Terminal Configured Vehicle Program

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NASA's Terminal Configured Vehicle (TCV) Program is an advanced technology research activity established to develop, evaluate and demonstrate new concepts of airborne systems and candidate operational flight procedures to:

* Improve the capacity and efficiency of air terminal areas.
* Improve approach and landing capabilities in adverse weather.
* Reduce the exposure of communities to aircraft noise.

The TCV Program, managed by NASA's Langley Research Center, is primarily concerned with identifying airborne systems—both avionics (aviation electronics) and air vehicle systems—that will be needed for efficient operation in future high-density terminal areas. These terminals will be equipped with new landing systems, navigational aids, data links, and other advanced Air Traffic Control (ATC) systems now being developed by the Federal Aviation Administration (FAA) and the Department of Transportation (DOT).

Equal emphasis is placed on identifying operational flight procedures that are required to work effectively in the ATC environment anticipated in the future. Other benefits from TCV Program research should include: reduced approach and landing accidents, reduced weather restrictions, reduced air crew workload, increased productivity for air traffic controllers, and fuel saved through the use of more efficient air terminal area techniques.

Primary areas of interest in the TCV Program are illustrated along a characteristic flight profile in Figure 1. Most of today's air traffic problems occur after descent into a terminal area. Streamlining the descent-to-landing process will help to significantly increase terminal area efficiency and airport capacity. Assuming that no new major airports will be built in

Figure 1. TCV Program Primary Areas of Interest
the foreseeable future, present airport capacity, unless improved, will limit the growth of air transportation. The TCV Program's principal interest is to develop improved aircraft performance, automatic functions and pilot management tools that will complement the FAA's development of improved ground systems.

TCV RESEARCH AIRPLANE

The TCV Program operates a Boeing 737-100 airplane to conduct flight test aspects of the program. The airplane is equipped with a special research flight deck, located about 20 feet aft of the standard flight deck. An extensive array of electronics equipment and data recording systems is installed throughout the former passenger cabin (Figure 2).

![TCV B-737 Research Airplane Diagram](image)

The airplane can be flown from the aft flight deck in a fly-by-wire Instrument Meteorological Conditions (IMC) mode, using advanced electronic displays and automatic control systems that are all-digital and can be reprogrammed for research purposes. Two safety pilots in the front flight deck are responsible for all phases of flight safety and most traffic clearances. Two research pilots usually fly the airplane from the aft cockpit during test periods, which can last from takeoff through landing. The only airplane systems that cannot be controlled from the aft flight deck are the landing gear and the speed brakes. The safety pilots can take control of the airplane at any time by overpowering the aft flight deck controls or by disengaging the aft flight deck.
The aft flight deck (Figure 3) includes three Cathode Ray Tube (CRT) displays that are available to both research pilots. The lower display unit and keyboard allows each pilot to use, control and monitor the airplane's navigation computer, which stores a complete set of geographical information about waypoints and landmarks on the U.S. Eastern Seaboard. The computer also contains direct route, airway, Standard Instrument Departure (SID), Standard Terminal Arrival Route (STAR), and runway data for the geographic area of interest.

The center display is an Electronic Horizontal Situation Indicator (EHSI) that provides each pilot with a pictorial navigation display of the airplane's position relative to desired guidance path, flight plan waypoints, and local points of interest such as airfields, mountains and ground radio navigation stations.

The top display is an Electronic Attitude Director Indicator (EADI) that provides the pilots with a display of the airplane's pitch and roll attitude for instrument flight. Optional symbols for velocity vector, flight path acceleration, vertical guidance, and speed error are integrated into the EADI display format. A forward-looking, low-light-level television image (from a TV camera located in the airplane's nose) can be presented on the EADI in registration with the symbols. A computer-generated runway drawing, showing the true perspective of the runway (based on navigation position estimates), can also be displayed.
The TCV airplane's navigation, auto-land and auto-throttle systems permit the plane to fly complex two-, three- and four-dimensional (position and time control) flight paths. The flight plan can be programmed before takeoff or developed and modified in flight through the navigation computer's keyboard. An on-board data acquisition system records pertinent flight information for analysis after a test. Information can also be transmitted to a ground station within a range of 50 nautical miles.

**TCV PROGRAM RESEARCH TASKS**

The TCV Program is concerned with several specific research tasks (Figure 4). These involve identifying, developing and evaluating displays, controls and crew procedures that will be required for more efficient and acceptable flight operations in high-density terminal areas in an improved air traffic control environment of the future.

**NASA TCV PROGRAM GOALS AND AREAS OF EMPHASIS**

**IDENTIFY AIRCRAFT AND FLIGHT MANAGEMENT TECHNOLOGY THAT CONTRIBUTES TO MORE EFFICIENT CTOL OPERATIONS IN DENSE TRAFFIC TERMINAL AREAS IN LOW VISIBILITY**

**Figure 4. TCV Research Tasks**

**MLS Operations.** The TCV airplane, with its advanced control systems, displays and data monitoring equipment, is well suited to flight test and exploit the full operating potential of the Microwave Landing System (MLS) now being developed by the FAA. The MLS will eventually replace the Instrument Landing System (ILS) now in use at all major airports in the world, and at many smaller airports. One advantage of the MLS is its ability to provide precise guidance information to landing airplanes that approach an airport runway from many directions. Airplanes using the ILS must approach and align with the runway from many miles away, which often involves detouring from the most direct course and wasting fuel.
The TCV airplane has supported the FAA with test flights that use guidance information from the U.S.-sponsored Time Reference Scanning Beam (TRSB) MLS at airports in New Jersey (NAFEC), Buenos Aires (Aeroparque Jorge Newbery), New York (Kennedy International) and Montreal (Dorval). The automatic, close-in landing paths flown during these MLS demonstrations are compared with a typical ILS approach in Figure 5. An additional advantage of the MLS is that curved or segmented landing approaches can be designed to bypass noise-sensitive communities around air terminals.

