Post Experimental-Flight Evaluation Report

Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS)

Date	September 20, 2022 – September 24th, 2022
Location	George Bush International Airport (IAH)
Participants	United Airlines, Collins Aerospace, FAA
Airplane	B737-900ER – N37471

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Background

The FAA Surveillance Broadcast Services (SBS) Group seeks the adoption of Automatic Dependent Surveillance-Broadcast In (ADS-B In) to increase safety and efficiency in the National Airspace System (NAS).

ADS-B In equipped aircraft that can display ADS-B Out data from nearby aircraft provide increased situational awareness benefits for crews, which results in improved safety margins and reduced workload for both pilots and air traffic control.

Purpose & Participant Roles

The FAA and United Airlines (UAL) co-operative agreement tasks UAL with evaluating ADS-B In capabilities, specifically Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS). For the purposes of this agreement, UAL will be evaluating a Collins Aerospace demonstration ADS-B In system developed using conceptual input provided to Collins by UAL.

Participant	Roles
FAA	Project sponsor seeking participant feedback of ADS-B technology
United Airlines	Participant supplying B737, flight test crews, engineers & technicians Feedback on system usability and technology adoption
Collins Aerospace	Supplier of ADS-B hardware/software Data Collection and observation

Goals

1) Pilot feedback on ADS-B In usability in a simulated low visibility environment

2) Pilot feedback on the CAVS avionics system

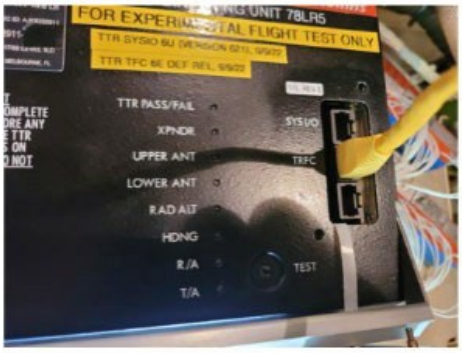
3) Report feedback and results to the aviation community

ADS-B Technology Setup

From 20-24 Sept 2022, UAL Flight Test flew four test flights using Collins' CAVS demonstration system at Houston Inter-Continental airport (IAH). These flights and evaluation support the United Airlines and FAA co-operative agreement described above.

Collins Aerospace provided a demonstration system consisting of components currently under development for install on aircraft including the B737-900ER used in the test. The Collins system included the following key components:

- TTR-2100 Traffic Computer with experimental build of ADS-B CDTI and CAVS software; installed in place of the existing Traffic alert and Collision Avoidance System (TCAS) computer
- Aircraft Interface Device (AID) installed with a custom bracket and wiring kit for the experimental flight
- Forward Field of View (FFV) Display presented on an iPhone 12 mini to replicate a 3 ATI display instrument
- Personal Electronic Device (PED) iPads provided by the flight crew and loaded with the Collins "ADS-B on PED" application



TTR-2100


Custom AID Install


iPhone FFV


PED in FO Position

Due to limitations on system install complexity and touch-time, the Collins team provided a solution on an iPhone for use in the FFV.

An application was created to replicate the symbology planned for the Collins 3 ATI display. Data to and from the PED and iPhone were routed through the AID via Wi-Fi and sent between the TTR-2100 and AID using ARINC 429.

A comparison of the Collins demonstration system and the production system currently under development can be found in the table below.

Function	Demonstration System	Collins Proposed Production System for B737NG
ADS-B Data Processing	Experimental Software	TSO-C195c Software Class C4, C5, C8
Data Server	AID with Basic Wi-Fi	DO-356 Secure AID with Enterprise Wi-Fi*
CDTI and CAVS Guidance (FFV)	iPhone Application	3 ATI LCD Display Class B4, B5, B
Target Selection/Designation	PED Application iPhone Application	3 ATI LCD Display PED Application* MCDU Interface*
CAVS Manual Termination	iPhone Application Emulated Button	3 ATI LCD Display Physical Button MCDU Interface*

*The production system supports either an MCDU or AID/PED-based selection and designation method in addition to the 3 ATI LCD which also has this capability

