FACT SHEET

NASA/FAA FULL-SCALE TRANSPORT CONTROLLED IMPACT DEMONSTRATION

NASA's experience in aeronautical flight testing, structures, and electronics is supporting the Federal Aviation Administration's (FAA) Full-Scale Transport Controlled Impact Demonstration (CID) Program.

The program focuses on the controlled impact of a typical transport airplane at NASA's Dryden Flight Research Facility, Edwards Air Force Base, Calif. A full-scale Boeing 720 will be remotely piloted in the air-to-surface "impact survivable" demonstration. The 720 is a typical four-engine jet of intermediate-range design which entered airline service in the mid-1960's. Its physical design features and construction are common to United States and foreign airframe manufacturers.

The test includes a wide range of experiments. In addition to FAA studies of a fire-suppression anti-misting fuel additive and cabin fire safety, both agencies will make a detailed study of structural loads and deformation, the performance of energy-absorbing seat concepts, and loads imposed on dummy passengers.

Langley Research Center

NASA's Langley Research Center, Hampton, Va., began research on airplane ground impacts during a series of full-scale general aviation crash dynamics tests in the mid-1970's, using more than 25 single and twin-engine light planes. As a result of the tests and computer analyses, Langley has developed experimental concepts for energy-
absorbing aircraft subfloors and seats, shown how to improve structural integrity of cabin floors, and demonstrated new concepts for passenger seat restraint systems.

**Airframe Structural Loads**

Langley's principal responsibility in the 720 controlled impact demonstration program is to characterize airframe structural loads during impact, including development of a data acquisition system for the entire aircraft.

Three full-scale transport fuselage section drop tests were conducted at Langley's Vertical Test Apparatus to study structural deformations and loads in preparation for the full-scale aircraft test. Data were taken of structural, seat and occupant response to impact loads. The 13-by-14-foot sections were cut from different areas of a Boeing 707, nearly identical to the 720. The sections were stripped of nonstructural items—except seats—and anthropomorphic (human-like) dummies were added.

One section represented the area just forward of the wing, another represented the immediate rear of the wing (including wheel wells, keel beam and part of the rear wing spar), and a third represented an area further back on the fuselage where the 720 aircraft is expected to impact first.

The sections were dropped about six feet on a steel-reinforced concrete pad at 20 feet-per-second vertical impact velocity without roll, pitch or yaw. The test apparatus allows the tailoring of an input pulse to simulate different impact situations. A vertical pulse was chosen for the transport drop tests that subjected the systems to between 1.2 and 1.5 times the impact loads expected during the 720 test.

Preliminary data indicate that the forward section collapsed inward about two feet in the lower fuselage area (baggage compartment), and failures developed along both sides of the section at one-third the vertical height between the fuselage bottom and floor. No significant damage occurred to the upper fuselage, floor or seats. A maximum acceleration of 20 g's (20 times the force of gravity) was measured on the fuselage bottom. Because of lower fuselage crushing, accelerations on the floor were 10 to 12 g's. Pelvic accelerations measured in the dummies ranged from 6.5 to 8 g's.

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NASA SUPPORTS IMPACT TEST

A look at the stiff "rear of the wing" section provided these tentative conclusions: no damage occurred to the fuselage or floor during impact; high loads were transmitted from the lower fuselage to the floor, seats and dummies, and upper fuselage; and bending failures developed in several ballasted seats along the lateral support tubes of the seat frame where the seat projects over the legs. At other seats containing dummies, failures occurred where rubberized seat pans attach to seat frames. An acceleration of 71 g's was measured on the fuselage bottom, 70 g's at the floor beam/inboard seat rail and 95 g's at the floor beam/frame. Pelvic acceleration in the dummies was 44 g's.

Third test section response was similar in load transmission to the forward section.

DYCAST

Structural response data for the tests will corroborate an analytical model developed by Langley and its contractors for crash dynamics analysis of aircraft structures. A non-linear finite element structural analysis computer program called DYCAST was developed with the Grumman Aerospace Corporation as part of Langley's general aviation crash dynamics program.

