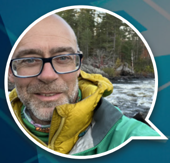
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"MANAGE THE GREEN"

OBSERVATIONS OF HOW CONTROLLERS STAY IN CONTROL OF TECHNOLOGY

In the Canadian air traffic management system, controllers work with cutting-edge technology to stay in control. Tab Lamoureux, Chelsea Kramer and Catherine Dulude observed and interviewed controllers to better understand how they stay on top of technology, resulting in five key insights.

KEY POINTS

1. **Automation and cognitive capacity:** Controllers use automation to free up cognitive capacity, allowing them to handle more aircraft and complex problem-solving tasks efficiently.
2. **Understanding how the technology works:** Controllers need to understand the underlying mechanisms of technological systems to an appropriate level to interpret alerts accurately and maintain system integrity.
3. **The role of continuous interaction:** Maintaining control involves continuous interaction with display objects, systematic scanning, and active confirmation of automated functions to synthesise data into a coherent operational picture.
4. **The importance of visual scanning techniques:** Despite technological advancements, traditional scanning techniques remain essential, helping controllers understand what's going on and identify potential issues.
5. **Understanding the airspace and traffic flows:** Controllers' deep understanding of airspace dynamics and predominant traffic flows allows them to anticipate and respond effectively to operational challenges.

INTRODUCING THE CANADIAN ATM SYSTEM

Although the Canadian air traffic management (ATM) system infrastructure and the associated human-machine interfaces have been in use for many years, the current system remains one of the most functionally advanced in the world. The system has kept pace with increasing traffic volumes and complexity, accommodated advanced decision support and automation, and supported the highly varied and unique challenges of our airspace. With the sometimes subtle changes that have occurred over the years, we wanted to know how controllers stay in the loop. Since the system as a whole remains human-centred, with people in control, it is important to understand from controllers what they do to stay on top of the technology. Such insights help to shape the next generation of ATM systems to ensure that the human-automation partnership is mutually effective.

To get a better understanding of this issue, we observed and spoke to eight controllers in four units. The approach to both observations and interviews was unstructured and opportunistic. After explaining our interest in how they keep on top of, or ahead of, the automation, controllers described their strategies. We then probed further based on what the controllers said. In this article, we summarise five ways in which controllers stay in control based on what we saw and heard.

> "Controllers felt that well-designed automation can help to free up time and capacity to handle more aircraft and yet still have spare capacity to deal with more complex problem-solving activities."

1. STAYING IN CONTROL MEANS ALLOWING AUTOMATION TO FREE UP CAPACITY

Controllers felt that well-designed automation can help to free up time and capacity to handle more aircraft and yet still have spare capacity to deal with more complex problem-solving activities. This includes time to scan the situation display, identify conflicts and find route efficiencies.

Prior to the integration of today's advanced technology, more time was spent planning and attempting to work 'ahead' of the traffic. Automation and associated alerts now provide appropriate warning of events that controllers need to be aware of. Controlling aircraft today involves more validation of information with a shorter time horizon than previously.

For instance, CPDLC (controller-pilot datalink communication) and space-based ADS-B (automatic dependent surveillance–broadcast) are key enablers over the North Atlantic. These technologies permit communications and surveillance where previously procedural control had to be used. The ATM system presents all information on a single display, showing a mix of extrapolated and surveillance targets. The system determines what separation must be applied and then provides the controller with notifications (and warnings if necessary) for flights. This has resulted in a change in this unit's style of controlling. Previously, controllers would work from the strips to the situation display. Now, because surveillance is the norm, controller attention is focused more on the situation display than on the strips.

As well as tactical control over the ocean, this unit is responsible for planning traffic onto the ocean. Conflict-free profiles are employed so that, if no communication were possible, all aircraft would remain separated for the duration of the route. The complex planning task is now aided by automation; specifically, a problem-solving and decision support tool that reduces demand on working memory, mimicking the manual tools used by controllers.

