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Air Traffic Controllers Operate Successfully Without Flight Progress Strips in Study

Changes in the human-computer interface for en route air traffic control may eliminate flight progress strips. Controllers in experimental no-strip conditions spent more time watching the plan view displays, called up more flight plan readouts and took longer to grant pilot requests. But there was no difference in performance or perceived workload in strip vs. no-strip conditions.

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Aviation Writer

Although many air traffic controllers consider flight progress strips to be indispensable to their work, a new study based on extensive simulation tests suggests that controllers can perform about as well without them. The study results were published in the U.S. Federal Aviation Administration (FAA) report *How Controllers Compensate for the Lack of Flight Progress Strips*.

The research testing, performed at the Atlanta (Georgia, U.S.) Air Route Traffic Control Center (ARTCC) dynamic simulator, found that a "stripless environment" actually gave controllers more time to watch the plan view displays (PVDs) that represent aircraft on their video consoles.

But the simulations also showed that controllers compensated for the absence of strips by calling up more flight plan readouts (FPRs), which are on-screen displays that show the complete flight plan of an airplane. This change in controllers' behaviors tended to "slow the time to grant pilot requests." And surveys found that many controllers value the readily available information in the strips.

The study was sponsored by the FAA Office of Aviation Medicine and the FAA Research and Development Service, and was performed jointly by the FAA Civil Aeromedical Institute (CAMI) in Oklahoma City, Oklahoma, U.S., and the University of Oklahoma Department of Psychology in Norman, Oklahoma. The study's findings are of interest to aviation officials who are considering long-range plans to automate the interface between controllers and computers.

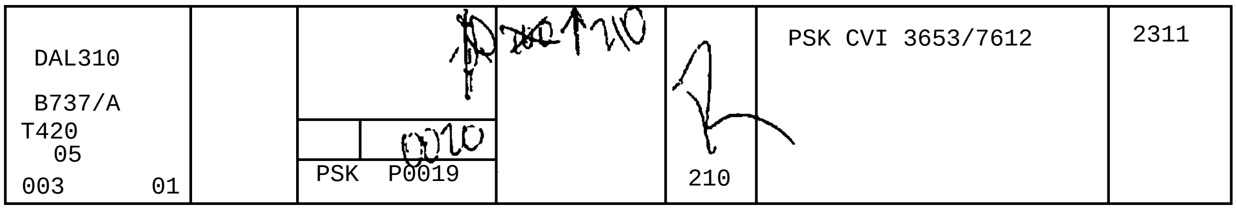
The flight progress strip (Figure 1, page 2) is one of the two primary tools now used for the en route control of high-altitude flights between airports. The strip offers 31 possible data fields for flight information, including the flight's call sign, planned route, filed airspeed, assigned altitude and estimated time of arrival.

While an aircraft is in the controller's sector, the controller writes on the appropriate strip to show the control instructions, which are changes that have been made in the flight plan and any other contacts made with the aircraft.

The other key tool for air traffic controllers is the video console PVD (Figure 2, page 2), which provides computer-augmented radar information on the altitude, position and speed of each aircraft.

Despite the advantages of strips, researchers concluded in their report that "the decrease in workload afforded by the removal of strip marking appears to outweigh the detrimental effects of changing or removing strips." One possible solution in future

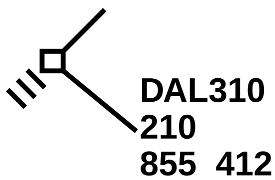
Aircraft Representation on a Flight Progress Strip



Source: U.S. Federal Aviation Administration

Figure 1

Aircraft Representation on a Plan View Display



Source: U.S. Federal Aviation Administration

Figure 2

automation might be to retain the strip "but eliminate the requirement of strip marking."

The report said, "Understanding the way in which controllers compensate for changes in the strip is necessary if we are to determine the amount of information [that] they need to efficiently perform their jobs without compromising aviation safety."

