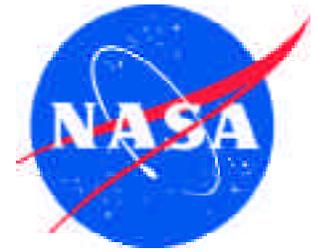


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FS-2002-09-049-DFRC

# Eclipse Tow Launch Demonstration Project



*Eclipse project's EXD-01 lifts off under tow by a USAF C-141A aircraft. NASA photo EC97 44357-10*

NASA Dryden Flight Research Center supported a Kelly Space and Technology, Inc. (KST)/U.S. Air Force project, known as Eclipse, which demonstrated a reusable tow launch vehicle concept.

The purpose of the project was to demonstrate a reusable tow launch vehicle concept conceived and patented by KST. Kelly Space obtained a contract with the USAF Research Laboratory for the tow launch demonstration project under the Small Business Innovation Research (SBIR) program. The USAF SBIR contract included the modifications to turn the QF-106 into the Experimental Demonstrator #1 (EXD-01), and C-141A aircraft to incorporate the tow provisions to link the two aircraft, as well as conducting flight tests. The demonstration consisted of ground and flight tests.

These included a Combined Systems Test of both airplanes joined by a tow rope, a towed taxi test, and six towed flights. The project's primary goal of demonstrating the tow phase of the Eclipse concept using a scaled-down tow aircraft (C-141A) and a representative aerodynamically-shaped aircraft (QF-106A) as a launch vehicle was successfully accomplished.

On Feb. 6, 1998, the Eclipse project made its sixth and final towed flight, bringing the project to a successful completion. Preliminary flight results determined that the handling qualities of the QF-106 on tow were very stable; actual flight measured values of tow rope tension were well within predictions by the simulation, aerodynamic characteristics and elastic properties of the tow rope were a significant component of the towing system; and Dryden's high-fidelity simulation provided a representative model of the performance of the QF-106 and C-141A airplanes in tow configuration. Total time on tow for the entire project was five hours, 34 minutes, and 29 seconds. All six flights were highly productive, and all project objectives were achieved.

## Project Goals

All three of the project's objectives were successfully accomplished. The objectives were: demonstration of towed take-off, climb-out, and separation of the EXD-01 from the towing aircraft; validation of simulation models of the towed aircraft systems; and development of ground and flight procedures for towing and launching a delta-winged airplane configuration safely behind a transport-type aircraft.

## Participant's Roles

NASA Dryden served as the responsible test organization and had flight safety responsibility for the Eclipse project. Dryden also supplied engineering, simulation, instrumentation, range support, research pilots, and chase aircraft for the test series. Dryden personnel performed the modifications to convert the QF-106 into the piloted EXD-01 aircraft. During the early flight phase of the project, Tracor, Inc., provided maintenance and ground support for the two QF-106 airplanes.



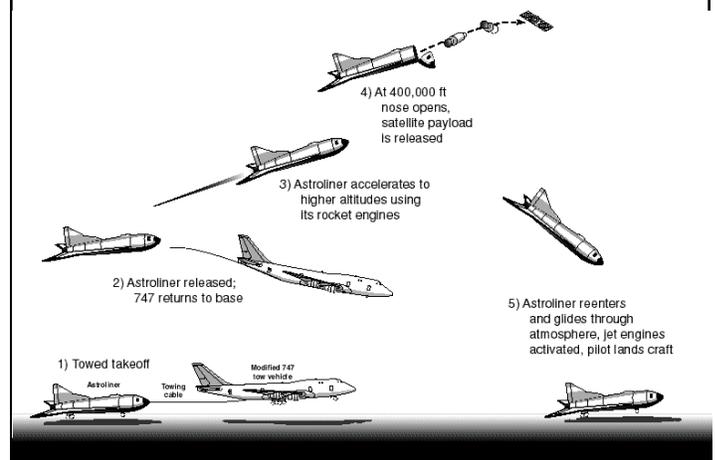
*Eclipse project's EXD-01 and a USAF C-141 takeoff for the first flight on Dec. 20, 1997. NASA photo EC97 44357-8*

The Air Force Flight Test Center (AFFTC) provided the C-141A transport aircraft for the project, its flight and engineering support, and the aircrew.

Kelly Space and Technology provided the modification design and fabrication of the hardware that was installed on the EXD-01 aircraft.

Kelly Space and Technology hopes to use the data gleaned from the tow tests to develop a series of low-cost reusable launch vehicles, in particular to gain experience towing delta-wing aircraft having high wing loading, and to demonstrate various operational procedures such as ground processing and abort scenarios.

## Kelly Space and Technology Eclipse Astroliner Tow-Launch Concept



## Background

The first successful towed flight occurred on Dec. 20, 1997. Prior to the first tow test flight, the C-141A and EXD-01 were used to conduct a series of tethered taxi tests to validate the tow procedures. Previously, a successful joint flight test was conducted in late October 1996, by Dryden, AFFTC, and KST, in which one of Dryden's F-18 chase aircraft flew at various ranges and locations behind the C-141A to define the wake turbulence and wingtip vortex environment. This flight test was replicated in July 1997, with an unmodified QF-106 flight proficiency aircraft.

