN, with its intense focus on the turnaround and improved visibility of all influences improves the situation even further. We will now look at what the services do for the turnaround itself.

For each inbound flight, a Target In-block Time has been determined, based on the location of the pre-assigned gate and calculated taxi time. This target time, including the current availability of the

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

stand, is shared with the aircraft and the ground handler by the Aircraft Status Report Service. It is the responsibility of the ground handler to ensure that the stand is free and the handling equipment and staff are present by the appointed time.

The minimum reaction time for gate/stand allocation changes is around 30 minutes prior to the scheduled in-block time in view of the necessity of re-routing passenger and baggage flows within the terminal. For repositioning the ground handling crew a minimum reaction time of 15 minutes is applicable. This time depends strongly on the airport layout and the size of the handling resources. If reactionary times to change stand and gate allocations are higher than the calculated aircraft taxi time, a new estimated in-block time will be shared by the Aircraft Status Report Service.

> Did you know... That the services we are talking about here are typically only the conduits of the information. Calculations of, for instance target times, may be performed by other functions or systems and then shared so that the results become available also for the services. If you want to know more about how this information sharing works, read paragraph 3.1.4.

In case the allocated stand is still occupied at the predicted in-block time, this information should be available in sufficient time so that the airport can re-allocate gates and will need to temporarily hold the inbound aircraft on a remote area only exceptionally or if the predicted delay of the outbound aircraft is within pre-agreed limits. The stand allocated and any possible changes related to it, together with the new target in-block time, is published via the Aircraft Status Report Service while the activities around the new gate is monitored via the Airport Information Report Service.

As the flight arrives at the allocated gate, its trajectory becomes idle in the spatial sense while it continues to evolve in the time dimension. Even in this idle status the trajectory is consuming resources and changes can happen in the time dimension. In other words, a delay occurs... The spatial dimension continues to exist in a virtual sense, expressing only the constant position of the aircraft and affecting short term planning.

The actual in-block time is automatically detected and published by the Aircraft Status Report Service.

The progress of the ground handling activities is constantly monitored by the Aircraft Status Report Service which reports the current status of each handling process/event (fuelling, catering, cleaning, etc). For each activity of the turnaround, a target completion time is provided to the responsible handling agent on a device of their choice. If the actual completion times give rise to the conclusion that reaching the target off-block time is in danger, a warning is shared by the Aircraft Status Report Service. To help in formulating the most appropriate response, the warning can take one of three forms. If the problem is such that by using part of the built-in buffer time the situation can be resolved, the warning is only a reminder that the operation needs to be tightened up somewhat as there is only a limited amount of slack left in the system. If the situation has taken the form of a definite delay unless immediate action is taken, the warning becomes a kind of overall alarm and invitation to all the partners to engage in a collaborative decision making process to find a solution. The warning-status is reset when the agreed solution is implemented. In cases when the delays is such that there is no way to avoid it, a warning is issued and collaborative action is expected, though the urgency is somewhat less.

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

> Did you know... That an environment like TITAN depends to a very large extent on the timely availability of information regarding the completion status of all the relevant activities. This information can come from manual inputs, automatic inputs or deduced automatically from indirect information. Manual inputs should be the last option as they are often forgotten by the partners concerned.

Using the access to all the shared information available, the warnings are made "intelligent" in the sense that they always include contextual information on the airframes, passengers, baggage, connections, gate usage, eventual curfews and so on, to help partners in their decision making. The intention is to make sure that partners do not need to hunt for support information all over the systems. Instead, most if not all of what they need is made available automatically. This does not mean that everything will also be displayed all the time. Available in this context means easy to reach from a single screen without having to search.

The decision making information is automatically formatted to fit the device on which it is going to be displayed while essentially keeping the structure of the displayed information to ensure that the visual experience is the same, regardless of the device on which a given partner is working at the moment (tablet, laptop, desktop, smartphone, etc.).

With the significance of hold cargo increasing as the capacity of wide-body aircraft grows (to the disadvantage of dedicated cargo aircraft), TITAN has introduced a dedicated service to deal with information related to cargo and mail. This is the Cargo/Mail Flow Information Service.

This service issues warnings if part of the cargo/mail cannot be delivered as planned and hence will not be available for loading on time to achieve the estimated departure time. Taking the alternatives into account (e.g. the availability of other transport means) the partner concerned initiates a collaborative decision making process in which they agree whether or not the end of the loading process should be modified or what mitigating measures should be taken, such as de-coupling the particular cargo item from the flight. Since here again all partners will be sharing the same information and hence the same view of the situation, even if they are physically located on different ends of the continent, they will be tied together by the Cargo/Mail Flow Information Service and their actions will show up in the information carried by that service. The other TITAN services react to the changes since they too are tied into the same shared information space.

In this concept, the aircraft is a node on the information network and hence the flight crew also gets the target off-block time on their cockpit display, delivered by the Aircraft Status Report Service.

When the target-off block time is calculated, the collaborative departure sequence is set up and so on, the above services continue to play a crucial role in monitoring the situation and reacting to anomalies that may occur.

We know that air traffic control and the airlines are particularly sensitive to allowing outside "services" to interact with their environments. The services therefore always run externally to those systems and only the information content is exchanged via the information sharing arrangements which of course contains all the necessary safeguards to ensure problem-free operation.

An important element of the concept and hence of the scenario is that access to the services is not limited to airlines, airports, handling agents and air traffic management, the traditional partners in collaborative decision making. Any other organization with a substantive interest in the information created in the context of the turnaround or with information that can be useful is entitled to be part of the service use arrangements. Of course such partnering is subject to data protection and other regulations but the scope is not limited artificially.

