Progress Toward First Flight of the QuickReach™ Small Launch Vehicle

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ABSTRACT

AirLaunch LLC has made steady and impressive progress over the past three years in design and development of the QuickReach™ Small Launch Vehicle. QuickReach™ is carried inside of and launched from a C-17A or other large cargo aircraft. It is designed to meet the needs of the DARPA/U.S. Air Force Falcon SLV program to deliver 1,000 pounds to Low Earth Orbit for $5M per flight with less than 24 hours response time. The vehicle is also intended to fulfill the National Space Transportation Policy priority of demonstrating Operationally Responsive Space (ORS) capability by 2010.

A responsive and flexible launch capability, such as AirLaunch, can deploy specialized small satellites that provide the warfighter with real-time data and communication during time-urgent situations. Responsive space would allow the government to react quickly and launch small satellites equipped with sensors to augment or replace baseline space assets for urgent needs.

AirLaunch has accomplished significant milestones to date in Phase 2B of the Falcon SLV program, including building and testing engine and payload fairing hardware, conducting engine test fires and analyzing the vapor pressurization (VaPak) propulsion system, establishing a comprehensive safety program using Air Force and Mil Std processes, proving its "Gravity Air Launch" methodology through successful drop tests from the C-17 aircraft, and completing the Incremental Critical Design Review (I-CDR).

This paper gives a status on the technical and safety progress of the QuickReach™ to date and the next steps planned toward first flight.

Introduction

AirLaunch has completed Phases 1 through 2B of the joint Defense Advanced Research Projects Agency (DARPA) / Air Force Falcon Small Launch Vehicle (SLV) program. This program originated with a call for proposals in June 2003, resulting in awards to 9 companies in September 2003 to conduct 6-month Phase 1 design studies for an SLV. In September 2004, DARPA held another open competition and selected 4 companies for further Phase 2A studies and demonstrations leading to a SLV Preliminary Design Review. In October 2005, the program selected AirLaunch LLC for contract continuance through Phase 2B, with a $17.8 million value. AirLaunch completed Phase 2B in April 2007.

The Falcon program is governed by a Memorandum of Agreement (MOA) signed by DARPA and the Air Force in May 2003 with DARPA managing the Falcon SLV program and the Air Force funding the program from its Operational Responsive Space (ORS) budget line. The intent has been to develop operational responsive space launch vehicles as called for in the United States Space Transportation Policy.

Responsive space would allow the government to react quickly and use small satellites equipped with sensors to monitor and provide communication for urgent military needs. Having a quick reaction launch system that can launch specialized small satellites will provide the warfighter with real-time data and communication during time-urgent situations. AirLaunch's system achieves responsiveness by launching from an unmodified C-17 or other large cargo aircraft.

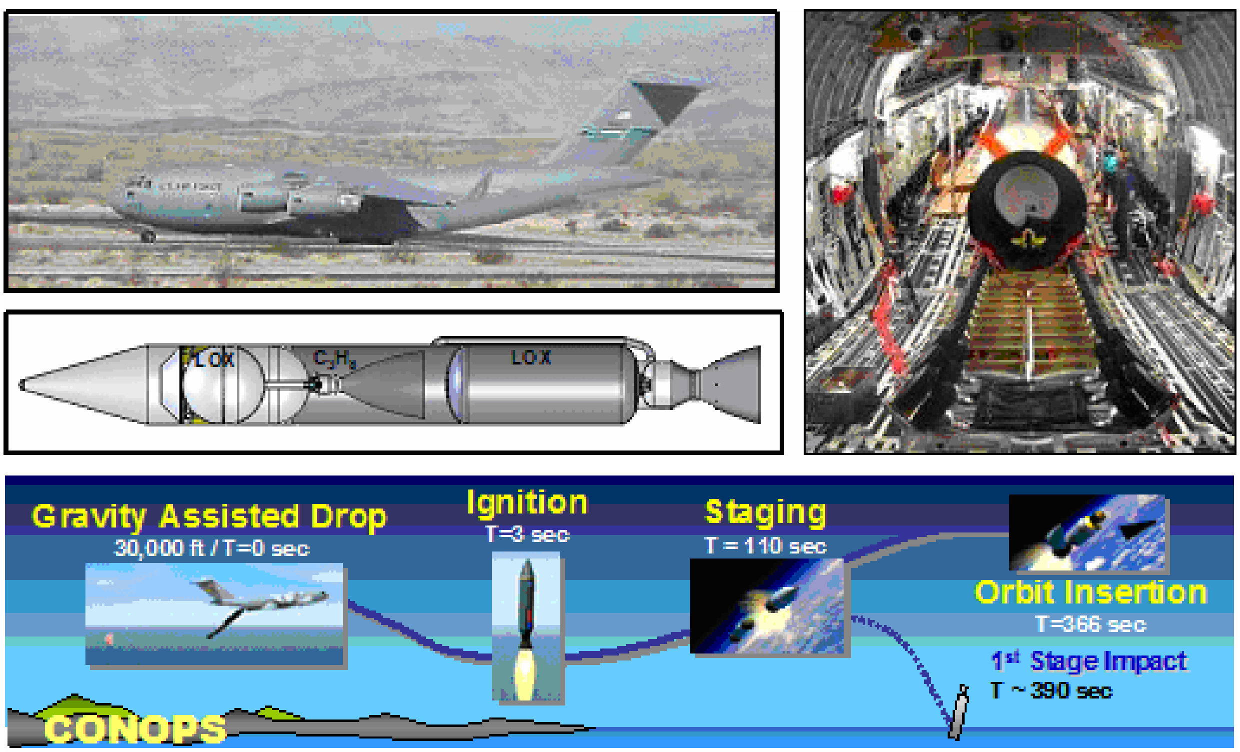
QuickReach™ Small Launch Vehicle Overview

The QuickReach™ SLV is designed to meet the needs of the DARPA/Air Force Falcon SLV program: deliver 1,000 pounds to low earth orbit (LEO), for $5M per flight, with response time of less than 24 hours. It is an air-launched, two-stage liquid fueled rocket, designed for use with an unmodified C-17A military transport aircraft and compatible with other transports with comparable or greater capacity, such as the An-124 or C-5A. Satellite launch missions will be conducted with a single QuickReach™ vehicle loaded in the aircraft along with range support equipment.

