# CONTROLLER ASSIGNED AIRBORNE SEPARATION (CAAS) RESULT OF STRATEGIC PAIRWISE STUDY

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## Abstract

A study of the Controller-Assigned Airborne Separation (CAAS) strategic crossing application has been completed by the MITRE Corporation's Center for Advanced Aviation System Development (CAASD). The strategic CAAS procedure permits delegation of separation authority from the air traffic controller to the aircrew in specific situations, while assisted by ground-based automation for conflict detection and resolution, as well as data communication for clearance delivery..

Nine former Air Traffic Controllers worked various simulated air traffic scenarios both with and without strategic CAAS. Controller performance measures and subjective responses were collected and analyzed. Overall, results indicate that the concept of CAAS is promising. Controllers reported that it could be a useful procedure for reducing workload and therefore contribute to a more productive work environment. They also indicated that it is a reasonable step in the evolution of more sophisticated tools and procedures.

Further research is proposed in four areas: (1) Additional Controller applications for CAAS, (2) pilot evaluations, (3) integrated pilot-controller experiments, and (4) analysis of benefits and costs.

## Introduction

This paper describes simulations conducted to explore the viability of delegating separation authority, using integrated ground automation and data communications, to flight crews equipped with cockpit capabilities for situational awareness.

This work is part of a broad research effort by the MITRE Corporation's Center for Advanced Aviation Systems Development (CAASD) to explore long term concepts that hold promise for enhancing NAS scalability, efficiency, productivity, and throughput [1]. It is consistent with international research efforts under the Airborne Separation Assistance Systems (ASAS) [2], and with future vision goals as cited by the Federal Aviation Administration (FAA) [3], the Joint Planning and Development Office (JPDO) [4], and RTCA [5].

The breadth of this effort includes a portfolio of paradigm shifts and system enhancements for the future such as Time-Coordinated 4D trajectory navigation, Performance Based Operations, Decision Support Systems and Automation, System-Wide Information Management, and much more.

In that broader context 'delegation', whether it be for aircraft separation or for any NAS activity, represents a fundamental principle for enhancing system scalability. The objective of the delegation principle is to distribute workload throughout the system such that the work is better balanced across the system and performed by the person(s) or entity(s) best suited to carry it out. The principle implies that delegation is good and should be used where practical and appropriate, but not to the detriment of other system goals such as safety or efficiency.

The research community is moving forward in earnest with the exploration of technology and procedures that enable flight crews to attain situational awareness, and act on that awareness to ensure separation and spacing from other aircraft [6][7][8].

Today, air traffic controllers can delegate separation authority under Instrument Flight Rules (IFR) when conditions permit the use of visual separation[1]. In the future, technology and automation will widen the scope of operational

[1] Per FAA Order 7110.65, Section 7-2-1, a procedure which temporarily delegates separation responsibility to positively controlled aircraft to using visual means.

conditions in which separation can be delegated. The challenge is to define procedures that allow this to occur without compromising safety, and to provide automation support for the ground and air participants to carry out those procedures.

Where delegation is applied to separation authority for aircraft crossing, merging, or along-path spacing, it represents opportunities to develop powerful productivity enhancing applications. This paradigm shift postulates that delegating of separation and spacing responsibility to the flight crew permits aircraft maneuvers of greater precision and smaller magnitude, achieving the following:

1. Increased safety
2. Minimized perturbations to strategic trajectory-based plans
3. Reduced air traffic controller (ATC) workload.

Conceptually, delegating separation for crossing aircraft and during merging and spacing situations alleviates critical tactical monitoring on the human service provider, and thus the need to issue corrective maneuvers to ensure separation. The balance of time and cognitive effort otherwise spent on these activities can then be available for other tasks requiring their attention. By strategically identifying and coordinating such delegated maneuvers with automation and data communications, further tactical tasking can be offloaded. This could be one means of providing safe scalability for the system to grow the number of flight operations in the future NAS.