**TCV B-737 / TRSB MLS EXPERIENCE**

![Diagram of MLS coverage and landing paths](image)

**Figure 5.** Summary of Automatic, Close-in Landings Made With MLS-Equipped TCV B-737 Airplane

An MLS will be installed at NASA's Wallops Flight Center (located on Virginia's Eastern Shore) in late 1979 to support research to identify and exploit other potential uses and benefits of MLS. One important part of the TCV Program is defining cockpit displays that will allow an air crew to accurately follow curved approaches made possible by MLS. Several promising concepts are now under investigation.
Improving Airport Capacity. The TCV airplane is used to develop advanced guidance and control laws that precisely control the touchdown process, including approach, flare, landing, and rollout. Present automatic landing systems control an airplane's rate of descent, but not touchdown position along a runway. Reducing touchdown dispersions is necessary to increase airport capacity by permitting more effective use of high-speed exits that rapidly clear a runway for the next airplane arrival.

Advanced auto-flare control laws are being developed that use guidance signals from the new MLS to provide precise touchdowns. Research includes evaluating the benefits of high-speed exits that might use buried magnetic cables or some other method of providing proper nose-wheel steering commands to an airplane. A research high-speed exit will be built at the Wallops Flight Center airfield, beginning in late 1979.

The effectiveness of a Direct Lift Control (DLC) system incorporated in the TCV airplane will be evaluated as a way to improve approach tracking, touchdown precision, passenger ride quality, and reduced pilot workload.

Integrated Situation Displays. Considerable TCV research is devoted to developing a better integrated situation display for pilots. The EADI display (Figure 6) includes important horizontal situation information not found on standard vertical situation displays. Use of this particular CRT display by TCV research pilots has significantly improved landing approach stability and precision, compared with approaches made with standard cockpit instruments. Presenting pilots with the smallest amount of necessary information in the proper format reduces workload and improves performance.

This display research should yield improved landing performance and safety, particularly in marginal weather. Improved reliability of schedules is another important benefit that will occur when air carriers can operate routinely (manual or monitor) in low visibility conditions.

Figure 6. Electronic Attitude Director Indicator Display
Cockpit Display of Traffic Information (CDTI). A program operated by the FAA and NASA's Langley and Ames Research Centers is evaluating the capabilities, benefits and limitations of CDTI to augment the present and future ATC system. This traffic information should greatly aid a pilot, who may then be able to take a more active role in the ATC system.

Some proponents of CDTI argue that the present ATC system tends to limit the efficient use of air space and, therefore, airport capacity. Unless a pilot becomes involved in the separation process, the situation cannot improve. Others think of CDTI only as a monitoring device to augment the present ATC system and permit increased detection of controller and other aircraft and ATC system errors. The FAA/NASA program will attempt to define and evaluate the potential role of CDTI in the future ATC system. Extensive use will be made of simulation and the TCV airplane with computer-generated interactive traffic displayed on the EMSI (Figure 7). The TCV airplane will be modified to receive real traffic information, using a Beacon Collision Avoidance System (BCAS) and the Discrete Address Beacon System (DABS) data link.

![Figure 7. Cockpit Display of Traffic Information Display](image-url)
Energy-Efficient Descent. Large amounts of aviation fuel can be saved if high-performance aircraft are permitted to descend into a terminal area in a "clean" configuration at idle thrust, starting from cruise altitude and continuing to final approach. Any necessary ATC delays required to match airport capacity should be absorbed near cruise altitude rather than by stretching flight paths (vectoring) at low altitudes. These "profile descents" can enhance safety by reducing the exposure time of high-performance aircraft to general aviation (light) airplanes that typically fly Visual Flight Rules (VFR) at lower altitudes.

The FAA has begun to implement revised ATC procedures at major U.S. airports to permit profile descents. An air traffic controller will usually clear an airplane to execute a profile descent at the pilot's discretion. The air crew is responsible for determining the best time to begin the descent so the airplane will arrive at the assigned metering fix at the proper speed and altitude.

The TCV Program is doing research to determine what additional cockpit instruments and displays are needed by a crew to best perform profile descents. One concept being evaluated is the addition of target altitude and speed symbols to the EHSI navigation display (Figure 8). This will enable a pilot to establish the descent angle and thrust-drag ratio necessary to achieve a target speed and altitude at any desired navigation fix.

Figure 8. Range Altitude and Range Speed Display
SUMMARY

The goal of the TCV Program, through the development of improved airborne systems, is not an "automatic" airplane, but an airplane equipped so its crew can better plan, manage, evaluate situations, and make decisions. This will assure safe and efficient flight in an increasingly demanding environment.

For more information, call or write:

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