Collaborative Management of Key Milestone Event Information During Flight Life Cycle

Tan Wei
ATC Division
Middle-southern Regional Air Traffic Management Bureau, CAAC.
Guangzhou, China
tanwei1@atmb.org

Sheng Minmin
Area Control Center
Middle-southern Regional Air Traffic Management Bureau, CAAC.
Guangzhou, China
mmpp11104@163.com

Wu Qian
Department of Aviation Safety Management
Civil Aviation Management Institute of China
Beijing, China
wuqian@camic.cn

***Abstract*—with the rapid growth of civil flights in China and the increasing saturation of airspace units, the importance of air traffic flow management (ATFM) has become more prominent. During a typical flight life cycle, from initial planning to in-block at the gate of destination airport, there are some crucial moments that require special attention, such as start-up, take-off, boarding, etc. Under the framework of collaborative decision making (CDM), these significant events during the planning or operation of a flight- milestone- will trigger the decision making process for downstream events and influence both the further progress of the flight and the accuracy with which the progress can be predicted. The national ATFM system shall collect, share and make use of the milestone information. The Air Traffic Control (ATC), airports, airlines and other stakeholders shall bear respective responsibilities during this process. This paper describes the definition, application scenarios and interrelationships of some key milestones that have great influence on ATFM during tactical phase of operation. It also analyzes the milestone-related sequence algorithms and explains the common confusion of stakeholders. It's aiming to facilitate the ATFM process in a more collaborative and efficient way.**

Keywords—air traffic flow management, milestone, collaborative decision making, air traffic control.

I. INTRODUCTION

ATFM is used to manage the flow of traffic in a way that minimizes delays and maximizes the use of the entire airspace. ATFM can regulate traffic flows involving departure slots, smooth flows and manage rates of entry into airspace along traffic axes, manage arrival time at waypoints, flight information region (FIR) or sector boundaries, and reroute traffic to avoid saturated areas. In the Tactical phase of ATFM [1], those 'slots' are quite informative to all the participants, and can be seen as a milestone which indicates the change of status of the flight. With the milestone information sharing, the ATFM system can be smart enough to allocate the limited resource to the 'right' flight[1].

The Milestone describes the progress of a flight from the initial planning to the take off by defining Milestones to enable close monitoring of significant events. [2]The aim is to achieve a common situational awareness and to predict the forthcoming events for each flight with off-blocks and take off as the most critical events. Milestone information sharing needs to be implemented among all the stakeholders underlying the basic philosophy of CDM. The milestone approach combined with the information sharing is the foundation for ATFM. Corresponding milestones are generated at various stages of the flight's operation (FIGURE 1)

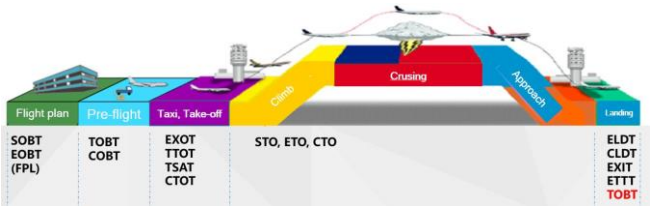

Figure 1. Milestones in Various Stages of Flight

During the implementation process of ATFM, each of the three major participants-ATC, airports and airlines-have first-hand access to some of the crucial milestones, in many occasions, those milestones are generated by the relevant stakeholders. The following figure shows the flow of key information between different parties and how the milestones function in traffic volume prediction and demand and capacity balance (DCB) analysis.

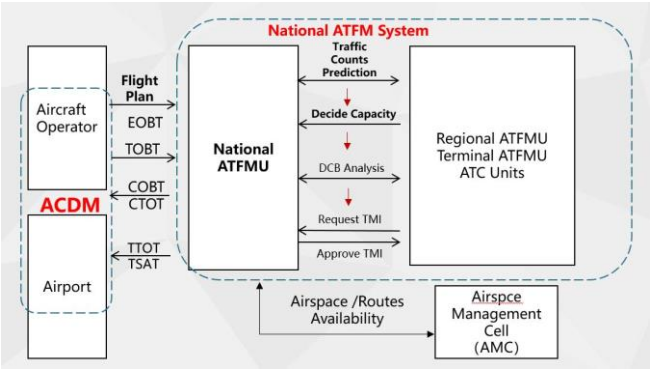

Figure 2. Flow of Crucial Milestones

At present, each of the seven regional Air Traffic Management Bureaus (ATMB) have their own traffic flow management systems and use different computing mechanisms, which leads to the same airline adapting to different rules in different regions, which is prone to confusion and misunderstanding. [3]In order to solve this problem, the Civil Aviation Administration is planning to build a national traffic flow management system. As a pioneering mechanism research, this paper sorts out the definitions of some key milestones from the perspective of

integrated air traffic flow management, clarifies the relationship between each other, and explains some of the sequencing algorithm.