B737 Aircraft and Recording Setup

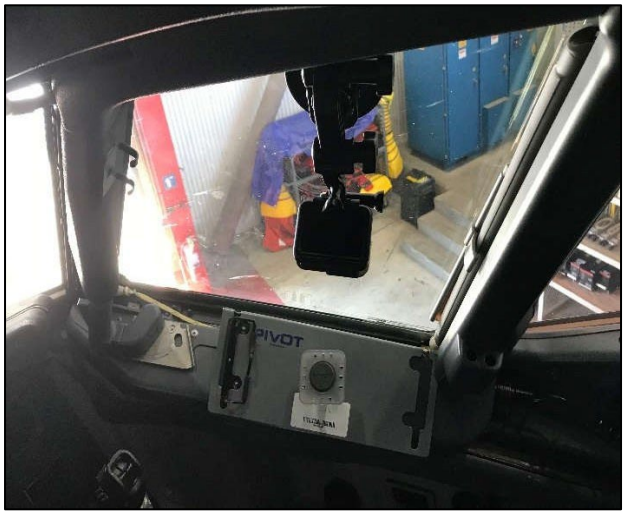
The Boeing 737-900ER used (N37471) was considered representative of the 737-900ERs in United Airlines (UAL) inventory. N37471 was placed in a non-standard avionics configuration to support the Collins Demonstration program.

4 video cameras were installed in the flight deck & recorded data for post-flight system analysis.

1) Right Glareshield, looking forward

2) Main Instrument Panel

3) First Officer's iPad mount



4) Rear of Flight Deck

Scope of Test

The objective of the four flights was to evaluate the Collins system while addressing questions posed by UAL Technical Pilots, Rocky Stone and Ron Renk, regarding:

1) Displays: Symbology, Ease of Interpretation, Form Factor, and visual angles when looking forward along the flight path.

2) User interface: are the content, arrangement, symbology, and format sufficient to preclude pilot confusion, increased workload or flight crew error for pilots that have limited training and exposure to CAVS?

Test Execution

Prior to flight, the Collins team performed a series of ground tests to validate the installation of the CAVS system and ensure that it would operate as expected during the approaches.

Through this process, the Collins team identified issues with the TTR-2100 software which intermittently prevented the system from displaying ADS-B targets.

The Collins and UAL teams decided to continue into Flight #1 with the system in this state to rule out any ground-based interference issues while the Collins engineering team investigated further.

Flight 1

On Flight #1, six profiles were flown to runways 8L and 8R during an afternoon arrival bank.

The ADS-B Traffic-To-Follow (TTF) aircraft would only display intermittently and then disappear from PED & iPhone displays, requiring the flight to request holding west of the airfield for system troubleshooting after each approach.

This resulted in the observing Collins technician designating most of traffic on his iPad, precluding both crew from fully evaluating system operation, workload management, allocation of roles, equipment ease of use and human factor/ergonomic considerations.

Collins requested Flight #2 go on as planned to allow more data collection and observation.

Flight 2

On Flight #2 three profiles were flown.

As in Flight #1, ADS-B TTF would only display for a few seconds before disappearing from all displays.

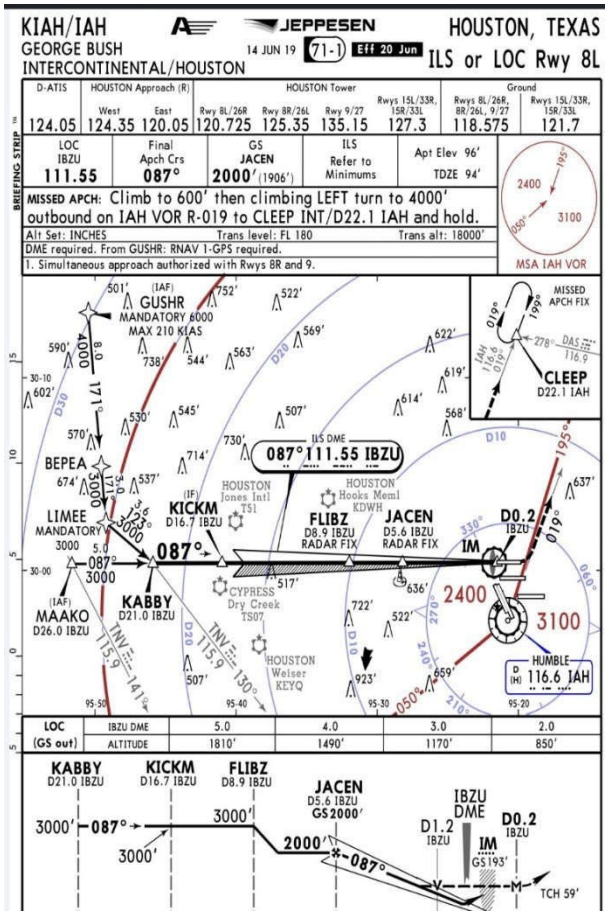
The crew observed no displayed ADS-B targets in the forward quadrant within ± 10 degrees of N37471's nose.