### *Purpose of This Study*

The purpose of this study was to gain first order insight into the viability and benefit of delegation from the ATC operations perspective, supported by key elements of an assumed future operating environment to include:

1. Ground-based automation support for delegated maneuvers
2. Data communication capability
3. Strategic upstream clearance procedures
4. Cockpit capabilities for situation awareness and airborne separation

## Overview of Strategic CAAS

CAAS for crossing/passing aircraft entails the delegation to one aircraft (the ‘instructed’, or ‘maneuvering’ aircraft) to pass behind another (the target aircraft) by a prescribed distance. Cockpit Display of Traffic Information (CDTI) is used in conjunction with Automatic Dependent Surveillance-Broadcast (ADS-B) and other support tools to manage the execution of the maneuver in compliance with the clearance [9].

### *Tactical CAAS Operations*

Tactical CAAS refers to procedures used by the radar controller to clear aircraft under his/her control to perform the airborne separation maneuver. Under tactical CAAS conditions conflicting pairs are identified manually (e.g., without the benefits of conflict probe), and clearances are issued verbally [10].

The simulated Tactical CAAS display is initiated by typing ‘DC’ (Draw CAAS) on the keyboard, then either slewing to both targets or entering the respective Computer Identification (CID) numbers[2]. Once enacted, a green line appears between the two position symbols, and a 3-mile[3] circle appears around the target aircraft (see Figure 1). The maneuvering (instructed) aircraft is always selected first, which automatically forces the circle onto the target aircraft.

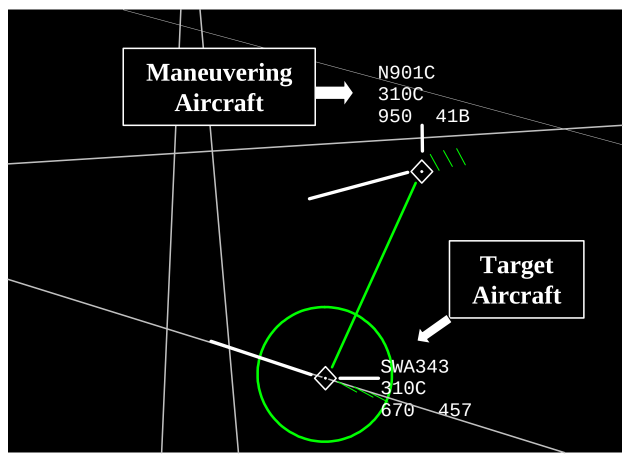


**Figure 1. CAAS Lines on Controller Display**

[2] A slewing action consists of target selection via the DSR trackball followed by an ‘enter’ command.
[3] Three mile separation was used in this study only for delegated separation maneuvers. Standard five mile en route separation was used for all other cases.

### *Strategic CAAS*

The largest operational distinction for Strategic CAAS is that it builds on Tactical CAAS by allowing the delegation clearance to be delivered upstream of the airspace where the problem is predicted to occur. This alleviates the need for the controller in that airspace to identify the problem and clear the aircraft tactically. Achieving the strategic implementation of CAAS necessitates the integration of:

1. Additional procedures and operational constraints
2. Automation to detect problems early and assess the necessary resolution parameters quickly
3. Data communications to convey all of the parameters of the situation and clearance to the pilot
4. New display features for controller situation awareness

Taken together, these added elements permit a shift in the timeframe that the situation is both identified and cleared/delegated to the pilot (i.e., 'strategic'), such that the clearance occurs prior to the aircraft entering the sector where the problem is predicted to occur.

The simulated source of the clearance for a downstream maneuver in this case was a multi-sector service provider role, under conceptual development as part of the broader CAASD Future Vision work. However it is also procedurally viable that any upstream service provider can implement this procedure. This study focused on the operations and effects in the airspace where the delegated maneuvers occurred. The effect on upstream operations was not part of the scope of this initial viability assessment.

For Strategic CAAS, the delegation clearance is responded to by the flight crew of the instructed aircraft. As in Tactical CAAS, all instructed aircraft are to pass behind the target aircraft.

Assuming the flight crew accepts the data linked CAAS clearance upstream, including the Aircraft Identification (ACID) of the target aircraft, the maneuver start point, and revised flight path to pass behind the target aircraft, the fourth line of the datablock becomes visible to the controller when it appears on the DSR (Figure 2). The controller can then find and view the other aircraft in the CAAS operation by clicking the fourth datablock line on either target.