Langley has contracted with Boeing Commercial Airplane Company to adapt DYCAST to the 720 aircraft impact analysis, which helped determine the CID impact plan for the aircraft. (A complementary analytical effort was contracted to Lockheed-California Company by the FAA. An FAA/NASA study of selected transport accident records also contributed to the impact plan.) The section tests were a confidence-building step in the DYCAST effort; the CID program will be another important step toward building computer prediction capability.

Data Reduction and Analysis

After the demonstration, Langley will conduct data reduction and analysis for all FAA/NASA structural response and seat experiments. Langley provided the data acquisition system for the entire aircraft. The system will record all structural, seat/restraint system, and dummy responses, and has a multi-camera photographic system to further interpret detailed electronic data. Final results should be reported in 1985.

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The 352-channel data measurement system will transmit aircraft and experiment performance data to on-board tape recorders from a point just before impact, through slide out and deceleration, until the aircraft stops. The system will simultaneously broadcast electronic data through four independent telemetry channels to recorders on the ground. Ten on-board high-speed motion picture cameras, with lights and power pallets, will photograph most aspects of the test.

In developing the aircraft's instrumentation systems, Langley researchers conducted shock studies and developed shock and fire protective packaging for all on-board instrumentation—telemetry, data acquisition, and photographic systems.

**Crashworthy Seat and Restraint System**

Langley developed a crashworthy seat and restraint system that will be evaluated during the demonstration program. The seat is a modified Fairchild-Burns Airest 2000 triple seat with a composite tube to absorb energy. Langley modified the legs of a standard triple seat so it will simply fold forward flat to the floor on impact. An energy-absorbing graphite-epoxy tube is arranged diagonally to the legs and designed to crush uniformly—shock absorber style—in the stroking direction. Langley developed the tube's particular wrap and fiber orientation to start crushing when the seat's vertical load approaches 12 g's, an effort to reduce excessive loads transmitted to passengers.

Seat performance with three instrumented dummies will be compared with a standard triple seat with dummies and with earlier results from Langley's general aviation crash dynamics program. Langley will also document the interaction of the seat, passenger restraint system, and cabin floor.

Dr. Robert J. Hayduk is principle Langley investigator for the FAA/NASA CID program. He is responsible for structural and seat instrumentation and analysis.

**Remotely Piloted Research Vehicle**

The RPRV technique was developed by NASA Ames Dryden in the early 1970's as a less hazardous way to flight test experimental aircraft and advanced technologies. The technique allows a pilot, in a ground cockpit with telemetry and radar, to fly a test
a aircraft in actual flight test maneuvers. Control commands are sent electronically from
the ground cockpit to the aircraft and flight information is returned in the same manner.

The RPRV technique differs from conventional remotely piloted aircraft because it
permits the pilot to fly precise test maneuvers instead of merely guiding the aircraft
from point to point.

RPRVs flown at Ames Dryden include a sub-scale oblique wing aircraft that
demonstrated the feasibility of flying the manned AD-1 oblique or "scissor-wing"
airplane; a sub-scale F-15 to investigate the spin characteristics of a modern full-scale
fighter; Drones for Aerodynamic Structural Testing (DAST) aircraft used to investigate
transport advanced wing technology; and the Highly Maneuverable Aircraft Technology
(HiMAT) sub-scale fighter-like aircraft of the future with nearly twice the
maneuverability of today's fighters. HiMAT is the culmination of RPRV technique and
technology for flight research.

**Boeing-720 Aircraft**

The CID test aircraft is NASA 833, a Boeing-720 transport aircraft purchased by
the FAA in 1960 and given to NASA for the program. The B-720 is the largest remotely
piloted research vehicle ever flown. It is powered by four Pratt & Whitney JT 3C-7
turbine engines and carries approximately 12,000 gallons of fuel. Maximum take-off
weight is 202,000 pounds, length is 136 feet and wingspan is 130 feet, 10 inches. Height
at the tail is 41 feet, 4 inches. While with the FAA, it flew more than 20,600 hours and
made more than 50,000 landings.