II. Collaborative Management Of Milestone

A. Rules on flight plan management

Flight plan is the basic element of aviation operation. The airline shall organize the flight operation according to the plan approved by the civil aviation authority. If cancellation, merge, replenishment of flights occurs, the flight plan shall be updated in time, and the accuracy of the corresponding flight plan shall be verified in the national ATFM system. The airlines which take the initiative to update flight plan modifications such as cancellations and merges in a timely manner, will obtain more priority in terms of slot exchange and priority in sequencing[4].

All traffic flow management initiatives that generate CTOT are based on flight plans, so in order to improve operational predictability, it is suggested that the flight operator should submit the flight plan (FPL) 60 minutes before SOBT, otherwise the ATFM system will consider it as a no-show and move the flight into the waiting pool; the flight plan which is not submitted within 6 hours after SOBT, the ATFM system regards it as not executing and removes it from the flight plan list.

B. Estimated Off-Block Time (EOBT)

The ATFM system obtains EOBT data by directly referring to the flight plan list of the flight plan centralized processing system, or acquires EOBT time by automatically disassembling the flight plan fixed format telegram. The ATFM system only triggers the COBT/CTOT release mechanism after acquiring EOBT data.

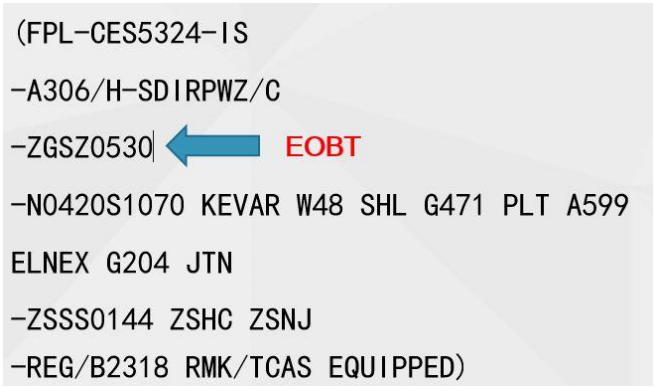

Figure 3 Extracting EOBT from FPL

After the ATFM system obtains the EOBT data, the airline or airport can update the TOBT using the traffic flow management system or on its own automation system on the premises that data transfer between the two systems has been completed[5].

C. CTOT(Calculated Take-off time) ,COBT (Calculated Off Block Time),TOBT (Target Off Block Time) Calculation And Usage Rules

CTOT is calculated by ATFM system based on constraints of the controlled source (MIT or acceptance rate). CTOT minus variable in-block taxi time equals COBT.

TOBT can be seen as the most important milestone in the ACDM category. It will have a direct impact on the sequence calculation and determine whether a flight can comply with he assigned time slots.

Theoretically speaking, TOBT should be submitted to the air traffic control department by airlines or airports. However, due to the different understanding on the concept and various level of information management, a considerable number of participants (airlines, airports) do not take initiative to submit TOBT. However the ATFM system will automatically calculate the TOBT first. The major mechanism is to calculate the expected landing time (ELDT) of the previous segment of flight based on its departure time after receiving DEP, then plus the minimum turnaround time (MTTT) and we get the TOBT[6].

$$TOBT=ELDT+MTTT$$

Once the TOBT is modified by the airline or the airport, the ATFM system will no longer automatically update the TOBT; if the airline does not submit the TOBT, ATFM system will do the job.

COBT given by ATFM system will be equal to or later than the TOBT. If the updated TOBT is earlier than the COBT, the system will not trigger to recalculate the COBT when the external flow control conditions remain unchanged. The following examples are to further illustrate this.

TABLE I Case 1

Flight	EOBT	TOBT	COBT
A	0800	0800	0900
B	0820	0900	0930
C	0830	0850	1000

In case 1, when flight A revise the TOBT to 0840, what is going to happen?

Actually nothing. Because a TOBT that's less than COBT will not 'trigger' a recalculation.

But what if we revise TOBT of flight A to 0920?

First, the ATFM system will find the TOTB submitted is late than the original COBT, which means flight A won't be ready to get off the block at 0900.