With our passenger in his seat and the baggage loaded, it is time to push-back. Under the watchful eyes of the Aircraft Status Report Service of course...

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

5. EPILOGUE

We have come to the end of The Book, this irregular reference work on A-CDM and TITAN. Whether you have read it through from beginning to the end (unlikely) or took to reading parts you thought might be interesting, we hope you have now a better understanding of the concept of Collaborative Decision Making and the TITAN project that was born out of it.

CDM and TITAN show clearly how powerful information sharing is and how improved decisions, based on collaboration and common situational awareness, bring substantial benefits to the partners involved.

TITAN has also demonstrated the power of the service based approach. By identifying the processes involved in the turnaround and defining the business-level services they need to properly complete, an exceptionally clear description of the of the concept is arrived at. The design of the system is then driven by these business level considerations and then the IT level will facilitate their realization rather than create obstacles.

The conclusions from TITAN go further than just the airport environment.

Extending the boundaries of information to be considered, sharing information, common situational awareness, improvements in partner systems to be able to work efficiently in the new, information sharing environment, the service oriented approach are all applicable to various degrees also in other areas of air traffic management.

One could of course write another "book" on those aspects but we will leave it for a new project that is still to be defined.

In the meantime, we hope you enjoyed reading TITAN The Book!

6. LIST OF ABREVIATIONS

Aviation seems to be teeming with abbreviations... possibly much more than any other discipline. Our propensity to use abbreviations probably stems from the old days when communications methods required things to be expressed in the shortest possible form. After all, QFU is much shorter than saying Magnetic Bearing of the Runway in Use...

With so many specialized terms in our documents, using abbreviations of them seems a logical idea... even if it drives the unwary nuts. The problem mushroomed in particular when the various technical areas of aviation grew so wide that no single person could cover them all. Of course each of the areas developed their own set of abbreviations for their own area. Worse, in some cases they all used the same combination of letters to mean completely different things. Several attempts were made over the years to create a comprehensive dictionary of aviation abbreviations, several exist out there but so far no one has managed to really address the consistency issue across the board.

A similar situation exists in the area of definitions. The different interpretation of air-side and land-side is just one example of this problem awaiting a solution some time in the future.

As you will have seen, The Book too is teeming with abbreviations and we have made a real effort to give the full meaning of each when it first occurs. In some cases, like when the abbreviation surfaces first in a figure, this method is not easy to use. Anyway, in the following table you will find the meaning of the abbreviations used in The Book.

2D	Two Dimensional
3D	Three Dimensional
4D	Four Dimensional
ABT	Airport Business Trajectory
A-CDM	Airport Collaborative Decision Making
ADEXP	Aviation Data Exchange Protocol
ADS-B	Automatic Dependent Surveillance, Broadcast
AGHT	Actual Ground Handling Start Time
AIRS	Airport Information Report Service
AIS	Aeronautical Information Service
ALDT	Actual Landing Time
ANSP	Air Navigation Service Provider
AOBT	Actual Off Block Time
AOC	Airline Operations Center
ARDT	Aircraft Ready Time
ASAS	Airborne Separation Assistance System
ASBU	ATM System Block Upgrades
ASRS	Aircraft Status Report Service
ASRT	Actual Start Up Request Time
ATC	Air Traffic Control

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

ATFM	Air Traffic Management
ATM	Air Traffic Management
ATOT	Actual Take Off Time
ATS	Air Traffic Services
BDT	Business Development Trajectory
BFIS	Baggage Flow Information Service
CBA	Cost/Benefit Analysis
CDD	Capability Development Document
CDM	Collaborative Decision Making
CFMU	Central Flow Management Unit
CMFIS	Cargo/Mail Flow Information Service
CONOPS	Concept of Operations
CTOT	Calculated Take Off Time
DISA	Defence Information System Agency
DoD	Department of Defence
DOT	Department of Transportation
DPI	Departure Planning Information (message type)
EATCHIP	European Air Traffic Control Harmonization and Integration Program
EIBT	Estimated In Block Time
EOBT	Estimated Off Block Time
E-OCVM	European Operational Concept Validation Methodology
ETOT	Estimated Take Off Time
EU	European Union
EXOT	Estimated Taxi Out Time
FAA	Federal Aviation Administration
FADE	FAA/Airline Data Exchange
FMS	Flight Management System
FOC	Flight Operations Control (Center)
FUM	Flight Update Message
GA	General Aviation
GIG	Global Information Grid
IATA	International Air Transport Association
IBM	International Business Machines Corporation
ICAO	International Civil Aviation Organization
IP	Implementation Packages
IT	Information Technology

Project co-funded by the European Commission and TITAN consortium. www.titan-project.eu

L4CDM	Level Four CDM
M	Milestones
MET	Meteorology
MILS	Multiple Independent Level of Security
NCES	Net-Centric Enterprise Services
NM	Network Manager
NPV	Net Present Value
OBT	Off Block Time
PFIS	Passenger Flow Information Service
RBT	Reference Business Trajectory
RFID	Radio Frequency Identification System
SBT	Shared Business Trajectory
SESAR	Single European Sky ATM Research
SO	Service Oriented
SOA	Service Oriented Architecture
SWIM	System Wide Information Management
TBO	Trajectory Based Operations
TIS	Titan Information Sharing
TITAN	Turnaround Integration in Trajectory and Network
TOBT	Target Off Block Time
TOBT	Target Off Block Time
TSAT	Target Start Up Approval Time
TSAT	Target Start Up Approval Time
US	United States