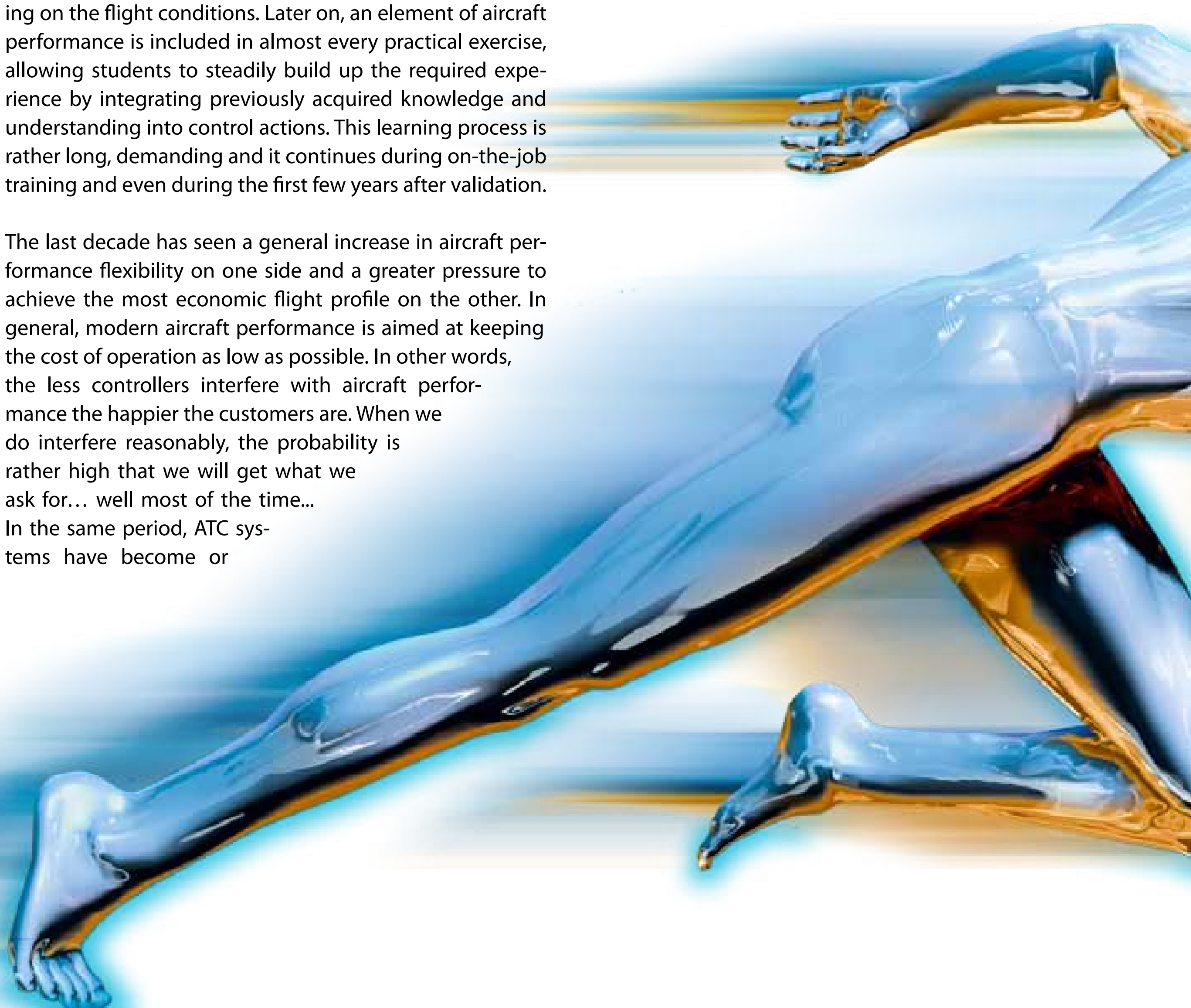
Training aircraft performance for modern/future ATC systems

by Dragan Milanovski

Knowledge of aircraft performance is essential for the provision of a safe and efficient air traffic control service. Every day, every hour, controllers are using this knowledge to provide separation, decide the allocation of cruising levels, create approach or departure sequences, use speed control for sequencing, provide wake turbulence separation and exercise other air traffic control techniques.