Second, ATFM system is very generous. It will then try to find another flight which can swap slot with flight A. In this case, both B and C are able the catch the 0900 slot, as flight B's EOBT is earlier than flight C, flight B will grab the chance and get to takeoff earlier.

TABLE II Case 2

Flight	EOBT	TOBT	COBT
A	0800	0800	0900
B	0820	**0910**	0930
C	0830	**0930**	1000

In case 2, things are a bit different. For flight B and C, the TOBT value are 0910 and 0830 respectively, so at such, if flight A revise TOBT to 0920, neither flight B nor flight C is able to use the 0900 slot, which means flight A can't find a flight to swap slot with it, so 0900 slot will be wasted. By

now, if we continue to do the deduction, flight A will take the 0930 slot because compared to flight B, flight A has a earlier EOBT time, and as we mentioned before, EOBT determines the priority of sequencing. So in the same way, flight B will take the 1000 slot.

In consideration to the experience of passengers, if flight A notify the system of it not being able to comply with 0900 slot early enough, for example, at 0700, maybe flight B and C could adjust their boarding time and grab the 0900 by revising TOBT. Even not, flight B and C can defer the boarding time because its 0930 COBT has been 'forced' by flight A. Although it's not the most desirable situation, it's acceptable as long as the passengers are not shut off in the cabin.

At this time, we can be sure that for flight A, it shouldn't just notify the system of unable to comply 0900 slot in the last minute right before 0900 and get a substitute COBT immediately without any consequences. That s not fair, so in the real work, slots will be locked when reaching a window close to the execution time. And flights like A won't be able to 'push' to take somebody else's slots if they are locked. If flight A can't find a flight to swap slots, and can't take out the locked slots, it could be prone to relative long delay at such situation[7].

Hence we suggest that airline or airports submit TOBT as early as possible.

According to the feedback of airline and airports, sometimes they have concerns and inconveniences of continuously updating TOBT, because it takes extra work for the personnel. But if they don't do this, they are afraid that the system will not assign the best COBT to them according to the principle of maximizing profit.

To solve this problem, Baiyun airport has modified the ACDM system by adding a variable delta. Delta means the least amount of time that's required by the airlines or airports to get ready, this may including get the passengers on boarding or call the flight crew to get on the plane. In this way, the airlines can either input a fixed TOBT value or input a delta (40min, 90min, 180mins and so on). If the variable is chosen, TOBT then equals current time plus delta.

TOBT=current time +delta.

D. Slots Swapping

Slot swapping provides flexibility for system sequencing, and is encouraged to use by the airlines when they want some later flight to take-off earlier because of very important person on board and so on.

Airline can initiate a time slot exchange with the flight from the "exchangeable time slot flight list" provided by the ATFM system, and modify the TOBT in the mean while.

It should be reminded that the traffic flow management system does not have the same flight range and list generation logic for the list of exchangeable time slots provided by different levels of traffic flow management units, airlines and airports. See the table below for details[8]:

TABLE III CONDITIONS FOR SLOT SWAPPING

ATFM USERS	RULES	SCOPE
National ATFMU	1. flow control restrictions are exactly the same; 2. hasn't pushed or started up	All flights
Regional ATFMU		Departure flights within jurisdiction area.
Terminal ATFMU		
ATC TOWER	1. flow control restrictions are exactly the same; 2. hasn't departed	Flights of the same airport
Airlines	1. flow control restrictions are exactly the same; 2.not locked	Flights of the same airport

E. Waitng pool

For some reasons, when the flight cannot comply with assigned time slot, it needs to be placed in the waiting pool. After the new TOBT is submitted, the ATFM system recalculates a new time slot for it[9].

Usually, the conditions for entering the waiting pool include the following aspects:

a) The COBT minus the current time is less than 55 minutes, but the airline does not confirm the COBT nor submit a new TOBT, and the system automatically moves the flight to the waiting pool.

b) SOBT minus the first FPL EOBT is greater than 15 minutes. It's aiming to prevent some airlines from playing smart to deliberately delay the flight to rush hour.

c) For non-passenger flights (Fly Type is H/G or H/Y), SOBT is in the range of 23:00-06:00, but EOBT is delayed to 06:00-23:00.

d) The current time minus the COBT time is greater than 5 minutes, and the flight has not entered the RDY state, which pilots may tell lies about their ready for taxi.

e) The current time minus the flight P-S time is greater than 10 minutes, and the flight status is still P-S. The same logic as 'd' above

To leave the waiting pool, one should:

a) Find available time slots according to flight TOBT, and,

b) Does not affect the first 8 flights of the same flow control.

c) Does not affect manually locked flights;

d) At least 60 minutes after the original COBT;

III. A CASE REVIEW AT GUANGZHOU AIRPORT

On July 9, 2019, Guangzhou Baiyun had encountered moderately strong precipitation with thunderstorms near the terminal area and the airport from 14:00 to 24:00. The air traffic control department issued an MDRS yellow warning one day in advance.