**Ames Dryden Responsibilities**

Ames Dryden has responsibility for overall CID Program flight research
management, systems integration, and flight operations. Responsibility includes
remotely piloted research vehicle/flight control and simulation, aircraft/ground
interface, integration of test and systems hardware, impact site preparation, and Boeing-
720 flight test preparations.
Flight Control

Flight commands in the 720 aircraft for engine throttles, elevators, ailerons, flaps, rudder, landing gear and other commands are sent from the ground cockpit to the aircraft through an uplink system. Commands for the elevators, ailerons, and rudders, which provide direct flight path control, are fed through an onboard autopilot system. Other functions are fed directly to the appropriate systems.

Flight information such as engine pressure ratio, exhaust gas temperature, RPM, fuel flow, and flight navigational information such as heading, attitude, altitude and airspeed is returned to the ground cockpit with a downlink system.

The prime control and data collection system for the CID RPRV flights is a triplex uplink and downlink telemetry system. Guided by a NASA FPS-16 C-band beacon track radar trained on the aircraft, the system provides pulse code modulated (PCM) signals for the RPRV flight control system.

Two on-board aircraft receivers receive the uplink signals from antennas on the upper and lower fuselage of the 720 aircraft. The signals are then combined, decoded and routed for distribution to each appropriate system. The telemetry system also carries control signals for the data acquisition system, data cameras, batteries and lights, and forward-looking nose video cameras.

The FPS-16 C-band beacon tracking radar also provides accurate location of the aircraft in flight within two to three yards and provides guidance information to the telemetry system antenna. Radar data are supplied to the Ames Dryden Flight Control Room to give flight direction information to ground controllers and flight data to various system and instrumentation engineers. It provides back-up altitude, airspeed and vertical velocity to the CID project pilot in the ground cockpit.

An independent termination system can be activated from the Flight Control Room if the test aircraft tries to leave the designated test boundaries. During early manned flights, the terminate system was not connected to the flight controls, but to an electrical test box. For the CID impact flight, the system is connected to both the

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| **ANTIMISTING KEROSENE (AMK)** | • Verify AMK can preclude ignition  
• Demonstrate AMK in operational fuel/propulsion system |
| **STRUCTURE (FUSELAGE, WING, FLOOR)** | • Examine structural failure mechanisms and correlate analytical predictions  
• Provide baseline metal crash data to support FAA and NASA composite crash dynamics research  
• Define dynamic floor pulse for seat/restraint system studies |
| **SEAT/RESTRAINT SYSTEM** | • Assess regulatory criteria  
• Evaluate performance of existing, improved, and new lightweight seat concepts  
• Evaluate performance of new seat attachment fittings |
| **STOWAGE COMPARTMENTS/GALLEYS** | • Evaluate effectiveness of existing/improved retention means |
| **ANALYTICAL MODELING** | • Validation of "KRASH" and "DYCAST" models to transport aircraft  
• Verify predicted crash test impact loads |
| **CABIN FIRE SAFETY** | • Seat cushion blocking layers  
• Burn-through resistant windows |
| **FLIGHT DATA AND COCKPIT VOICE RECORDERS** | • Demonstrate/evaluate performance of new systems  
• Demonstrate usefulness for accident investigation analysis |

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<td><strong>EXPERIMENT</strong></td>
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<td>ACCIDENT INVESTIGATION ANALYSIS</td>
<td>• Assess adequacy of current NTSB forms and investigation procedures</td>
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**IMPACT DEMONSTRATION EXPERIMENTS**
throttles and the flight control system. A terminate command will shut down the engines and drive the horizontal stabilizer and rudder flight control surfaces to a position that would cause a steep right-hand spiraling descent to the ground.

**Experiments**

Ames Dryden is responsible for integrating all experiments and subsystems aboard the aircraft that have been provided by Langley, the FAA, and other agencies. Each agency is responsible for providing its own sensors and instrumentation, but NASA is responsible for integrating them into one data acquisition system.

Inflight data will be gathered from aircraft structural components (fuselage, wings and floors), aircraft interior (seats, stowage compartments and galleys) and simulated occupants (73 anthropomorphic dummies). Sensors will be at 352 locations, using two 176-channel data acquisition systems. All data channels will be telemetered through the Ames Dryden telemetry system and two back-up recorders will record all channels. Ten photo cameras on the aircraft will record seat/restraint system and dummy interactions during impact.