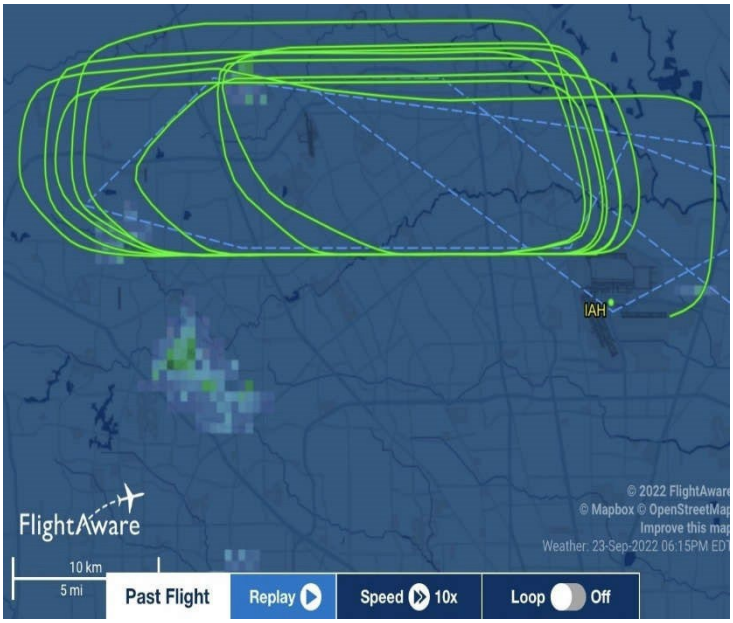
After the additional troubleshooting on Flight #2, Collins identified the issue within the TTR-2100 causing the anomalous behavior and was able to issue a software update prior to Flight #3 and Flight #4.

Flight 3

The 3rd flight occurred during an afternoon eastbound arrival bank. Weather: VFR with haze. The test aircraft, operating within 25 miles of IAH, flew eight profiles on traffic arriving via runway 8L. Due to high traffic volume, ATC maintained very tight control of N37471's airspeed and heading, limiting the amount of flexibility the pilots had to exercise the system. Designating the selected TTF aircraft was accomplished by the FO's iPad app for data recording. System operation was much more stable compared to the first two flights, with CAVS maintaining constant acquisition for 6 of the 8 approaches.

Flight #3 Profiles





NOTE: Collins identified that temporary reduction in the ADS-B quality indicators triggered automatic termination in the 2 instances where designation of the TTF was lost. DO-317C defines a "coasting feature to address these cases by maintaining the validity and trajectory of a target for a certain period when quality is lost. The Collins product being developed does include coasting, but it was not yet implemented in the demonstration system brought to IAH.