Until the ATC system receives a data linked 'Confirm' message from the instructed aircraft the fourth line of both aircraft data blocks (if both are visible) blink, and the line of the line/circle display is beige to indicate that the flight deck's status is 'Looking'.

When the flight crew of the instructed aircraft confirms the CAAS clearance, the beige line turns green and the fourth line of the datablock stops blinking[4]. This is an indication the the pilot has both acquired the target aircraft on the CDTI and has officially accepted responsibility for the separation maneuver.

Upon reaching the maneuver start point, the instructed aircraft begins a turn within a conformance range to pass behind the target aircraft (the lines above and below the revised flight path in Figure 2). The conformance range is determined by the conflict probe application to be the range of maneuver freedom while remaining conflict free downstream.

After the maneuvering aircraft passes the Closest Point of Approach (CPA) to the target aircraft, it turns back to its original airway or assigned route of flight.

## Simulation Environment

The study of Strategic Delegation to the cockpit using Controller Assigned Airborne Separation (CAAS) took place in June 2005, in the Integrated ATM Laboratory at the CAASD facility in McLean, Virginia. The laboratory is equipped with multiple air traffic control workstations capable of simulating en route and terminal operations, as well as cockpit simulators. The laboratory also contains pseudo-pilot workstations, which were used in support of this study.

The study used one simulated en route Display Replacement System (DSR) console for the controllers, and a single pseudo-pilot position that was physically separated from the controller console. Simulated controller-pilot push-to-talk communications were provided.

[4] The beige and green lines were derived by CoSpace [7].

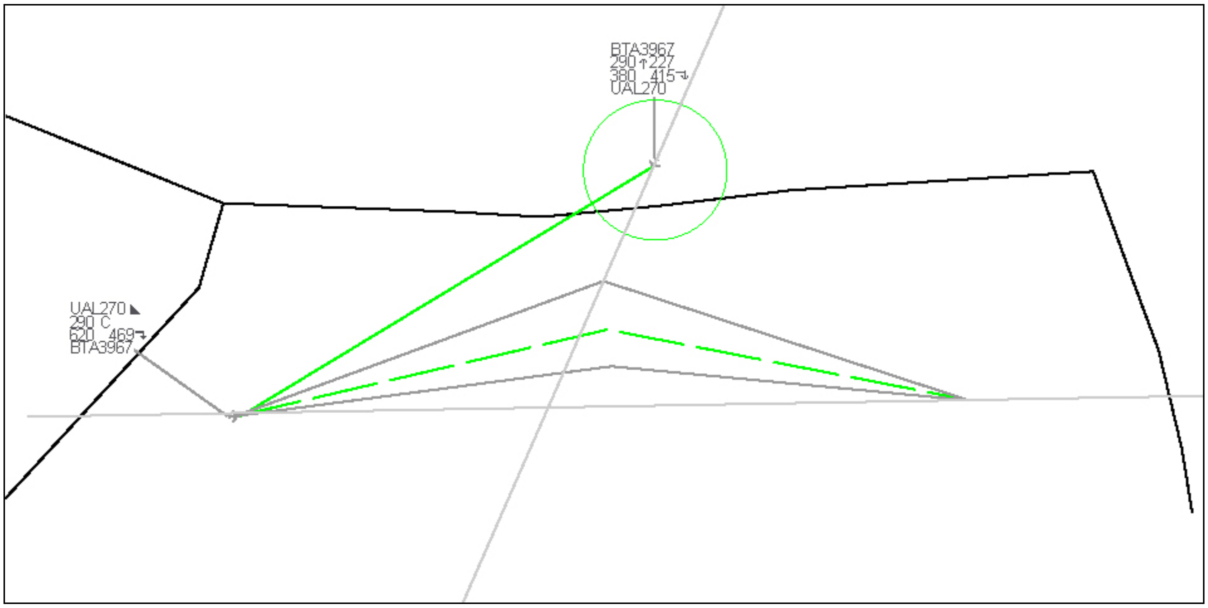


**Figure 2: Two aircraft using Strategic CAAS**

## Simulation Description

The study included three control conditions, with two scenarios of different traffic levels for each, for a total of six simulated traffic scenarios. Control conditions were Baseline (current operations), Tactical CAAS only, and Strategic CAAS. The Strategic CAAS condition also included use of data link communications. The traffic levels were Moderate (an average of 8 aircraft under control simultaneously, with a maximum of 15), and Heavy (an average of 15 aircraft under control simultaneously, with a maximum of 20).