## Simulation

To enhance flight safety and reduce the number of unknowns during flight tests, the Eclipse project relied on a high-fidelity flight simulator. Full nonlinear mathematical models of the EXD-01 aircraft, C-141A aircraft, and the tow rope were modeled in the Eclipse simulator, which had a piloted and an off-line, batch version. The former was used to train pilots for normal and emergency operations, while the latter was used for dynamic analyses and for validation of major design decisions. As the flight project progressed the simulation validated the flight data. An additional benefit of the fully validated simulation is the ability to extrapolate the Eclipse tow dynamics to larger, future tow launch concepts.

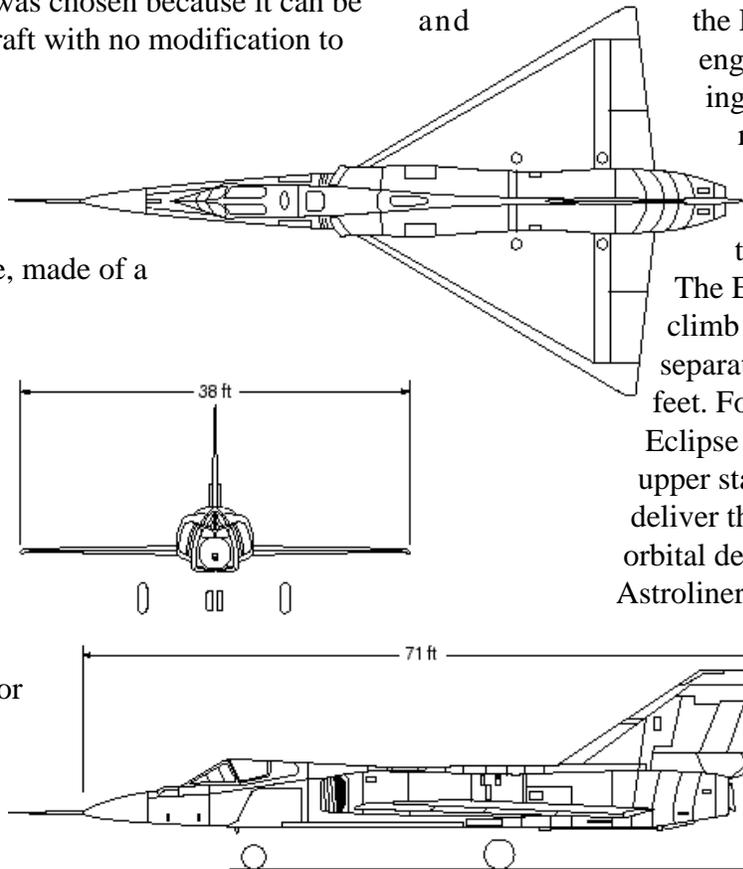
# Aircraft Modifications

Modifications to the QF-106 included shortening the nose pitot boom, and the addition of a tow cable attachment and release mechanism. In addition, cockpit modifications such as the addition of a tow rope tension display were made.

Modifications to the C-141A were minimal, with all of its towing and tow rope jettison equipment placed on a standard cargo pallet secured in the rear of the aircraft. During earlier tests, smoke-generating devices were placed on the C-141's wingtips to enhance the visualization of the aircraft's wake vortices as the EXD-01 flew behind it.

The QF-106 was selected by KST because the aircraft has a delta wing planform representative of the Astroliner spacecraft that the company plans to build. The QF-106 is a rugged, reliable aircraft, which was available from the Air Force's drone target aircraft inventory. The C-141A was chosen because it can be configured as a tow aircraft with no modification to the airframe.

The 1000 foot-long tow "train" used to tow the EXD-01 aircraft consisted of the tow rope, made of a synthetic fiber normally used in marine applications; a breakable link designed for safety and to break if too much stress was placed on the tow train. Nylon straps were used on the first three flights in the middle of the tow train for damping to help any spring tendencies in the tow train. The straps were not needed for the last three flights.



Three view of QF-106 aircraft.

# Funding

Kelly Space and Technology obtained a contract with the USAF Research Lab for the tow launch demonstration project under the Small Business Innovation Research (SBIR) program. The USAF SBIR contract includes the modifications to the QF-106 and C-141A aircraft to incorporate the tow provisions to link the two aircraft.

# Technology Commercialization

Kelly Space and Technology's Eclipse Astroliner concept, which the current Eclipse project is demonstrating, will use a Boeing 747 to tow the planned Astroliner vehicle from a conventional runway to a launch altitude of about 45,000 feet. At that altitude the tow line would be released, the Eclipse Astroliner's rocket engine would be ignited. Releasing a vehicle at that altitude results in greater fuel economy for the launch vehicle than would a typical ground-launching. The Eclipse Astroliner would then climb to its designated payload separation altitude of about 400,000 feet. Following ejection from the Eclipse Astroliner, the payload's upper stages would be ignited to deliver the payload to its specified orbital destination. The Eclipse Astroliner vehicle then would descend as a glider, much like the Space Shuttle, to land using either remote piloting capability or an automatic landing system.