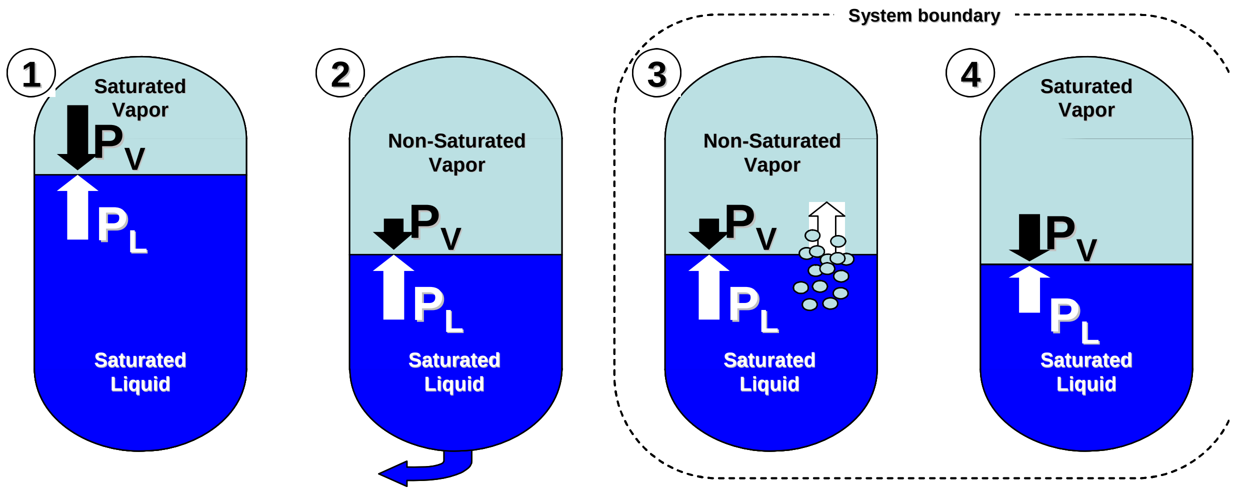
Launching from altitude provides a unique opportunity to operate a simple, low-cost rocket system while maintaining the high performance characteristics of most two stage launch vehicles. AirLaunch opted to launch its vehicle from a cargo aircraft at altitude to provide increased performance to take advantage of the efficiency of the innovative liquid oxygen and propane vapor pressurization (VaPak) propulsion system that QuickReach™ employs.

Conceived in 1960 by Aerojet, VaPak combines the simplicity and reliability of a solid rocket with some of the performance advantageous of a liquid propellant design. VaPak is based on using the internal energy of a liquid stored in a closed container to provide the pressure and to perform the work required to expel the liquid from the container. The principle of VaPak propellant pressurization is similar to the process that pressurizes a simple can of hair-spray. In a VaPak propulsion system, the propellants are pressurized by the vapor pressure in the ullage volume, generated by the liquid propellant phase being maintained at a saturated state.

VaPak systems hold the promise of low complexity propulsion systems for highly reliable and cost-effective vehicle designs. VaPak eliminates costly components such turbopumps, gas generators, high pressure bottles, or complex valving used in a typical pump-fed launch vehicle. In conjunction with appropriate engine design, the resulting systems are equally useable for trans-atmospheric or in space operations.



QuickReach™ Small Launch Vehicle
Providing Extraordinary Capability with Ordinary Technology



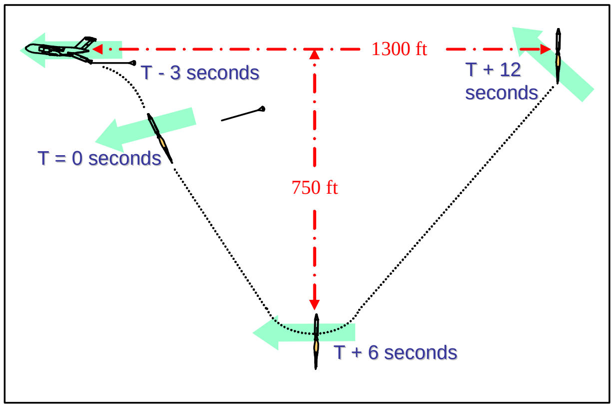
The VaPak model is based on an enthalpy balance, assuming an isentropic process, with both liquid and vapor phases at uniform temperature at a fully saturated state

Air launching takes advantage of the low outside atmospheric pressure at altitude (30,000 feet or greater) which allows a pressure-fed launch vehicle to use high area ratio nozzles while operating at relatively low engine chamber pressures. AirLaunch's approach provides weight and specific impulse (Isp) performance that is competitive with high-pressure turbopump-fed systems without the associated safety, cost, or complexity issues.

AirLaunch's approach simplifies operations and minimizes reliance on fixed launch ranges. For example, required coordination is minimized with other users of the range, weather constraints can be avoided by flying to open sky, and there will be fewer delays waiting for specific launch windows (to match desired orbits) because the launch vehicle can be flown to an alternate launch point that is better aligned with the desired orbit. In addition, ground launches are often postponed when ships enter the ocean zones near the coastal launch sites or where rocket stages are expected to drop. The QuickReach™ carrier aircraft can avoid such delays by flying to a different release point. Public safety is greatly enhanced since the launch takes place over the open ocean, far away from any populated areas. Air launching minimizes range costs and maximizes operational flexibility by allowing deployment from any 4,000 foot runway without need for fixed installations.

For an actual launch mission, the design goal is to be able to load QuickReach™ onto the aircraft in 20 minutes, and then fly to a nominal launch point ~200 or more miles off the coast. The aircraft will climb to ~30K–35K feet altitude where it cruises to the desired drop point. The aircraft can loiter before launching for several hours. If a dangerous situation arises on-board, emergency extraction may be triggered by the loadmaster anytime during flight. During an emergency extraction all rocket components and propellants would be extracted in less than 30 seconds.

The carrier aircraft will be flown to a "drop box," an approximately 1 x 1 mile area over the open ocean for an operational mission. Several minutes prior to launch the aircraft deck angle is established at approximately 6 degrees nose up, cabin pressure is equalized with local atmospheric pressure, and the aft cargo door is opened. Fifteen seconds before launch, a small drogue parachute attached to the first stage nozzle is deployed. Upon launch command, the rocket is released and gravity pulls the launch vehicle out of the aircraft, assisted by the small stabilizing drogue chute. The launch vehicle pitches up after leaving the cargo bay due to cresting the end of the cargo ramp. The drogue chute damps this pitch rate and after about 3 seconds the launch vehicle's pitch attitude is 70 to 80 degrees above the horizon.