The current system of computer displays was developed in the 1960s, and has become outmoded and inadequate amid increasing air traffic, with U.S. controllers now handling about seven million flights a year. "The combination of these antiquated computer displays and the projected increase in air traffic over the next few years underscores the need for updating the ATC [air traffic control] system now in use," the report said.

During the next few years, advanced automation systems are likely to be introduced, making major changes in the human-computer interface in en route ATC. It is not yet clear exactly how the new systems will display the types of information that are now shown by PVDs and strips, but the report says that "it is likely that the automation will considerably change the manner in which flight data will be displayed and manipulated.

"The automation will most likely combine, in some way, the information currently available on the strip and the information presented on the PVD." Because such automated displays may be limited in the amount of flight information they can present, the report said, it is important for researchers to identify hazards that would be posed by removing, or altering the display of the information now available on strips.

Because people tend to remember the details of things they do themselves better than those of things that are done for them, proposals to automate flight following have led to considerable debate among researchers, the report said.

In the late 1980s, British researcher V.D. Hopkin expressed concern that automating some tasks that controllers now perform manually, including marking strips, could be detrimental if the cognitive impact of that automation is not taken into account.

For example, Hopkin wrote in a 1989 report[1] that if a controller offsets or marks on a "particular flight strip … as a memory aid … the fact that the action was under the controller's initiative helped the controller remember why [the action] had been taken and what had to be remembered."

In a related study in 1990, researchers O.U. Vortac and C.F. Gettys[2] asserted that replacing strips by an electronic display may qualitatively change the controller's interactions with flight data.

Because the ATC system has become so complex, other experts suggest that controllers' behaviors to compensate for the loss of the strips may yield some advantages. For example, for controllers who are now required to maintain written records of aircraft control actions, the report suggests that "removing manual strip board management tasks may increase the time controllers have available to scan the PVDs.

"The elimination of strip marking would likely free up cognitive resources to deal with other aspects of controlling traffic. In fact, informal reports of controllers suggest that strip marking becomes secondary to PVD separation under high traffic density and workload."

Some previous research suggested that controllers' workloads would be reduced if the strips were available, but the requirements of strip marking and board management were eliminated. A 1993 study[3] suggested that the workload decrease achieved by eliminating the need to update the strips may, in fact, have beneficial results. When strip marking was eliminated, controllers tended to respond sooner and grant more requests to planes not yet in controlled airspace. Also, controllers who did not mark strips appeared to be better at anticipating future actions.

With those results in mind, CAMI and the University of Oklahoma researchers decided to study the consequences of eliminating the flight progress strip entirely, using more realistic simulation conditions than those of the previous studies, whose subjects were FAA Academy instructors controlling a fictitious airspace.

The CAMI/University of Oklahoma simulations involved 20 volunteers, all air traffic controllers at the FAA Atlanta ARTCC (Atlanta Center).

All but one of those controllers — a group whose members' Atlanta Center experiences varied from eight months to 34 years — were full-performance level and from the same area of specialization at the Atlanta Center. [Full-performance level controllers are those who have become certified on all required positions at the facility they are assigned to.]

The experiments used the Atlanta Center's dynamic simulator, which provided high-fidelity simulation of fictional air traffic in the center's busy Pulaski sector, a high-altitude sector whose controllers are responsible for air traffic from flight level 240 (24,000 feet [7,320 meters]) to flight level 290 (29,000 feet [8,845 meters]) in portions of Virginia, Tennessee and North Carolina.

For each controller, the PVD console was situated to the left, and the strip bay to the right. Two researchers and a subject-matter expert observed directly each controller's activities. A third researcher, using a headset, monitored air-traffic communication. And three FAA training experts operated the scenarios from remote positions, simulating pilot communication and activity, as well as communication and coordination with adjacent air sectors.

Researchers used two 25-minute scenarios that were considered to be equal in complexity. One consisted of four departures, 10 arrivals and nine overflights; the other consisted of nine departures, four arrivals and nine overflights. Nine pilot requests, such as asking for changes in the altitude or route, also were included in each scenario.