Understandably therefore, aircraft performance has been an important part of ATC training since the very beginning. It starts with memorising basic aircraft performance data for the most common aircraft types and understanding how these performance parameters may vary depending on the flight conditions. Later on, an element of aircraft performance is included in almost every practical exercise, allowing students to steadily build up the required experience by integrating previously acquired knowledge and understanding into control actions. This learning process is rather long, demanding and it continues during on-the-job training and even during the first few years after validation.

The last decade has seen a general increase in aircraft performance flexibility on one side and a greater pressure to achieve the most economic flight profile on the other. In general, modern aircraft performance is aimed at keeping the cost of operation as low as possible. In other words, the less controllers interfere with aircraft performance the happier the customers are. When we do interfere reasonably, the probability is rather high that we will get what we ask for… well most of the time...
In the same period, ATC systems have become or are becoming technologically more advanced, with a lot of tools to support controller decision making. For example, having an arrival or departure manager deciding the sequence is a more and more routine part of the job now.



The cruising speed in Mach number form as well as rates of climb and descent are available to controllers through enhanced Mode S. MTCD is used to project ahead and predict potential conflicts and CPDLC has been enhancing controller-pilot communication for quite some time now. In reality, not all the ATC systems are equally advanced but this is nevertheless the broad direction for expected developments in the near future.

Considering all of the above, inevitable questions arise for the two possible directions for aircraft performance learning in future ATCO training. Will controllers still need to do all that hard work to build up their aircraft performance-related competence as we do today when clearly this will be required less and less in the future? Or, will controllers need a more complex type of competence, considering that they will not need to use these skills very often, but when they do, it will be at a higher level of complexity, which involves achieving minimal adverse effects on the economics of the flight profile?

I would not exploit the common argument (used whenever something new is introduced in ATC) that controllers must have the required competence available should the automation fail. This argument has been abused and over-used in the past and it has been proven wrong in many instances. Maintaining an unused competence over long periods is practically impossible when the automation works as expected and without failures. Despite this, the subject continues to be one of the most popular in many discussions – but that is another story…

Instead let's have a look at a few examples in the search for an answer to the questions above.

Use of Rate of Climb (RoC) to ensure separation on opposite tracks

This technique is often used to ensure that vertical separation is established when an aircraft is climbing with conflicting traffic on the opposite track, where the level cross will take place head-on, before the aircraft pass each other. It can also be used as a follow-up, when an aircraft has already been cleared to climb through the level of the opposite direction traffic at significant distance, but by monitoring the rate it has been determined that unless positive action is taken the aircraft will not reach the expected level at the required distance prior to crossing the opposite direction traffic.

To achieve the most economic flight profile, modern jet aircraft need to fly the best climb rate for a given speed. The objective is to reach the cruising level (where jet engines are more efficient) within the shortest possible time while maintaining optimum forward speed. Requesting an aircraft to increase its rate of climb, even for a small portion of the climb phase, has a negative economic consequence. The rate of climb is increased at the expense of the forward speed, so the aircraft will probably reach its cruising level sooner but will also take longer to get to its destination. It is also worth mentioning that the maximum rate of climb is limited by the minimum climb speed of the aircraft so the rate assigned has to be reasonable and for a short period. Once the restriction is cancelled, most of the excess thrust will initially be used to increase the forward speed at the expense of the rate of climb.

Alternative solutions for these sort of traffic situations involve either use of an intermediate flight level until passing the op-

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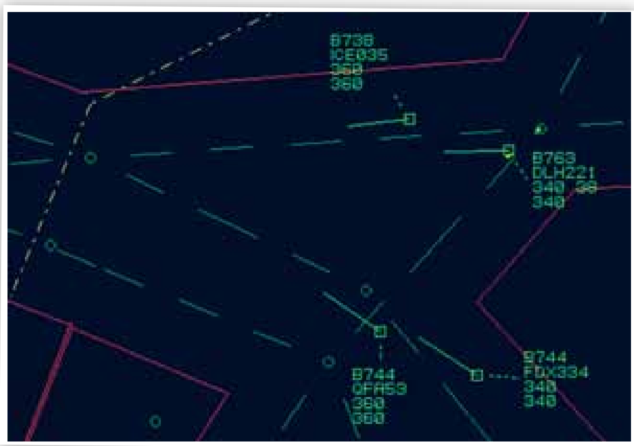
posite traffic or radar vectoring. From the economic point of view, levelling off at a lower altitude rather than the cruising level has a greater negative impact than assigning a specific rate of climb. Radar vectoring is usually a more efficient option, but it cannot completely replace the rate of climb solution (because of airspace restrictions, workload etc). In addition, it also increases the distance the aircraft will have to fly.