### *Training*

The study included one hour of background information and familiarization of the Future Vision concepts, including the derivation of CAAS and its relationship to international research. In addition, a 20-minute hands-on training scenario was provided prior to the Tactical and Strategic scenario sets.

### *Scenarios*

The first pair of scenarios was used to establish a baseline for measuring performance and workload using conventional ATC methods, as such these were performed without conflict probe automation, and no data communication. Traffic levels were moderate and high, with no CAAS available.

The second pair of scenarios used Tactical CAAS with moderate and high traffic levels with no automation tools to detect conflicts in advance (conflicts were detected manually, and controllers had to determine which aircraft would pass behind the other before issuing the CAAS clearance).

The third pair of scenarios used Strategic CAAS with moderate and high traffic levels, with automation to detect conflicts. In these scenarios CPDLC was assumed to deliver the CAAS clearances to maneuvering aircraft.

### *Airspace and Procedures*

A high-altitude airspace sector from the Indianapolis Air Route Traffic Control Center (ZID) was adapted at the MITRE ATM laboratory for this study. Recorded traffic was modified to induce a desired number of CAAS-applicable traffic situations in the time available. Furthermore, the traffic flows were simplified to create a more generic sector operation, thus reducing training time. Six major flight paths were used between FL240 to FL329 (three sets of nearly parallel routes) such that intersecting traffic appeared at predictable points (see Figure 3), and most traffic was in level flight.