Each subject controller worked in both a "strip" condition and a "no-strip" condition. In the strip condition, controllers were asked to control traffic as they normally would; in the no-strip condition, they were told that no strips were available, but that they would be given a notepad on which to write any information they needed. Researchers counterbalanced the order of scenarios and the condition (strip or no-strip) of the scenarios.

During each scenario, one researcher used a hand-held stopwatch to record the total amount of time the controller watched the PVD. A second researcher watched the controller and recorded four measures: the number of times the controller called up an FPR; the number of times a route was displayed; the total number of "J-rings" (polygons placed around selected aircraft on the PVD) that the controller activated to help check separation between aircraft; and the number of conflict alerts that occurred during the scenario. A conflict alert is a software feature that causes the data blocks of two or more aircraft to flash when the computer projects that they will lose standard separation in three minutes.

Also recorded were the requests pilots made to controllers, as well as the length of time controllers required to respond to those requests. Researchers noted the number of times each controller requested information from the pilots, and the number of controller requests to other flight centers, such as for control of airplanes about to enter the controller's sector.

As soon as the simulation ended, controllers completed a workload- and performance-measuring instrument (adapted from the U.S. National Aeronautics and Space Administration [NASA] Task Load Index [TLX]) revealing mental and physical demand, effort, frustration and performance. Controllers also completed feedback questionnaires after the simulations, and were interviewed to "determine if there were perceived differences between real air traffic control and the simulations." Meanwhile, the subject-matter expert checked the status of the planes in the simulation, and then completed FAA Form 3120-25, evaluating each controller's performance.

In general, researchers found "no significant differences" between performance ratings for controllers functioning with flight strips and those working under no-strip conditions.

The subject-matter expert observing each controller's activities rated the controller on 27 items related to performance skill using Form 3120-25 (Table 1, page 4). There were three possible responses for each item: "satisfactory," "needs improvement" and "unsatisfactory." A chi-square analysis showed no significant differences between controllers in strip vs. no-strip conditions.

Of the controller actions measured during the simulations, researchers found that each of the 10 measured controller actions either took longer or occurred more often in the no-strip condition (Table 2, page 5). But the simulations showed significant differences in only three areas. Controllers in no-strip operation:

- Spent more time watching PVDs. During the 25-minute scenarios, controllers operating in the no-strip condition spent a mean of 18.98 minutes watching PVDs, vs. 14.24 minutes for controllers operating in the strip condition.

  This was considered a possible advantage. "Allowing controllers to watch the PVD for a significantly longer period of time could result in a better representation, or 'mental picture,' of the dynamic and complex situation," the report said, referring to the 1993 Vortac et al. study;

- Called up a greater number of FPRs. Controllers in the no-strip condition called up a mean of 22.4 FPRs, vs. only 5.8 FPRs called up by controllers in the strip condition.

  "To compensate for the absence of strip information, controllers used the FPR function to get information normally printed on a strip," the report said. But researchers added that the increase in keyboard activity "was arguably a reasonable trade-off relative to the time normally needed to scan the strip bay"; and,

- Took longer to grant pilot requests. Controllers in the no-strip condition took a mean of 34.87 seconds to grant pilot requests, vs. 24.01 seconds in the strip condition.

Controllers operating in the no-strip condition left slightly fewer actions remaining to be performed at the end of 25 minutes than did the controllers operating in the strip condition (Table 3, page 5).

Even though controllers operating in the no-strip condition took longer to respond to pilot requests, there were no significant differences in perceived workload, as measured by the TLX in the strip condition and the no-strip condition (Table 4, page 5). Researchers were unsure of the reason for that apparent disparity.

"Although perceived workload ... was not affected, time to grant pilot requests for the previous analysis could be viewed as a secondary measure of workload," the report said.

"Alternatively, the difference may have been simply due to the amount of information readily available to the controller. In the no-strip condition, controllers may have had to do more [FPRs] for relevant information before granting a request, thereby slowing time to grant it."