QuickReach™ Launch Sequence

The Stage One engine ignites when the launch vehicle is over 200 feet from the aircraft, with the launch vehicle descending at 100 feet per second (fps) down and traveling 50 fps aft relative to the aircraft. At the point of ignition, the parachute is released by the simple mechanism of having its risers burned off. Following ignition, the vehicle aligns itself into the desired ascent trajectory and performs a gravity turn through the region of maximum dynamic pressure. Because of the relatively low thrust to weight (T/W) of the Stage One engine, the launch vehicle needs another 500 feet of altitude to arrest its descent. The rocket flies to a vertical heading and continues in this attitude until it re-crosses the launch altitude more than 1,000 ft behind the launch aircraft 15 seconds after extraction.

In this segment the first stage engine operates on liquid combustion and tanks are pressurized using the VaPak mode. Once the liquid in the tanks has been depleted, the vehicle transitions to vapor burn mode, and both tank and engine chamber pressure drop rapidly. The stage is shut down and separated when the T/W is less than one.

Following separation, the second stage ignites under VaPak operation. The payload fairing is released when the environment outside of the vehicle is no longer harmful to the payload. The second stage burn is designed to transition to vapor operation prior to completion of the initial burn. This allows the second stage to restart following the coast to apogee, with only vapor in the propellant tanks, which eliminates propellant settling concerns. Lastly the second stage engine performs the final injection burn into a circular low earth orbit.

Development Progress to Date

AirLaunch LLC completed Phase 2B of the Falcon Small Launch Vehicle (SLV) program in April 2007. During this phase, AirLaunch completed an Incremental Critical Design Review (I-CDR) of the QuickReach™ system; conducted 30 test fires of its second stage engine on the Horizontal Test Stand (HTS) and 5 test fires of the QuickReach™ Integrated Stage 2 (IS2) on the Vertical Test Stand (VTS); completed the payload fairing and executed a payload fairing separation test; performed a full-scale stage separation test; conducted numerous analyses of VaPak, engine and vehicle performance; and completed two record-setting drop tests of full-scale inert test articles from the C-17.

In 2005, Team AirLaunch completed Phase 2A on time and within budget with significant hardware development and testing. This included 4 engine test firings, a stage separation test, a ground drop test, and a C-17 drop test. Phase 2A ground tests and the first air drop generated early data on propulsion, airframe, avionics and operations.

<u>Design Status</u>

In November 2006, AirLaunch successfully completed the Incremental Critical Design Review (I-CDR) of the QuickReach™ SLV. In addition to the DARPA and Air Force program management team, government personnel from a variety of agencies participated in the review.

All Mil-Std-882 safety tasks assigned to Phase 2B were completed to the satisfaction of the program system safety review board, which included representatives from the C-17 Airworthiness Review Board at Wright Patterson AFB and the Safety Review Board at Edwards AFB. Both review boards approved the successful drop tests of inert test articles from the C-17 in Phase 2B.

<u>Drop Tests from C-17 Aircraft</u>

A total of three drop tests from three separate unmodified C-17 aircraft have been performed by AirLaunch as part of the Falcon SLV program, each test setting a record for the longest and heaviest single objects dropped from the aircraft. Each one dropped a simulated QuickReach™ rocket at 65.8 feet long, of increasing weight up to full-scale.

AirLaunch Preparing for Drop Tests

- Drop # 1 was conducted during Phase 2A on September 29, 2005, with a 50,000 lb Drop Test Article (DTA) dropped from 6,400 feet above ground level. This drop set the record for the longest single object, at 65.8 feet, ever dropped from a C-17 aircraft. The flight test crew was nominated by Air Force Materiel Command (AFMC) for the 2005 Mackay Award, for the most Meritorious Air Force flight of the year.

- Drop # 2 was conducted during Phase 2B on June 14, 2006, with a 65,000 lb DTA from an altitude of 29,500 feet and a true airspeed of 330 knots. This drop set the record for the heaviest single object ever dropped from the C-17 aircraft.

- Drop # 3 was conducted during Phase 2B on July 26, 2006, with a full-weight 72,000 lb DTA from an altitude of 32,000 feet and a true airspeed of 330 knots. This drop broke its own record and set a new one for the heaviest single object ever dropped from the C-17 aircraft.

The test series was designed to assure that AirLaunch could safely extract the QuickReach™ rocket from a C-17. In each test, the simulated QuickReach™ booster rested inside the aircraft cargo bay on a Storage and Launch Carrier, consisting of 84 tire/wheel assemblies. As the aircraft turned nose up by six degrees, gravity pulled the test article across the upturned tires and out the aft cargo door.

The tests demonstrated the QuickReach™ release technology and the feasibility of Gravity Air Launch (GAL). Unlike the standard heavy equipment airdrop method, GAL imparts much of the launch carrier aircraft's altitude and airspeed onto the rocket, which in turn improves payload mass to orbit. Each test used a separate C-17 aircraft, demonstrating that any C-17 can be used for AirLaunch drops and ultimately for QuickReach™ launches.

AirLaunch has completed 34 test fires of the second stage engine on the Horizontal Test Stand (HTS)

AirLaunch's Record Setting Drop Tests from C-17 Expanded Aircraft Envelope

The tests were conducted at Edwards Air Force Base by the Air Force Flight Test Center 412th Flight Test Wing and 418th Flight Test Squadron, in conjunction with the Air Force Space Command Space and Missile Systems Center / Detachment 12, and the C-17 Systems Group and Air Mobility Command which supplied the aircraft.

Engine / Stage Testing

AirLaunch has conducted a total of 39 test fires in Phases 2A and 2B of the Falcon SLV program. All tests have used AirLaunch's innovative VaPak propulsion system and gathered data to validate its use with liquid oxygen and propane. Thirty-four (34) tests have been performed on the HTS with the QuickReach™ second stage engine, totaling 282.5 seconds of burn time, in addition to several cold flow tests.