At that time, the weather of the airport was changing, and together with many external restrictions had imposed a great impact on the on time performance at the airport.

According to statistics, on July 9th, a total of 611 passenger departure flights were carried out, and TOBT unchecked flights were 372. There were 451 flights with

difference more than 5minutes (either positive or negative) between TOBT and the cabin door closed time. And 118 of them above 30 minutes, 50 of them above 48minutes.; A total of 299 classes received CTOT, there are 60 flights with a difference more than 5minutes between the actual departure time and CTOT .

It can be seen from the above data that the flight data maintenance data of the day is not done well, especially for the key millstones. Either is too late to submit or just submit nothing. The lack of millstone causes ATFM system not to make full use of available resources to allocate the most desirable slots for these flights. Especially for the flights that have submitted TOBT, but the actual cabin close time is before TOBT. In the real time operation, because the TOBT is transmitted, from the airline, even if the cabin door is closed earlier, the ATFM system will still think that the flight won't be ready until reaches the TOBT time. This is a pity, because there may be earlier slots for those flights if they had ipdated the TOBT according to their real status.

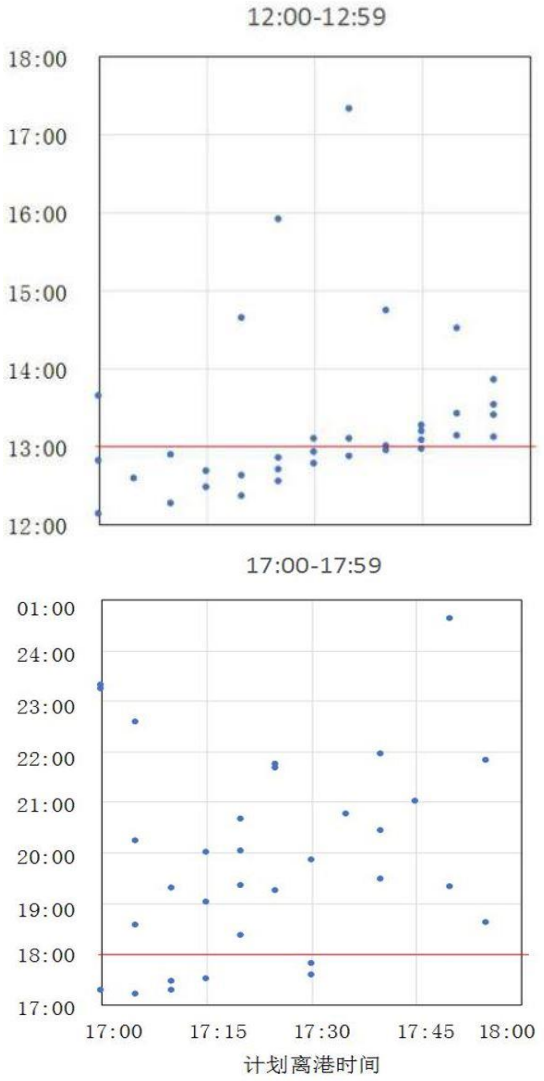

Figure 4 Operation Recovery Time Needed

We extracted two pictures of one-hour flight delays (Figure4). The horizontal axis represents the hourly period in which the flight was scheduled to takeoff, and the vertical axis represents the actual departure time of the flight. We can find that the first observing hour is accurate in terms of data transmission, and the milestones are accurate too. It took less time for the system to recover, as we can see on the left, for 1200-1250, millstone quality was good, accordingly, the COBT being calculated back was precise too.

IV. Conlusions

Through the definition and usage of the key milestones in the flight life cycle, the operating personnel should be able to see the story behind the data, which actually reflects the intention of the participants.

Collaborative flight information management is the foundation for collaborative air traffic flow management. ATC, airlines and airports are responsible for updating the milestones under their jurisdiction and sharing them without reservation. Only in this way can the rationality of the calculation mechanism of the traffic flow management system be continuously improved, the time slot jump of the system can be reduced, and the operational efficiency can be improved.

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