A postexperimental questionnaire (PEQ) was administered to the controllers following the experiment. The responses revealed that controllers found the strips had more "usefulness"

Table 1
FAA Form 3120-25 Rating Frequencies, Strip vs. No-strip Condition

Job Function Category	Job Function	Satisfactory	Needs Improvement	Unsatisfactory
Separation	Separation is ensured.	19/19	0/0	1/1
	Safety alerts are provided.	19/19	0/0	0/0
Control Judgment	Awareness is maintained.	15/15	2/3	3/2
	Good control judgment is applied.	16/18	2/1	2/1
	Control actions are correctly planned.	20/19	0/0	0/1
	Positive control is provided.	20/19	0/1	0/0
Methods and Procedures	Prompt action is taken to correct errors.	17/17	1/0	0/0
	Effective traffic flow is maintained.	17/18	3/1	0/0
	Aircraft identity is maintained.	15/17	5/3	0/0
	Strip posting is complete/correct.	N/A	N/A	N/A
	Clearance delivery is complete/correct/timely.	2/0	0/1	0/0
	Directives are adhered to.	18/16	1/1	0/1
	General control information is provided.	19/18	1/1	0/0
	Equipment failures/emergencies get rapid response.	N/A	N/A	N/A
	Visual scanning is accomplished.	18/18	2/2	0/0
	Effective working speed is maintained.	20/20	0/0	0/0
	Traffic advisories are provided.	20/19	0/0	0/0
Equipment	Equipment status information is maintained.	5/5	0/0	0/0
	Computer entries are complete/correct.	19/16	0/1	0/0
	Equipment capabilities are utilized/understood.	18/19	0/0	0/0
Communication/ Coordination	Required coordinations are performed.	5/6	10/7	5/7
	Cooperative, professional manner is maintained.	20/20	0/0	0/0
	Communication is clear and concise.	17/19	2/1	1/0
	Prescribed phraseology is used.	19/17	1/3	0/0
	Only necessary transmissions are made.	20/20	0/0	0/0
	Appropriate communication method is used.	18/19	2/1	0/0
	Relief briefings are complete and accurate.	N/A	N/A	N/A

First number in each pair is for strip condition and the second is for no-strip condition.
FAA = U.S. Federal Aviation Administration.
N/A = Not applicable.
Source: U.S. Federal Aviation Administration

Table 2
Controller Behaviors, Mean Values, By Condition

Variable (Measured Units)	No-strip		Strip	
Time watching PVD (seconds)	1,137.80	(84.39)	854.45	(76.86)
Flight plan readout (N)	22.40	(3.66)	5.80	(4.38)
Route display (N)	1.45	(2.19)	1.15	(1.60)
J-rings (N)	2.85	(2.06)	2.65	(1.53)
Conflict alerts (N)	1.40	(0.99)	1.30	(1.17)
Time to grant requests (seconds)	34.87	(20.06)	24.01	(15.81)
Requests unable (N)	0.35	(0.58)	0.30	(0.73)
Requests ignored (N)	0.35	(0.67)	0.70	(1.03)
Total requests to pilot (N)	2.25	(1.02)	1.75	(1.45)
Total requests to center (N)	3.90	(2.59)	3.05	(1.70)

PVD = Plan view display. N = Number.
Effects shown in bold are significant.
Figures in parentheses are standard deviations.
Source: U.S. Federal Aviation Administration

and provided a greater "amount of information," at statistically significant levels (Table 5).

In their written responses to postscenario questions, 11 of the 20 controllers said that they preferred using the notepads to using the strips. The most common reasons they cited were that the strips were cumbersome and that the absence of strips gave them more time to view the PVDs. The other nine controllers preferred the strips, which they said made information readily available and were more comfortable to use.

In the oral feedback interviews, controllers said that strips were most useful for communication (five controllers); heading information (five); planning (four); aircraft speed information (three); route information (three); transitioning aircraft (two); and sequencing airplanes (two).