QuickReach™ Integrated Stage 2 Readied for Test

QuickReach™ Test Fires of IS2 in VTS, including longest VaPak burn in history (191 seconds)

Five (5) tests have been performed to date on the VTS with the QuickReach™ IS2, totaling 315.5 seconds of test fire time, as well as several loading and conditioning tests. The IS2 firings signal the beginning of the process to validate the QuickReach™ propulsion system, the ground propellant loading operations, and flight-type avionics, software and systems. Transition of liquid oxygen to gaseous oxygen has been demonstrated in test fires on both the HTS and VTS.

AirLaunch LLC and its teammates conducted its longest test fire to date on April 6, 2007, as the culmination of the Phase 2B activity. The stage contained over 6 tons of vapor-pressurized (VaPak) propellant and burned for 191 seconds, representing a liquid-liquid burn and a transition of the liquid oxygen (LOX) from liquid to vapor phase. The LOX-Propane engine performed as expected, testing the design of the injector with integral main propellant valve and demonstrating much lower than expected erosion rates on the ablative chamber. All test operation was initiated and controlled by the flight-type avionics wafer attached to the stage.

QuickReach™ Payload Fairing Elements and Payload Fairing Separation Test

This test was the longest VaPak burn in history. Aerojet conducted a 60 sec burn using VaPak on a Titan motor in 1963, and Scaled Composites performed a 77 sec burn using VaPak (oxidizer only) on the hybrid engine for SpaceShip One in 2004.

System & Component Testing

As the first major milestone of Phase 2B of the DARPA/Air Force Falcon program, Air Launch completed a full scale stage separation test of its QuickReach™ SLV. This test convincingly demonstrated that the innovative gas pneumatic stage separation technique, pioneered by AirLaunch's founder Gary C. Hudson, is practical and safe. Prior to this test, AirLaunch performed detailed modeling and conducted a number of component and subscale tests.

During Phase 2B, AirLaunch and its teammate Delta Velocity completed assembly of the payload fairing and payload adapter cone. A payload fairing separation test was conducted at NASA Wallops Flight Facility. All pyrotechnic sequences and mechanical actions operated properly.

Next Steps

DARPA and the Air Force have agreed for AirLaunch to move into Phase 2C and to jointly fund the activity. It is anticipated that Phase 2C will emphasize propulsion characterization of the liquid oxygen/propane VaPak system. Discussions are underway to define the Phase 2C technical content and associated milestones.
Future phases would include a full CDR, additional safety mitigation, design and development of the onboard propellant conditioning system, first stage engine testing, and additional drop tests. Approvals by the appropriate safety review and flight readiness review boards would be required prior to a first test flight.

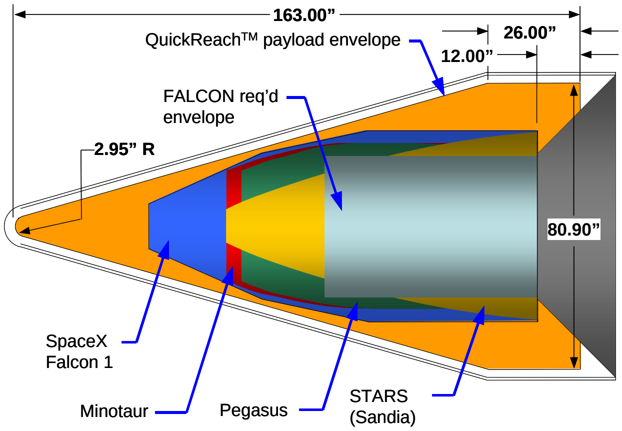
Payload Accommodations

QuickReach™ is designed to meet the DARPA/Air Force Falcon SLV program requirement of delivering 1,000 pounds to a reference Low Earth Orbit of 28.5°, 100 nmi, due east. Air launching has the added ability to launch at any azimuth, thus enabling similar performance to a variety of orbits. The aircraft can fly to the optimum drop point that satisfies overflight concerns, orbit inclination, and apsis location requirements. Specific cases can be run for individual customer missions.

Subscale and Full Scale Stage Separation Tests Completed

AirLaunch intends to offer customers a set of standard and optional services that can be tailored to satisfy payload needs. QuickReach™ will provide low cost, rapid call-up launch of payloads designed for responsive missions, so the basic launch service may appear to impose more restrictions on the payload than conventional launch vehicles. Conventional payloads that require support beyond that of the basic service can select from a variety of extra cost options.

The Falcon SLV program requirement is to carry a 40 inch x 60 inch satellite, and the QuickReach™ payload fairing was selected to provide the largest payload volume of any launch vehicle in the sub-2000 pound class. This provides the customer with considerable flexibility in payload design. As an example, satellites can be made more responsive if deployable appendages can be reduced or eliminated. AirLaunch's fairing is known as the "encapsulated cargo element (ECE)" – the design allows off-line payload processing independent of the launch vehicle. It also provides security and environmental control during ground processing, integration operations, and ascent.



QuickReach™ Payload Envelope Equals or Betters that of Other Small Launchers

QuickReach™ vehicle performance and payload accommodations were described in detail in the paper entitled, *AirLaunch's QuickReach™ Small Launch Vehicle: Operationally Responsive Access to Space*, SSC06-IX-4, presented at the 2006 Utah State Small Satellite conference. These details remain the same, and are available on our AirLaunch website for convenience.

Missions

The Falcon SLV program goal is to develop a vehicle that can launch a 1,000 pound satellite to Low Earth Orbit (LEO) for less than $5 million, within 24 hours of notice. Currently it costs about $20 million to launch a satellite of this size into space and the lead time can be months to years. Having a quick reaction launch system that that can launch specialized small satellites will provide a new capability for both military and civil applications as well as stimulate commercial opportunities.

QuickReach™ provides real value for changing the way the nation operates in the launch business. Integrating Air Force air (C-17) and space capabilities, with AirLaunch's responsive, low-cost and operable QuickReach™ rocket, ultimately gives the warfighter faster access to space, enabling a variety of ORS missions.

AirLaunch's capability will enable customers to respond quickly when a time-urgent need arises or in response to a natural disaster by launching small remote sensing satellites on short notice. These small satellites can be equipped with communication, camera and sensor payloads that allow special purpose support for military activities, hurricanes, and forest fires, as well as enable time-urgent communications in remote areas.