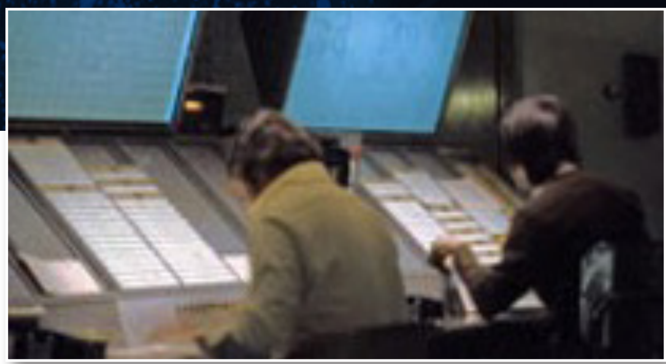

Figure 1: North Atlantic Control Position - Then

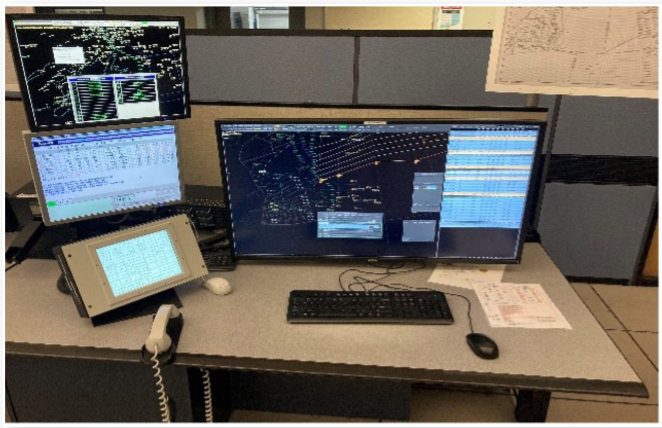

Figure 2: North Atlantic Control Position - Now

As another example, in some Canadian airspace, the lack of communication and surveillance coverage can mean that a controller needs to apply a variety of separation standards across their sector. To manage this challenge, the flight data processing system and associated controller tools are arguably the most highly adapted in the country, automatically anticipating the most likely controller input, validating other controller inputs, and prompting controllers when a different strategy needs to be employed. Controllers now routinely control far more aircraft than in the past with very high levels of trust in the technology.

2. STAYING IN CONTROL MEANS UNDERSTANDING THE SYSTEM

Appropriate trust in, and use of, technological systems means that controllers need to understand, to an appropriate level, the underlying technical system. The controllers all expressed a need to understand how the system works and what the automation is trying to tell them. Training provided to controllers teaches them what information is going into the technology and how to clarify any ambiguity. They are trained to always take warnings seriously. Here, the concept of 'display hygiene' is important; system messages are not left to persist in an elevated alert state. Controllers are taught to include system message lists in their active scan and will physically mouse-over the list with the cursor.

"The controllers all expressed a need to understand how the system works and what the automation is trying to tell them."

Overconfidence can creep in, so good operational habits should be constantly reinforced. An appreciation of common decision-making heuristics and biases that can affect operational performance with automation may help to maintain human performance. Such threats to human performance have been described as "ironies of automation" and "ironies of artificial intelligence" by Bainbridge (1983) and Endsley (2023).

3. STAYING IN CONTROL INVOLVES CONTINUOUS INTERACTION

Another finding from the study was that staying in control involves continuous interaction, not passive monitoring. This may include:

- systematic interaction with display objects via the mouse, and
- 'display hygiene' activities (e.g., acknowledging system alerts/messages, confirming that automated functions have been successfully completed).

This physical activity could be observed in controllers and was critical to the synthesis of flight data into a coherent mental picture of the operational situation. This takes us to scanning.

4. STAYING IN CONTROL MEANS KNOWING HOW TO SCAN

Although the job is changing, experienced controllers felt that new controllers should continue to be taught scanning, as has been done for previous generations. This is an active and engaged habit based on a good understanding of the airspace, deliberately searching for and selecting information to build a strong understanding of the dynamic situation. Continuous and deliberate scanning requires effort and discipline, especially when scanning includes information derived from automation.

"Experienced controllers felt that new controllers should continue to be taught scanning, as has been done for previous generations."

Controllers exhibit a number of different active scanning strategies. These include:

- identifying clusters of aircraft that might need some intervention
- identifying other sources of complexity (interactions between aircraft, special use airspace or overtaking which could result in turbulence)
- 'looking for green' or other unusual colours (green means an aircraft is available for communication and control)
- scanning outside the sector for aircraft that will arrive shortly
- reviewing lists
- scanning waypoints (those on the planned route and in the event of aircraft going direct), and
- looking for wrong-way altitudes.

Controllers apply a deeper knowledge when considering some of these factors. For instance, turning an aircraft or giving it a direct routing could create a wrong way altitude, while giving a very long direct routing can cause problems for flight plan data processing. As a whole, this scanning is critical to understanding the airspace and traffic flows, and this understanding informs scanning.