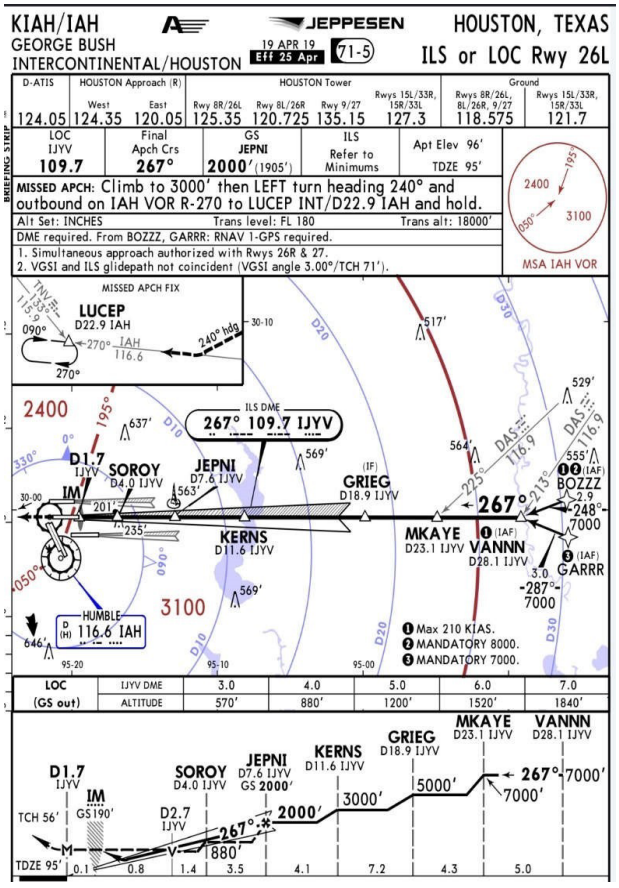
Flight 4

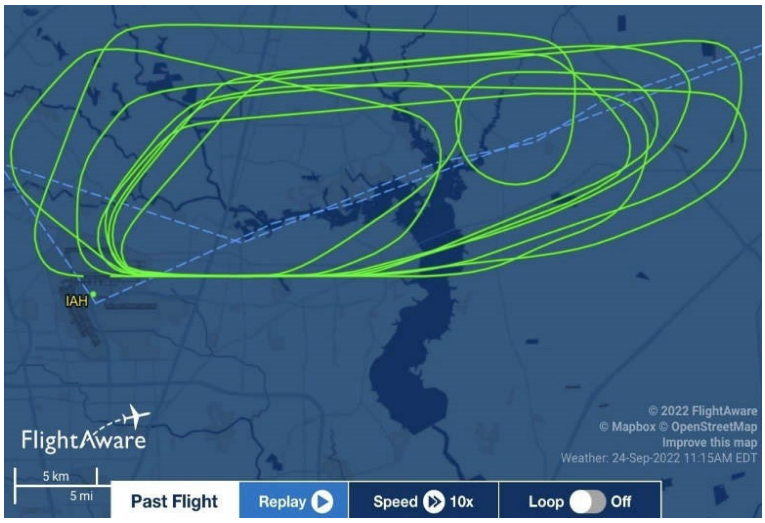
The 4th flight occurred between arrival banks during the late morning. Weather: VFR with haze. Small, scattered buildups were observed as the flight progressed. The test aircraft, operating within 20 miles of IAH, flew eight profiles on aircraft arriving via runway 26L.

Due to light traffic volume, ATC allowed much more leeway in N37471's use of airspeed and heading to reduce spacing with the TTF. ATC would designate traffic to follow, and the crew used a combination of self-initiated lead, lag, or direct pursuit headings to adjust final in-trail spacing from the designated aircraft. No heading commands were issued by ATC.

As in Flight 3, TTF designation was accomplished by the FO's iPad. System operation was again judged to be stable.

Flight #4 Profiles





United Airlines Feedback and Commentary

ADS-B Technologies

This effort was a first-look opportunity for United to experience CAVS and the advantages of this specific ADS-B In technology. This project also allowed a new entry into ADS-B In technology, Collins Aerospace, to have an opportunity for direct airline feedback and testing of their new product in development.

United Airlines has specific interest in ADS-B In technologies as reported in the NextGen Advisory Committee Tasking 20-1/21-2 Report. More specifically, there is near-term interest in:

1) Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS)
2) In-Trail Procedures (ITP)
3) Surface (SURF)

There are also other ADS-B In Technologies that United wants to keep its eye on in the future but puts its strategy at a crossroads: obtaining inexpensive equipage which lets the airline achieve near-term benefits with easier achieved applications, while also purchasing hardware that has growth potential for future more difficult applications like Flight Deck Interval Management (FIM).

Airlines have diverse Pilot groups and seek inexpensive technologies which are also intuitive and have the right amount of aircraft integration. The pilots using this system could see the benefits of the AIRB and CAVS functionality. Continued Airline and Collins engagement can help shape the user experience as it evolves from prototype to final product.

We have many variable costs and require constant expense to keep operations flowing smoothly. For ADS-B In to be successful, partnerships between airlines, manufacturers, regulators are needed to get the right requirements, right equipment and most importantly the right return on investment.

United appreciates the opportunity to support Collins Aerospace product development and providing the FAA feedback on use of this system in the National Airspace System. United has hub airports which could benefit from CAVS if the FAA Air Traffic Controllers can issue its use and the right mix of affordability and ease-of-use can be found.

Additional Feedback and Commentary

CAVS Solution Troubleshooting

As cited in the flight debriefs (pages 8 – 10), Collins Aerospace identified and troubleshot several TTR-related issues during the trial. Collins conducted software updates during the demonstration to address these issues as they arose.

Prior to Flight #1, TTR software updates were conducted to address issues related to 1) variable navigation accuracy category velocity (Variable NACv) and 2) target overloading. Ownship information and traffic output were not displaying correctly, however modifications to the software resolved these issues.

Prior to Flight #3, an issue with target prioritization was noticed after the previous target overload fix. Traffic nearest the ownship was not always being displayed. For the demo, a fix was implemented to ensure targets being passed between functions were always closest to the ownship.

During Ground Ops and several flights, intermittent losses of either ownship or target quality for the CAVS operation would cause CAVS to terminate. Collins attributed this to intermittent loss of quality and targets must be re-designated when the quality returns. A planned "coasting" software update is expected to resolve the CAVS terminations.