The antimisting fuel and fuel degraders that convert the fuel into a usable state for the aircraft engines are provided by the FAA. Ground and flight testing of the system is the responsibility of NASA.

NASA conducted a series of preliminary flights to evaluate the new systems and their integration. The aircraft was flown with normal Jet A-type fuel and standard engines, Jet A fuel and fuel degraders, combinations of Jet A fuel in some engines and antimisting fuel in others, and anti-misting fuel during certain portions of flights.

**Flight Plan**

The 720 test aircraft will have a sink rate of 15 to 17 feet per second, an impact of approximately 10 to 12 g's vertically and 6 to 10 longitudinally. The aircraft will fly a simulated glideslope of 3.3 to 4 degrees (comparable to a normal commercial airliner approach) with nose-up pitch of about 1 degree.

To ensure desired accuracy, the ground cockpit pilot will try to keep the test
FULL-SCALE TRANSPORT CONTROLLED IMPACT DEMONSTRATION PROGRAM

IMPACT SCENARIO

- REPRESENTATIVE OF: AN IMPACT SURVIVABLE ACCIDENT
- CRASH: AIR-TO-SURFACE; FINAL APPROACH/LANDING, MISSED APPROACH, AND/OR TAKEOFF ABORT
- AIRCRAFT CONFIGURATION: LANDING GEAR RETRACTED, FLAPS, SPOILERS (AS REQUIRED), SYMMETRICAL/STABILIZED

- SINK RATE: $17 \pm 2$ FPS
- GLIDE PATH: 3.3° TO 4.0°
- LONGITUDINAL VELOCITY: 150 $^{+5}_{-0}$ KNOTS
- GROSS WEIGHT: 175-195,000 POUNDS

IMPACT GOALS: AMK--WING TANK RUPTURE, 20-100 GALLONS PER SECOND PER SINGLE POINT RUPTURE, 4-5 SECONDS EXPOSURE WITH POSITIVE AMK IGNITION, SLIDE-OUT TO 100 KTS CRASHWORTHINESS--SURVIVABLE IMPACT, MAINTAIN FUSELAGE INTEGRITY, VERTICAL IMPACT PULSE (1 SECOND), LONGITUDINAL ACCELERATION DATA
aircraft within 15 feet of either side horizontally and within 75 feet longitudinally of the planned impact point. Roll angle and heading should not deviate more than 1 degree. Airspeed at time of impact should be approximately 150 knots, or about 170 mph.

**Test Site**

The CID test site is on Rogers dry lake bed next to the Edwards AFB Precision Impact Range Area (PIRA), which is used routinely for inert bombing missions. Runway 10 is the impact site designated for the CID program. The site will be covered with a 4-inch deep layer of 1-1/2 inch diameter hard rock, 1,200 feet long and 300 feet wide. A black lineup mark extends for 10,000 feet down Runway 10.

Thirty-four 10-foot tall photographic range poles are installed at the impact site as photographic identification aids. They will be at 100-foot intervals on each side of the runway, 310 feet across the runway from each other, beginning about 200 feet before the impact point.

Twelve low, impact-resistant, breakaway, landing approach light towers, each 10 feet tall with five lights, will be located every 100 feet, beginning 300 feet after the impact point, six on each side of the runway, 75 feet across from each other. They are lightweight fiberglass tubes with break-away couplings every 42 inches. The towers and their 60 (300-watt) approach lamps will provide a realistic fuel ignition source.

Eight wing openers are located between 50 and 100 feet past the impact point. Contact by the wing leading edge will cause the lower half of a wing opener to rotate upward and cut into the lower portion of the wing, rupturing the fuel tanks. Each wing opener weighs about 400 pounds and is 8 feet by 7 feet long (blade part) by 2 feet wide.

Six telephone poles, 14 inches in diameter and 18 feet long, are installed 6 feet into the lakebed in 38-inch diameter concrete-filled holes. They are in the same area as the wing openers and will help rupture the wing fuel tanks.

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