5. STAYING IN CONTROL MEANS UNDERSTANDING THE AIRSPACE AND THE PREDOMINANT TRAFFIC FLOWS

Controllers are trained to have a strong mental model of the airspace, geographical layout, boundaries and predominant flows. Over time, controllers develop sets of scenarios and strategies. With a solid mental model for the airspace, the strategy for managing air traffic demands relies on monitoring and responding to system prompts and maintaining an active scan, as described above. Related to point 2 above, controllers also need to know the limitations of surveillance and communication coverage, on the part of both the ATM system and the aircraft equipage, as this determines the separation standards to be used.

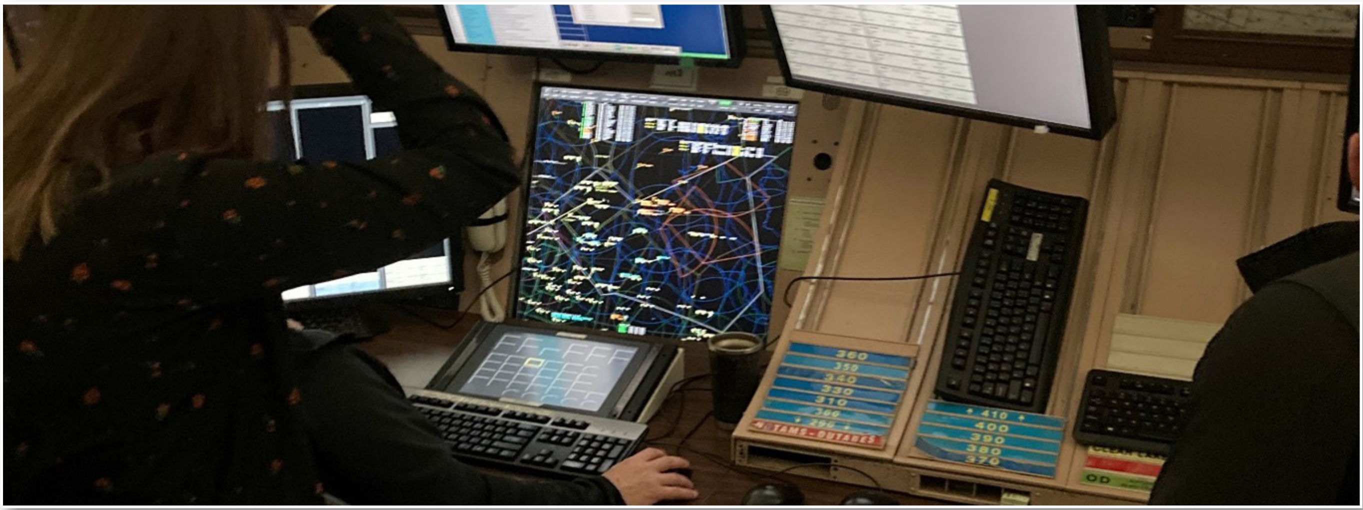

Figure 3: Current En Route Working Position (note: the controller is demonstrating functionality; the display would not normally show these arcs)

SUMMING UP

Our observations of Canadian air traffic controllers revealed an interplay between human expertise and advanced technology in managing complex airspace. Controllers effectively use automation to free up cognitive capacity, allowing them to handle more aircraft and tackle complex problem-solving tasks. The move toward more technologically advanced automated systems has transformed their roles, with increased real-time validation and confirmation of information in place of traditional planning.

Understanding and trusting the technological systems is crucial. Controllers are trained to grasp the underlying mechanisms of automation, ensuring they can interpret alerts and maintain system integrity. Continuous interaction with the display and systematic scanning practices helps controllers synthesise data into a coherent mental picture as the basis for controlling.

Despite technological advancements, fundamental skills like scanning and airspace knowledge remain vital. Based on training and experience, controllers employ scanning strategies to identify potential issues proactively and maintain situational awareness. This combined with their understanding of airspace dynamics and traffic flow enables them to anticipate and respond. Nevertheless, the specific skills of the job will change, and with each new technological advance consideration should be given to what skills no longer need to be taught or practised, and what skills may need to be reinforced.

Ultimately, these practices highlight the importance of both well-designed technological advancements and continuous training and adaptation to prepare controllers for evolving challenges and ensure the safe and efficient movement of air traffic. These findings should be incorporated into the next generation of ATM systems.

As NAV CANADA looks to the iTEC (interoperability through European collaboration) collaboration for its future ATM system, these insights will help us shape our journey to trajectory-based operations, as well as initial and refresher training, ensuring people remain in control, supported by technology.

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