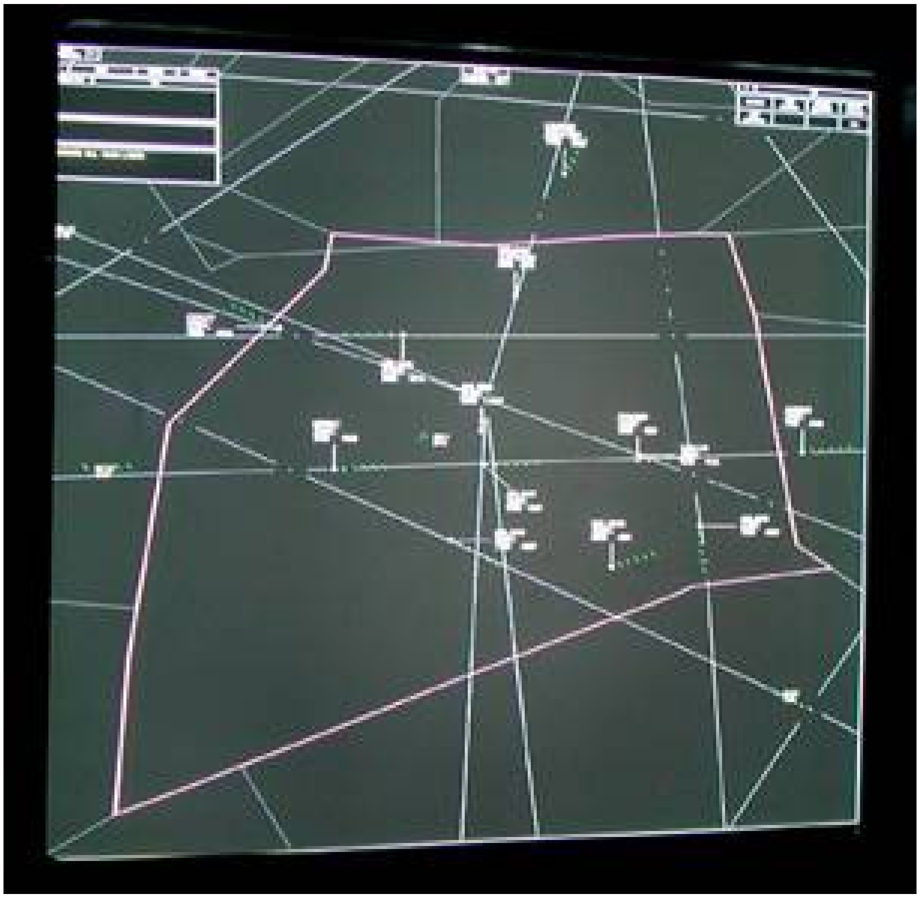

**Figure 3. Airspace for simulation exercise**

Handoffs for aircraft entering and departing the sector were automatic, including handoff acceptance for inbound traffic; the pseudo-pilot made initial contact with the controller after an inbound handoff was accepted. Controllers were instructed to assume coordination with adjacent sectors had been achieved such that aircraft could be turned without forcing a simulated call. The instruction to the controllers in this study was to concentrate on the traffic and account for strategically cleared/delegated aircraft, but identify the conflicts that occur tactically and use Tactical CAAS as a preferable means to resolve them[5]. For consistency with the baseline condition, conflict detection automation and data communications were simulated for the upstream clearing of delegated maneuvers only. These capabilities were not available to the active participants for real-time use in other aspects of their ATC operations. The participants remained responsible for manually identifying any additional problems that occurred, or were created, within their own airspace. For such problems, resolution clearances had to be verbally relayed to the pilots.

## Conduct of the CAAS-Pairwise Study

Nine participants served as controllers for the study. All were former Certified Professional Controllers (CPCs) with varied breadth of domain experience. Each controller experienced the following steps over approximately five hours:

[5] The controller can cancel a strategic delegation or use other separation techniques if operationally necessary.

1. An introductory briefing and discussion, which explained the derivation of CAAS in general, and the theory behind it. The introduction also provided an explanation of the operational procedures, including the following:
    a. Controller phraseology and pilot responses
    b. Activation and termination of the CAAS command
    c. Overview of the airspace, including surrounding sectors
    d. What to expect in terms of the scenarios

2. A 20-minute training session on the emulated DSR workstation, which provided familiarization with the operations and illustrated the following:
    a. The airway structure and the traffic flows
    b. The execution of the tactical CAAS command using the simulated multifunction syntax
    c. Illustration of CAAS lines between the maneuvering ('instructed') aircraft and target aircraft position symbols, plus halo around target aircraft
    d. Illustration of automatic deletion of CAAS lines on the DSR upon completion of the CAAS maneuver, and 'resume own navigation' back to the designated jetway after CPA
    e. Illustration of multiple simultaneous CAAS-Pairwise operations, including some where the indicator lines and halos overlap
    f. Illustration of headings generated on board the aircraft to achieve minimum separation (in most cases the headings were much shallower than controllers would normally assign)

3. Scenario 1: 20 minutes of moderate traffic using positive separation only (CAAS was not available), followed by a subjective workload rating
4. Scenario 2: 20 minutes of high traffic using positive separation only (CAAS was not available), followed by a subjective workload rating
5. Scenario 3: 20 minutes of moderate traffic with tactical CAAS available6, followed by a subjective workload rating
6. Scenario 4: 20 minutes of high traffic with CAAS available, followed by a subjective workload rating
7. Completion of an evaluation form pertaining to tactical pairwise
8. A 20-minute training scenario on Strategic CAAS, illustrating the features described in 'Implementation of Strategic CAAS".
9. Scenario 5: 20 minutes of moderate traffic with both tactical and strategic CAAS available, followed by a subjective workload rating
10. Scenario 6: 20 minutes of high traffic with both tactical and strategic CAAS available, followed by a subjective workload rating
11. Completion of an evaluation form pertaining to strategic pairwise

## Results

For the purposes of this study, both subjective and objective data was collected[7]. The results here will focus on the subjective survey results. The survey covered several areas of interest including: impression of the Strategic-CAAS concept, usability, procedures, workload, safety, and simulation fidelity.

### *Impression of the Strategic-CAAS Concept*

Participants were asked for their overall impression of the Strategic-CAAS concept. Of the nine participants, all nine responded favorably (as seen in figure 4), with one controller indicating that Strategic-CAAS, "should logically be extended to vertical and longitudinal maneuvers to achieve separation." Another controller qualified his response by commenting that a higher degree of trust would have to be placed in the decision support system that supports CAAS.

[6] Tactical CAAS does not provide conflict probe capabilities.
[7] Objective data included keystrokes and pilot commands, which were compared between the baseline and strategic scenarios.