A small launch vehicle may be a very attractive approach for providing affordable, responsive launch capabilities for bio-tech, lunar and other small spacecraft payloads of interest to civil, commercial, and university commercial users.

In August 2006, AirLaunch signed a Memorandum of Understanding with NASA Ames Research Center to explore collaborations in space launch systems and payloads launched from aircraft. NASA Ames Research Center is seeking partnerships to promote the development of a robust commercial space industry to benefit and support NASA's exploration mission goals, in particular to help provide sustainable exploration. Under terms of the agreement, AirLaunch and NASA Ames will explore areas of collaboration to include mission, vehicle, and payload concept analyses; systems engineering; and payload integration, as well as use of NASA Ames facilities, such wind tunnels, arc-jet facility, flight simulators, hangars, and runways.

Summary

AirLaunch's innovative process leads to growth opportunities and new markets for operationally responsive space. Its QuickReach™ vehicle is specifically designed to meet the needs of the DARPA / US Air Force Falcon Small Launch Vehicle program, capable of delivering 1,000 pounds to low earth orbit for $5 million per launch, with a 24-hour response time. AirLaunch's approach achieves responsiveness by flying the two-stage, pressurized QuickReach™ system inside an unmodified C-17A or other large cargo aircraft and deploying from the aircraft using Gravity Air Launch. AirLaunch provides a responsive, flexible Concept of Operations for multiple payloads, with short call-up to launch and multiple azimuth capability which avoids operational issues associated with current ranges.

AirLaunch has successfully completed Phases 1, 2A, and 2B of the Falcon SLV program. In total, AirLaunch has completed 2 stage separation tests; assembly of the integrated LOX/propane tankset for stage two and the vertical test stand; 34 engine test firings on the Horizontal Test Stand and 5 test fires of its Integrated Stage 2 on the Vertical Test Stand; assembly of the payload fairing and payload fairing separation test; series of ground drop tests and 3 record setting C-17 drop tests with a simulated full-scale, full-weight QuickReach™ rocket; and an Incremental Critical Design Review.

AirLaunch's significant hardware and testing to date can be attributed to the rapid prototyping process and milestone-based approach used in the Falcon SLV program. Technical and safety issues are addressed systematically, including use of Mil-Std safety processes.

AirLaunch welcomes payloads interested in flying on the test and early launches of the QuickReach™ system. The first test flight, with a live launch to LEO, is anticipated at the end of Phase 2D. Small payloads may fly together or in a ride-share arrangement, subject to coordination with the primary DARPA/Air Force Falcon SLV program customer. The first launch is expected to be conducted out of Wallops. Future launches of the Operational System may be conducted out of Wallops or any other site with a runway suitable for a large cargo aircraft.

Acknowledgements

AirLaunch LLC acknowledges the contributions of all members of Team AirLaunch shown in the map below, as well as employees and independent contractors.

Experienced Team Working Together

ATTACHMENT A:
Excerpts from Paper # SSC06-IX-4
15th Annual AIAA/USU Conference on Small Satellites

"AirLaunch's QuickReach™ Small Launch Vehicle:
Operationally Responsive Access to Space"

VEHICLE PERFORMANCE

QuickReach™ is designed to deliver small payloads to a wide variety of orbits. QuickReach™ can attain the full range of posigrade and retrograde inclinations through the flexibility inherent in an air launched system. Responsiveness of a launch system includes all events required to get a payload to its required orbital location. The restartable second stage and nearly infinite selection of launch locations allow QuickReach™ to achieve first pass coverage of specific ground sites and satisfy specific mission orbit parameters without time consuming orbital maneuvers.

Mission Description

Every QuickReach™ payload requires a mission design to satisfy payload, launch vehicle, and range safety constraints. AirLaunch uses commercially available trajectory optimization programs to assess QuickReach™ performance candidate orbits. The trajectory software can be set to optimize the delivered mass to a specified orbit, the maximum orbit for a specified payload mass, or other conditions of interest. Specific orbit parameters, launch window, and performance requirements for the mission, will be defined in the mission specific Payload Interface Control Document (ICD). Depending on mission requirements, the QuickReach™ vehicle may fly one of two different mission profiles. The most common is a circular LEO mission. In this case Stages 1 and 2 fire in rapid succession to inject the payload and second stage on a trajectory with the apogee altitude equal to the perigee of the desired orbit. Following a commanded second stage shutdown, the combined second stage and payload enter a coast phase to apogee, where Stage 2 is restarted to circularize the orbit at the desired altitude. During this coast period, the QuickReach™ Attitude Control System (ACS) can maneuver the stack to a specific orientation or initiate a slow roll for payload thermal control.

Payloads that desire injection into an elliptical orbit or carry on-board propellant for orbit raising may require the QuickReach™ vehicle to use a single Stage 2 burn. In this scenario, Stages 1 and 2 again fire in rapid succession, but Stage 2 only makes a single burn. This will allow the QuickReach™ vehicle to place a heavier payload on a transfer orbit trajectory where the payload's onboard propulsion system can then complete the mission. In either case, the combination of an air launched system that can select launch location and a liquid upper stage that can be shut down and restarted provides unmatched flexibility in mission design.

LEO Performance Capability

QuickReach™ is designed to meet the DARPA/U.S. Air Force Falcon SLV program requirement of delivering 1,000 pounds to a reference Low Earth Orbit of 28.5°, 100 nmi, due east. Air launching has the added ability to launch at any azimuth, thus enabling similar performance to a variety of orbits. The aircraft can fly to the optimum drop point that satisfies overflight concerns, orbit inclination, and apsis location requirements. Specific cases can be run for individual customer missions.

QUICKREACH™ PAYLOAD ACCOMMODATIONS

AirLaunch intends to offer customers a set of standard and optional services that can be tailored to satisfy payload needs. QuickReach™ will provide low cost, rapid call-up launch of payloads designed for responsive missions, so the basic launch service may appear to impose more restrictions on the payload than conventional launch vehicles. Conventional payloads that require support beyond that of the basic service can select from a variety of extra cost options. AirLaunch has simplified and streamlined the mission design and payload integration process to provide safe, reliable, responsive space launch services. The following sections describe the mechanical, electrical and support equipment interfaces between the QuickReach™ launch vehicle and the payload. Many of these interfaces are payload-specific and will be detailed in the Interface Control Document (ICD) developed for a given mission.