Allocation of cruising levels and speed control

Another typical situation is when two streams of traffic are converging into one, where the controller's job is to merge them by grouping aircraft types with similar performance at same levels. The usual control actions include a combination of assigning a lower than requested cruising level, speed control to ensure longitudinal separation and/or radar vectoring for sequencing (mainly to delay an aircraft).

Allocating a lower level for the cruise has a negative impact on aircraft fuel burn. Usually, assigning one or two levels below for a part of the cruise phase of flight is manageable, but more than that might have significant consequences later on in the flight. Requesting aircraft to fly at higher speeds than the optimal also increases the fuel burn but reduces the flying time to destination. The opposite happens when



lower speeds than optimal are assigned – the fuel burn reduces but the flying time to destination increases. Both options have a negative overall effect on the economics of the flight profile achieved. Radar vectoring for sequencing generally increases flight distance, so it also has an adverse economic effect.

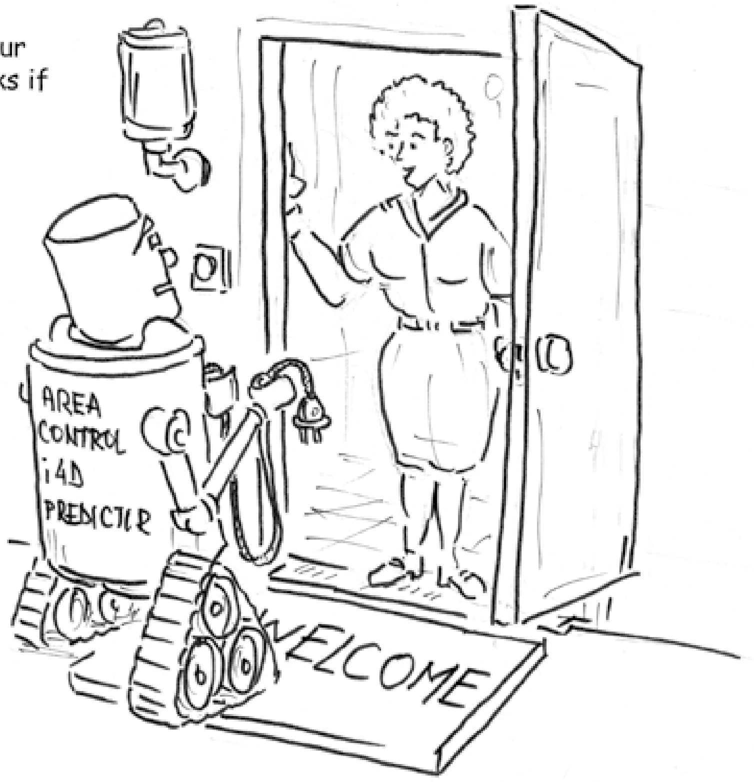
To make things more difficult, most of these actions are planned well before the controller can even talk to the aircraft concerned – consequently knowledge, understanding of aircraft performance and experience are crucial for minimising any unavoidable negative cost impact. Another important point is that controllers also have to deal with "unknown factors", such as routing and requested levels made by an aircraft which are beyond their control area, conflicting traffic in the downstream sectors, wind, weather, turbulence etc.

Top-of- descent (ToD) and/ or use of Rate of Descent (RoD)

Finally, let's have a look into another typical scenario where one aircraft needs to descend and pass through the level of one or more other aircraft which are on a crossing track when the minimum distance between the descending and the crossing track aircraft would be well below the necessary minimum radar separation. The two most common solutions involve either delaying the aircraft top-of-descent point so that it passes above the crossing traffic or initiating its descent early and setting a minimum rate of descent to ensure that vertical separation is re-established at a safe distance prior the crossing point.