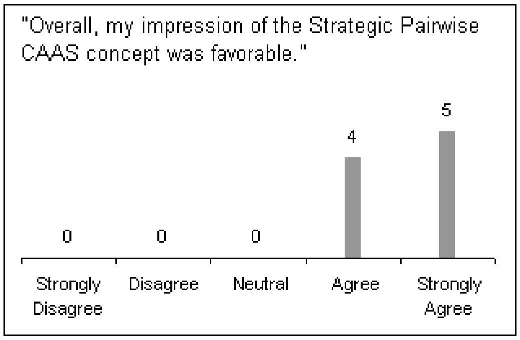


**Figure 4 - Number of Controllers per Response Category for the Question of Overall Impression of the Concept**

### *Usability*

Questions related to usability focused on the controller's ability to adequately monitor Strategic-CAAS aircraft while maintaining positive separation for other aircraft. As shown in Figure 5, six of the nine controllers indicated it was "easy" to monitor multiple CAAS maneuvers, and the remaining three went further, stating it was "very easy" to do so. When asked to comment, one controller said with a sufficient level of trust it would not be necessary to monitor CAAS maneuvers at all, while another stated that it was "easy to a point, but I do see that beyond about 3 of them it's distracting and I found myself continuously cross checking to see who was and who wasn't separated."

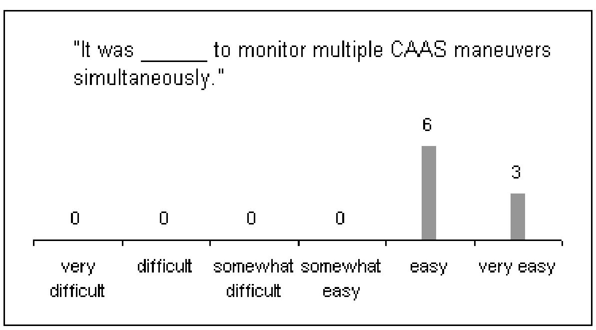


**Figure 5 - Number of Controllers per Response Category for the Question Monitoring Multiple CAAS Maneuvers**

We were also interested in the utility of interface tools developed for Strategic-CAAS operations. In particular, the beige/green line on the display that indicated to the controller the CAAS pair and whether or not the maneuvering aircraft had accepted the CAAS clearance.

As illustrated in Figure 6, eight of the nine respondents indicated that they agreed or strongly agreed with the statement "The beige/green line was helpful." Comments were largely favorable. The neutral participant indicated that rather than using the beige/green line, he elected to use the blinking fourth line of the data block.

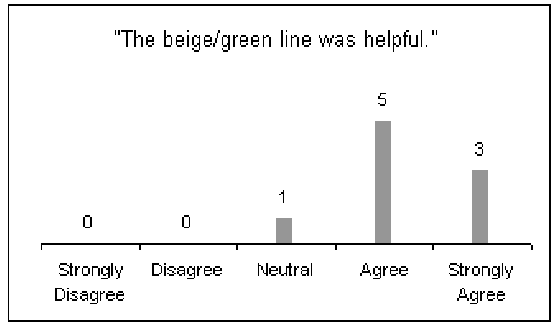


**Figure 6 - Number of Controllers per Response Category for the Question of Helpfulness of the Beige/Green Line Interface Tool**

### *Procedures*

Questions on procedures are intended to provide insight into possible implementation issues as they relate to the initiation, communication, and termination of Strategic-CAAS.

When asked if, at the implementation of Strategic CAAS, the pilot's intent to comply should be verbally communicated to the tactical controller, four of nine controllers did not feel it was necessary (figure 7). Of the remaining four controllers, one was neutral and the other three indicated the aircrew should communicate their intent to comply. Several controllers commented that confirmation should be done via datalink and that the aircraft's datalink reply should be automated.