Payload Fairing

The Falcon SLV program requirement is to carry a 40 inch x 60 inch satellite as shown in Figure 7. The QuickReach™ payload fairing was selected to provide the largest payload volume of any launch vehicle in the sub-2000 pound class, as shown in Figure 8. This provides the customer with considerable flexibility in payload design. As an example, satellites can be made more responsive if deployable appendages can be reduced or eliminated. AirLaunch's fairing is known as the "encapsulated cargo element (ECE)" – the design allows off-line payload processing independent of the launch vehicle. It also provides security and environmental control during ground processing, integration operations, and ascent. The fairing is a graphite/epoxy composite honeycomb structure. A solid graphite payload cone supports the payload and completes the ECE. The fairing is RF-opaque, however, the standard access door can be replaced with an optionally priced fiberglass version to act as an RF window.

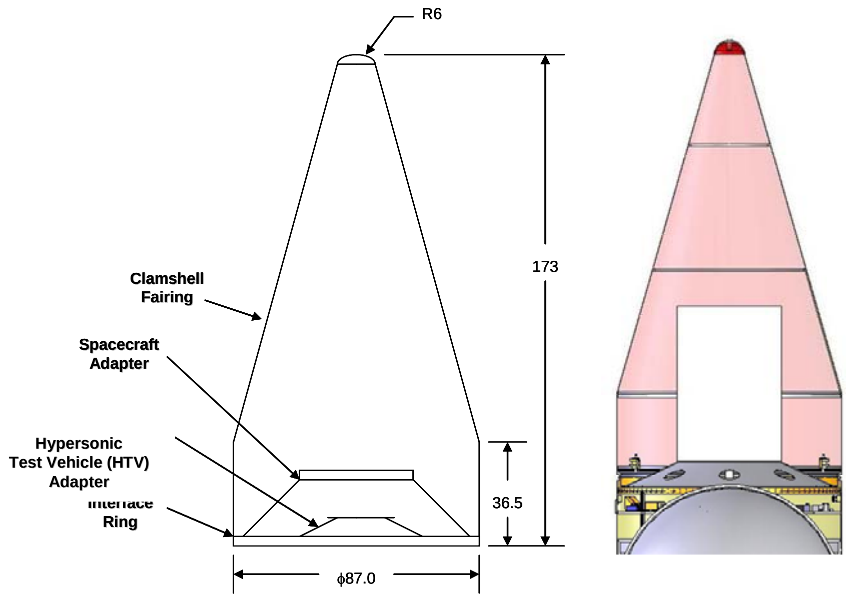


Figure 7: Left – QuickReach™ Payload Fairing Dimensions (in inches)
Right – ECE Shown with 40” x 60” Falcon-class payload

<u>Payload Dynamic Envelope</u>

Figure 8 also defines the dynamic envelope available to the payload. It is the customer’s responsibility to verify that the payload remains within the dynamic envelope under flight quasi-static and dynamic loads when all payload manufacturing tolerances and deflection are taken into account. If a payload is close to violating the dynamic envelope, an optional coupled loads analysis and critical clearance analysis can be performed. Local protrusions beyond the standard dynamic envelope can be evaluated on a case-by-case basis, again as an optional service.

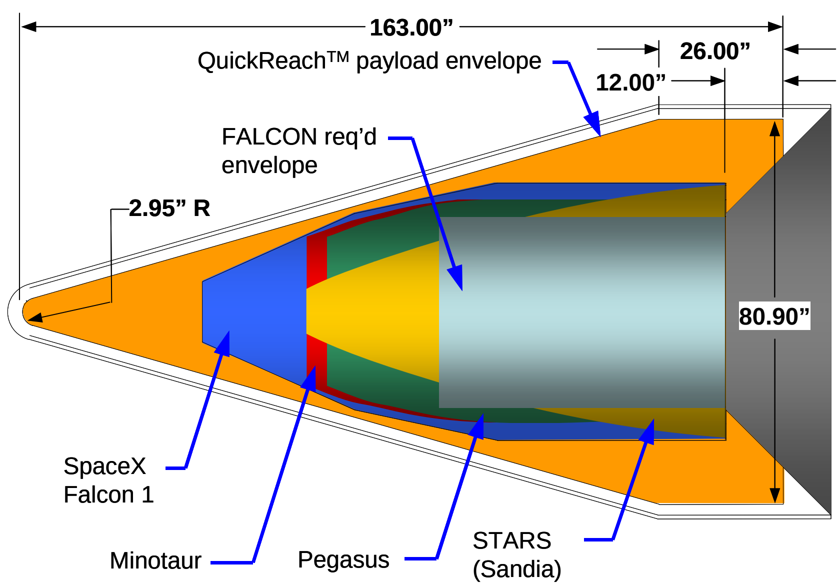


Figure 8: QuickReach™ Payload Envelope
Equals or Betters that of Other Small Launchers

Payload Access Door

One access door, 12 inches x 18 inches (305 mm x 457 mm), is provided for post-encapsulation payload access as a standard service. The 12 inch (305 mm) dimension in the direction of the launch vehicle thrust axis and the 18 inch (457 mm) dimension in the circumferential direction. The standard access door is RF-opaque. The door can be located anywhere in the cylindrical section of the fairing, with the exception of small stay-out zones adjacent to the separation system. The door is installed in the fairing shell after fabrication of the basic structure, so specific door location may be defined as late in the flow as one week prior to payload encapsulation.

Payload Mechanical Interface

The standard mechanical interface is a non-separating bolt pattern with 60 holes, 0.190" in diameter, on a 38.81" bolt circle. Commercially available separation systems that mate to this mechanical interface are optionally available and can be provided by AirLaunch or the satellite customer. Such systems include Lightband payload separation system from Planetary Systems Corporation and two marman clamp separation systems from Saab Ericsson Space of Sweden. Both vendors' separation systems are pre-assembled standalone units that bolt to the existing payload cone bolt circle and provide and another bolted interface for the spacecraft. The volume and weight of the separation system is chargeable to the payload. The Lightband system provides a 38.81 inch (986 mm) payload bolt circle, while the Saab separation system is available with either a 38.81 inch (986 mm) or a 37.15 inch (944 mm) diameter bolt circle payload interface. Payload-furnished separation systems can also be accommodated. A payload-provided separation system with line loads or load peaking that exceeds the design loads of the payload cone will require optional additional analyses and coordination with AirLaunch.