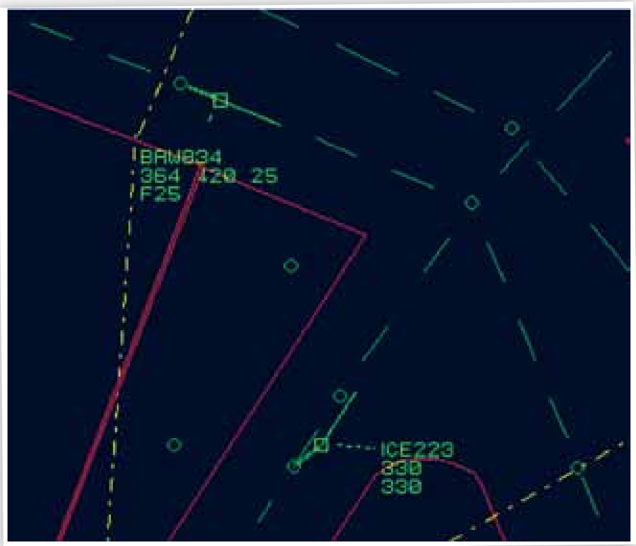
For jet aircraft, the most economic flight profile is with the engines at idle from the ToD until the aircraft arrives at the appropriate altitude and speed at the point where the approach for landing begins. If the ToD is delayed, the aircraft will have to descend with a higher rate after passing the crossing traffic. Increasing the rate with engines at idle is generally not a problem because it can be resolved by adjusting aircraft pitch attitude. The secondary effect, which is also a limiting factor for the maximum rate of descent, is the concomitant increase in speed. If ToD is delayed within reasonable limits, then the excess speed can usually be dissipated by extending the speed brakes. In extreme cases, the aircraft may then have to fly additional track miles at lower levels to reduce the speed. On the other hand, if initiating descent early and assigning a minimum RoD until passing the level(s) of crossing traffic is deemed more appropriate, then the descending aircraft will reach the approach altitude earlier than planned and will probably have to maintain level flight at these lower altitudes.

Honey, there's a robot at the door that says it's your colleague I Predictor. He missed the shuttle and asks if he can plug in for the night.



Radar vectoring to ensure radar separation whilst vertical separation does not exist – in this case a very short period of time, as one of the aircraft will be descending – is usually considered a less appropriate solution as it increases the distance that the aircraft will have to fly. But in exceptional cases, where the vectoring also provides a shortcut or when the minimum distance is close to the minimum radar separation and vectoring does not involve significant turns (>5 degrees), it might be the best option.

The "unknown factors" mentioned in the previous example have an even more significant role when the downstream sectors are lower and often busier airspace.



Now let's have a look at all three examples together, let's say it is the same aircraft that is affected during different phases of flight. The negative cost impact can accumulate as the aircraft passes through different sectors. Luckily, in reality the overall effect can be that successive impacts cancel each other out or, more likely, their cumulative effect will be lower than just a pure sum of the individual restrictions. For the time being we have neither the overview nor any control on how the various performance restrictions are accumulating during a flight, but at least there are developments for the future that look promising (4D trajectory management).

Instead of an answer

It is challenging to predict the future, but looking ahead is part of the job and I will give it a try. The traffic situations described above are likely to continue to exist in the future. I am sure you can think of many others too. Furthermore, flying free routes will probably add to the need for positive control actions which will usually have a negative cost impact. At the same time, future ATC tools will probably be available to support the controller decision-making so that we can provide the best possible service whilst minimising the negative effects of both , the "unknown factors" and cumulative effects. The required ATCO competence regarding aircraft performance will probably change, but this change is likely to be gradual and evolving to meet the future demands. Until then, here is a general guidance for assigning aircraft performance restrictions.

Whenever possible, aircraft should be allowed to fly the shortest possible routes at their requested cruising levels, own speeds and rates. When positive control action must be taken to ensure separation, the economic factors should also be considered with high priority before selecting the most appropriate solution to a given traffic situation. Performance restrictions should be kept to the minimum necessary to ensure separation and as much as possible should be distributed among the aircraft concerned in a balanced way. Adding extra buffers by default ("just in case") is not a good practice and neither is applying double restrictions ("just to be sure"). It is always a good idea to assign a limit for any restriction too, since this will allow pilots to plan ahead. When this is not possible, do remember to immediately cancel the restriction once it is no longer required.

Dragan Milanovski is an ATC training expert at the EUROCONTROL Institute of Air Navigation Services in Luxembourg. Most of his operational experience comes from Skopje ACC where he worked for a number of years in different operational posts. Now, his day-to-day work involves ATC training design as well as Initial Training delivery for Maastricht UAC.