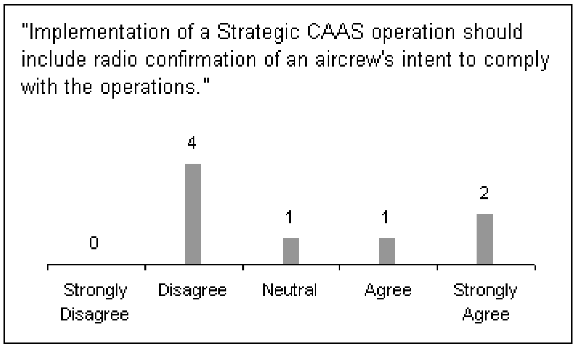


**Figure 7 - Number of Controllers per Response Category for the Question of Procedure Phraseology**

Controllers were also questioned about the conclusion of Strategic CAAS operations. Specifically, they were asked if, upon conclusion of a CAAS operation, it is necessary to announce resumption of course by the maneuvering pilot. Figure 8 shows responses were dispersed across all levels of the scale, but that a majority (five of nine) agreed that an announcement by the pilot (via voice or datalink) would be necessary once the conflict had been resolved.

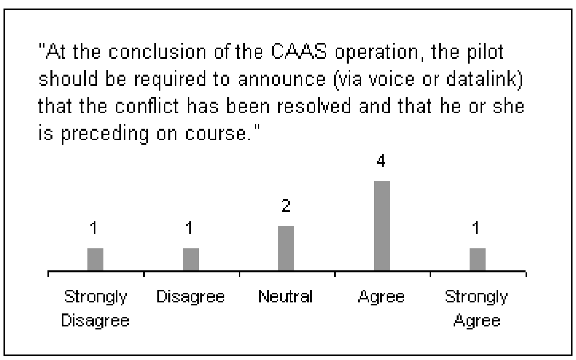


**Figure 8 - Number of Controllers per Response Category for the Question of Procedures for Conclusion of a CAAS Operation**

### *Workload*

One significant bound on controller productivity and contributor to workload is time, or the lack of it. It is hypothesized that Strategic CAAS may result in an easing of time pressures through a variety of means, one of which is a reduction in the time spent monitoring crossing situations[8]. As such, controllers were asked how the use of Strategic CAAS will change the amount of time spent crossing situations.

Results are shown in Figure 9. The majority of controllers felt that Strategic CAAS would decrease the amount of time spent monitoring crossing situations. One controller felt it would not change, indicating that, "If URET problem detection/resolution were used and refined, monitoring crossing situations should be minimal [regardless of CAAS]. If CAAS is compared to today, time required for monitoring should be greatly reduced."

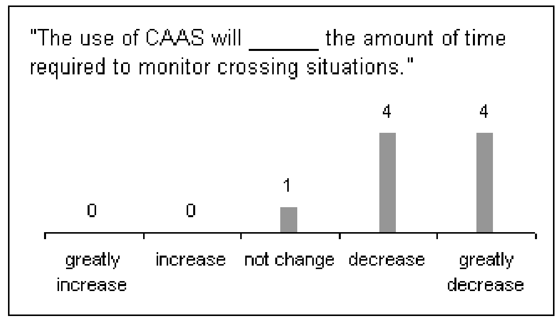


**Figure 9 - Number of Controllers per Response Category for the Question of Time Spent Monitoring Crossing Situations**

More generally, a NASA-TLX[9] measure found an overall reduction in workload when compared to traditional positive control. These results are shown in Figure 10.

[8] Controllers routinely monitor radar vectors when used to achieve lateral separation in a crossing situation; an adjustment to the vector is made, as required, until separation is assured.
[9] NASA-TLX (task load index) is a subjective measure of workload in which the participant rates the difficulty of a task (on a scale of 1 to 10) for several indices of workload. For this evaluation only the physical, mental, and temporal indices were included.

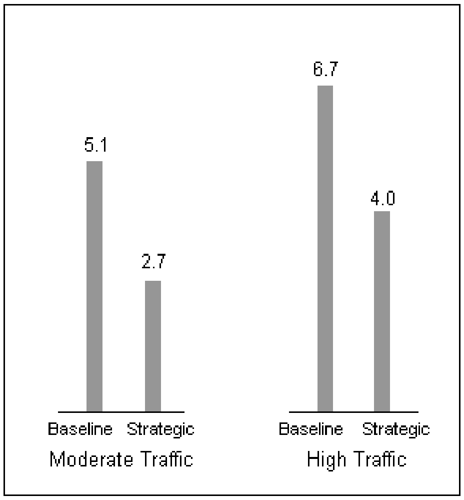


**Figure 10 - NASA-TLX Workload Ratings**

This subjective measure of workload finds support in objective measures collected during the evaluation. For example, as shown in figure 11, controllers issued fewer altitude maneuvers in the Strategic CAAS conditions than in the positive control, baseline conditions. This is also true for heading maneuvers, but, due to the small number of heading clearances, is more clearly illustrated by the difference in the number of altitude maneuvers.