Payload Electrical Interfaces

A standardized electrical interface simplifies payload integration and improves mission responsiveness. Sufficient interface capabilities are provided to accommodate the typical requirements of payloads in this class. A graphical view of the electrical interface capability is shown in Figure 9. The electrical interface to the payload is provided by two connectors located 180° apart on the payload cone. Wiring from these connectors runs to a T-0 umbilical connector at the outer perimeter of the payload cone. This connector is accessible after encapsulation through an opening in the payload fairing. These pass-throughs will be fully populated with a variety of conductor sizes and types and may be used by payload to communicate with payload-provided support equipment either while the ECE is in storage or during pre-launch operations.

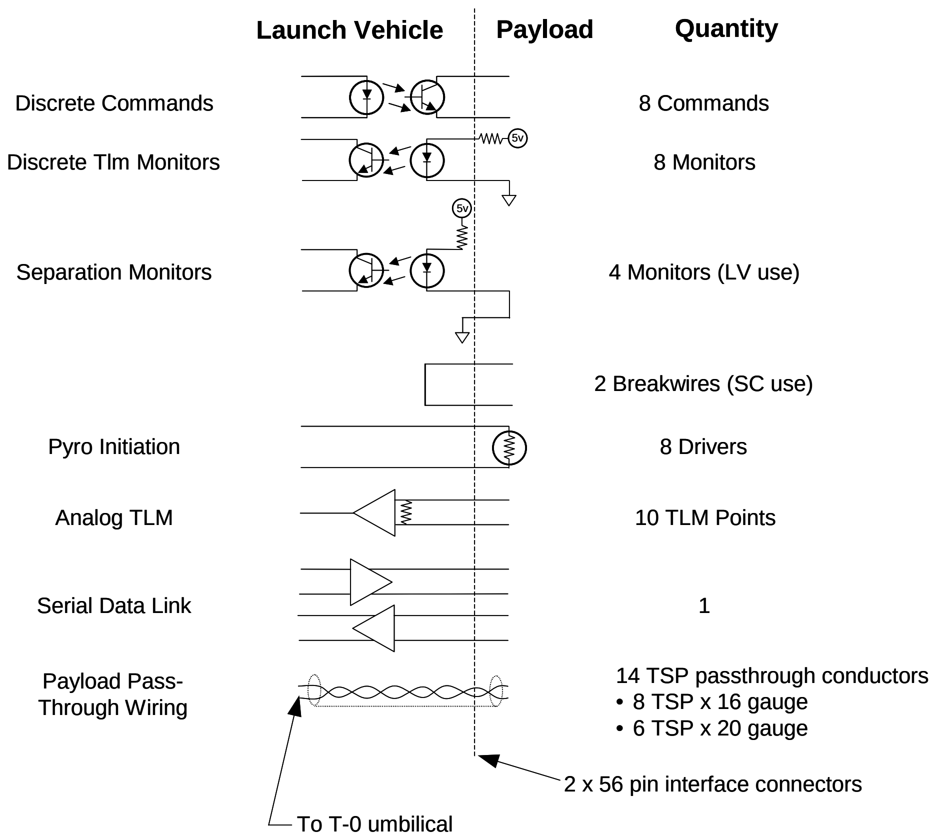


Figure 9: Standard QuickReach™ Electrical Interface Provides Ample Capability for Most Payloads

AirLaunch will provide the mating connector for the T-0 umbilical but it is the payload provider's responsibility to provide a wire harness that connects the T-0 umbilical to any payload-unique support equipment. Limited 19" rack space and power are available on the SLC for payload-provided ASE. Additional wiring from the interface connectors is routed to a QuickReach™ Remote Interface Unit (RIU) mounted on the underside of the payload cone. The RIU, which communicates with the launch vehicle flight computer through a serial interface, is able to monitor payload telemetry and provide discrete commands to the payload. The RIU also issues the digital arm and fire commands to the payload fairing and separation system ordnance.

Payload Interface Connectors

As a standard service, AirLaunch will provide two 56 pin payload interface connectors. The connectors include strain relief backshells and mounting bracketry on the payload cone. Each connector provides 48 20-gauge contacts and eight 16-gauge contacts. The connector design is a standard MIL-C-38999 shell with 25-4 insert. Four of the 20-gauge contacts in each connector are used by QuickReach™ to verify payload separation via breakwire loops, leaving 52 pins in each connector available for payload use.

AirLaunch will provide both halves of each interface connector and a fully populated wire harness on the launch vehicle side of the interface. The forward half of each flight connector will be provided to the customer for integration into an interface pig-tail harness. If additional connectors are required to fabricate non-flight cables in support of payload integration and test, they can be provided as an optional service.

T-0 Umbilical Harness

The T-0 umbilical connector enables direct electrical access to the payload from encapsulation through release of the QuickReach™ vehicle from the SLC. Twenty eight conductors (14 twisted shielded pairs) are wired from the two payload interface connectors to the T-0 umbilical. Eight pairs of the 14 available wire pairs are 16 gauge wire. These lines provide minimal power loss to support battery charging, external power, and other current needs of less than four amps. The remaining 6 pairs are 20 gauge and are typically used for signal and communication.

AirLaunch will provide the payload organization with a connector to mate with the T-0 umbilical on the ECE. It is the payload provider's responsibility to fabricate cabling as required to access the payload through the T-0 umbilical. This access is available at any time following encapsulation up through mating of the ECE to the launch vehicle.

Following mating, the umbilical is again available for access up through release of the vehicle from the carrier aircraft, however, any payload-provided equipment and cabling intended for power-on use in the carrier aircraft will require EMI compatibility testing with the aircraft. This testing is a non-standard service and must be completed prior to any launch processing operations.

Payload Command and Control

The QuickReach™ flight computer can provide discrete commands (in the form of switch closures) for payload use based on mission time or mission events. These discrete commands are optically isolated pulses of programmable lengths in multiples of 40 milliseconds. Eight such commands are available, each capable of multiple pulses. The payload must supply a source voltage less than or equal to 40 VDC and the current must be limited to less than 20 milliamps. These command lines will be opened at payload separation.