Table 3
Number and Type of Remaining Actions, Mean Values, by Condition

Action	No-strip		Strip	
Route changes	0.70	(0.92)	0.65	(0.67)
Altitude changes	2.15	(1.35)	2.80	(1.40)
Speed changes	0.10	(0.31)	0.05	(0.22)
Handoff acceptances	0.05	(0.22)	0.05	(0.22)
Handoff initiations	5.65	(1.79)	6.00	(1.45)
Frequency changes	7.55	(1.90)	8.25	(1.90)
Other	0.80	(0.95)	1.05	(1.00)
Total	17.00	(5.64)	18.85	(4.66)

Figures in parentheses are standard deviations.
Source: U.S. Federal Aviation Administration

Table 4
TLX Ratings, Mean Values, by Condition

Factor Related	No-strip		Strip	
Mental demand	6.41	(1.76)	6.77	(1.70)
Physical demand	5.38	(2.58)	6.23	(2.26)
Temporal demand	5.90	(2.00)	6.31	(1.95)
Effort	6.15	(1.85)	6.58	(1.91)
Frustration	4.71	(2.14)	4.41	(2.66)
Performance	6.04	(1.76)	5.84	(1.57)

The higher the score, the higher the perceived workload, with 4.8 = moderate, 9.6 = high. TLX = U.S. National Aeronautics and Space Administration Task Load Index. Figures in parentheses are standard deviations.
Source: U.S. Federal Aviation Administration

Nine of the 20 controllers said that the lack of flight strips did not impair their work. Others felt some degree of impairment, including complaints that, without the strips, information was not readily available (three controllers); there was a greater mental load (two); they could not plan (two); they had to call up more FPRs (two); and they simply were not used to the absence of strips (two).

Would a revised strip with less information meet controllers' needs? Asked to list the minimum essential information that should be included on a revised strip, controllers mentioned route (15 controllers); aircraft type (12); altitude (12); call sign (eight); speed (four); and destination (three). Three controllers said that they would prefer to have no changes to the current strip.

When asked what information would need to be included in the PVD data block to eliminate the need for strips, only one controller said that the strips could not be eliminated. The other controllers listed data items that they would want to add to the PVD, including route (five controllers); aircraft type (five); heading (five); requested altitude (three); a mark to indicate a flight outside its filed route (two); and beacon codes (one).

Table 5
PEQ Ratings, Mean Values, by Condition

Question	No-strip		Strip	
Usefulness	3.85	(3.79)	6.86	(2.91)
Likeability	4.71	(3.63)	6.53	(3.70)
Amount of information	7.56	(3.91)	10.48	(1.85)

The higher the score, the higher the rating. Figures in parentheses are standard deviations. PEQ = Postexperimental questionnaire.
Source: U.S. Federal Aviation Administration

Researchers concluded that the advantages of removing the strips — notably, giving controllers more time to watch PVDs — seemed to outweigh the disadvantages of changing or removing the strips.

But they suggested that more research is necessary to determine if removing strips might have more substantial long-term effects, and to learn if controllers responsible for other types of sectors, such as low-altitude arrival or nonradar sectors, can also compensate for the lack of flight strips.

"In any case, the current work shows that, at least for sectors like Atlanta Center's Pulaski, such compensation is possible without commensurate increases in workload or substantial decreases in performance," the report said.

Because the Atlanta simulations indicated that controllers focused more on PVDs in the absence of strips, the researchers suggested further investigation of whether expanding the information in PVD data blocks could allow the simplification or elimination of strips.

In theory, the report suggested, "the placement of more information on the [PVD] data block, and less on the strip, should result in more time to view the PVD, thereby allowing controllers to concentrate on the primary task of aircraft separation."♦

Editorial note: This article was adapted from *How Controllers Compensate for the Lack of Flight Progress Strips*, Report no. DOT/FAA/AM-96/5, February 1996, by Chris A. Albright, Todd B. Truitt, Ami B. Barile, O. U. Vortac and Carol A. Manning. The 14-page report includes figures, tables, references and appendices that summarize the TLX instructions and the postexperiment questionnaire.

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