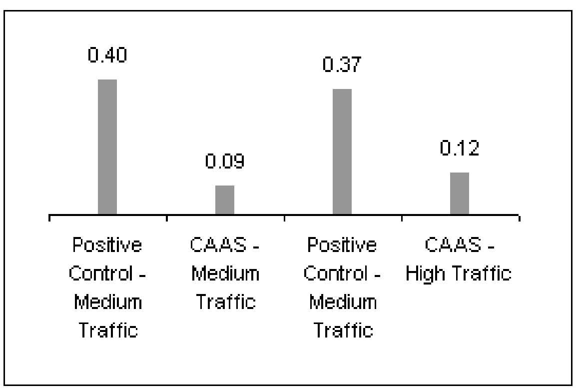


**Figure 11 - Number of Altitude Maneuvers per Aircraft**

### *Safety*

All nine controllers agreed with the statement "Strategic CAAS operations can be implemented safely" (Figure 12). However, in comments controllers also indicated that this safety is dependent on a reliable infrastructure and adequate training and controller acceptance.

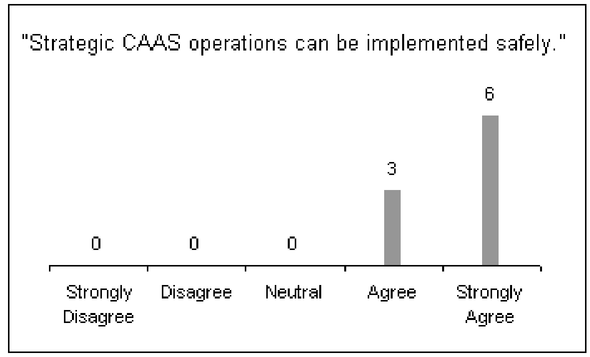


**Figure 12 - Number of Controllers per Response Category for the Question of Safety**

### *Simulation Fidelity*

Finally, in order to measure the realism of the traffic levels - thus providing an indication of the generalizablity of the results - controllers were asked to evaluate the simulation fidelity with regards to traffic levels. All nine of the participants indicated that traffic levels were sufficient for evaluation of the Strategic CAAS Concept.

## Conclusions

The overall reaction by participants to the Strategic CAAS pairwise procedure as presented was positive. Controllers reported that it could be a useful procedure for reducing workload and therefore contribute to a more productive work environment. They also indicated that it is a reasonable step in the evolution of more sophisticated tools and procedures that are undergoing international research [2][6][7].

Subjective workload ratings performed following the simulation scenarios indicated lower perceived workload when Strategic CAAS (including conflict probe and data link, as these are required for Strategic CAAS) was used compared to positive separation only, at both medium and high traffic levels. In addition, following their simulation runs, controllers did not foresee any notable safety issues associated with the procedure. Although the results from the present study are based on subjective reporting and do not include input from the aircrew perspective, they provide evidence that further research in this area is desirable. The results also imply that CAAS represents a positive step toward other Future Vision objectives as stated by MITRE/CAASD [1], the FAA [3], the JPDO [4], the international community [11, 12], and RTCA [5].

## Next Steps

The next steps for the pairwise evaluation include:

1. Pilot evaluations
2. Integrated pilot-controller experiments
3. Evaluation of Strategic CAAS effects on upstream sector operations.
4. Analysis of costs and benefits, including those attributed to conflict probe and data link
5. Analysis of cost savings and benefits to NAS users.

The future air traffic control experiments will use current adaptation for ATC sectors within the United Statesand recorded traffic data. In addition to subjective data collection, robust automated data measurements will be obtained to ascertain the acceptability of CAAS and its effect on capacity.

The pilot evaluations will analyze CAAS inputs and outputs from the cockpit to validate the procedures, phraseology, and workload from the crewmember perspective.

The integrated pilot-controller experiments will allow pilots and controllers to work together in a realistic environment, with flight crews assuming control over designated aircraft in the simulation.

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