Payload Discrete Status Monitoring

Eight payload discrete telemetry inputs can be monitored during pre-launch operations and down-linked during ascent. These monitors are optically isolated from the launch vehicle avionics and are typically used for voltage threshold or bus on/off type monitoring. The payload must supply a DC voltage source and the current resistor to limit the current to less than five milliamps. These discretes are monitored at 10Hz. These monitors will only be available when the QuickReach™ RIU is powered up and connected to either the flight computer or a GSE monitoring computer. Use of these monitors to verify inhibits or other safety-critical functions will require coordination with AirLaunch to ensure the appropriate level of RIU monitoring.

Payload Analog Telemetry Monitoring

Ten analog telemetry points may be monitored by the RIU during pre-launch and flight operations. The data will be interleaved in the launch vehicle telemetry stream. The A/D converter has eight-bit resolution and a 10 Hz sample rate. The payload provider must provide the scale and bias values for the analog telemetry inputs. Use of these monitors to verify inhibits or other safety-critical functions will require coordination with AirLaunch to ensure the appropriate level of RIU monitoring.

Serial Communication Interface

A serial RS-422 communication interface between the QuickReach™ flight computer and the payload can be provided. The flight computer will interrogate the payload at a pre-determined rate and will receive payload telemetry to be interleaved into the downlinked telemetry stream.

Payload Battery Charging

Post-encapsulation payload battery charging can be performed using the 16 gauge conductors in the T-0 umbilical. Payload-provided power supplies and charging equipment should be transportable to facilitate operations at the PPF, ECE storage facility, and the integration site. Payload battery charging equipment may be accommodated in the rack on the SLC, however, the use of this equipment in the carrier aircraft is subject to Electromagnetic Interference (EMI) compatibility testing and approval from the aircraft. The pass-through lines from the launch vehicle to the payload can accommodate a maximum charging current of four amps.

Pre-Drop Electrical Constraints

Prior to release of the launch vehicle from the SLC, all payload and payload electrical ground support equipment circuits shall be constrained to ensure that the current flow across the umbilical interface is less than or equal to ten milliamps.

Pre-Separation Electrical Constraints

For separating payloads, prior to payload separation all launch vehicle and payload interface circuits shall be constrained so that the current across the separation connectors is less than or equal to ten milliamps.

Payload Ground and Airborne Support Equipment

QuickReach™ is intended to launch responsive payloads. Such payloads are expected to require less support equipment than traditional satellites. Since the QuickReach™ system is designed to integrate the encapsulated payload and launch within a few hours, only limited accommodations for payload-unique support equipment are provided on the SLC and in the carrier aircraft. Prior to mating the ECE to the QuickReach™ vehicle, access to the encapsulated payload is available either through the T-0 umbilical on the ECE or through the 12" x 18" payload access door in the fairing. Payload-provided support equipment that is required at the ECE storage area and/or at the integration site should be designed to be readily transportable. Ground power is available at these sites at 115/230 VAC 60 Hz for payload G/ASE use.

Customer-supplied payload support equipment may be mounted on the SLC for use both before loading the SLC onto the carrier aircraft and during captive carry flight. Any payload equipment or SLC-mounted electronic support equipment that will be operational while on board the aircraft must either be previously approved or is required to undergo EMI compatibility testing with the aircraft. Use of all such equipment is subject to the approval of the carrier aircraft provider.

Interface to the payload through the QuickReach™ T-0 umbilical provides the capability for direct monitoring of payload functions. AirLaunch provides the T-0 umbilical mating connector. The cabling from the connector to the payload support equipment must be provided by the customer. If SLC-mounted support equipment is used, AirLaunch will route and secure the customer-provided cabling on the SLC.

The SLC provides a standard 19" rack for mounting payload support equipment. The rack is 30" tall and will accommodate a chassis up to 18" deep. AirLaunch will provide power distribution on the SLC using carrier aircraft power. An approved ruggedized laptop computer may also be used to either control the SLC-mounted payload support equipment or to interface directly with the payload through the T-0 umbilical.

Pyrotechnic Events

QuickReach™ can provide up to eight ordnance initiation events using smart initiators from Pacific Scientific (PacSci). These initiators provide ordnance outputs and mechanical interfaces identical to those of a NASA Standard Initiator, however, the PacSci initiators require only a low current digital signal. Up to four of these devices can be initiated simultaneously. The pulses are provided by the QuickReach™ Remote Interface Unit (RIU), which is in turn commanded by the flight computer through a serial communication link. If one of the optional AirLaunch provided separation systems is used, four of these pyrotechnic events will be used to initiate the separation system.

System Safety Constraints

Safety of personnel and equipment is the highest priority for AirLaunch. Each customer is required to conduct at least one dedicated payload safety review prior to launch. The customer must also prepare and submit safety documentation, for inclusion into the mission safety analysis and documentation.

Customers designing payloads that employ hazardous subsystems are advised to contact AirLaunch early in the design process to verify compliance with system safety standards. For example, AFSPCMAN 91-710 is a launch vehicle safety requirements document. This and other applicable safety documents must be strictly followed or tailored with approval. It is the responsibility of the customer to ensure that the payload meets all AirLaunch and government-imposed safety standards.

PAYLOAD ENVIRONMENTS

This section defines the environmental conditions that the payload will experience during encapsulation, prelaunch operations, captive carry, ascent to orbit, and on-orbit operations. Encapsulation covers mating the payload to the adapter, enclosing it within the fairing, local transportation, and storage of the encapsulated cargo element. Prelaunch operations include transportation of the ECE to the staging site, mating to the QuickReach™ vehicle, and installation of the QuickReach™ system in the carrier aircraft. Captive carry covers the period from aircraft engine start through release of the QuickReach™ vehicle from the SLC and the initial drop prior to ignition. Powered flight begins at Stage 1 ignition and ends at Stage 2 shutdown. QuickReach™ orbital operations begin after Stage 2 shutdown and end following payload separation and Stage 2 Collision/Contamination Avoidance Maneuver (C/CAM).

The environmental design and test criteria presented in the following section have been derived using analysis and measured data obtained from system development tests as well as from experience with similar launch systems. The predicted levels presented are intended to be bounding of mission specific levels. Payload design and qualification to these levels should reduce or preclude the need for extra-cost mission specific analyses.

Steady State and Transient Accelerations

Design limit load factors result from combining the effects of steady state accelerations with transient accelerations that take place during the launch. These values include uncertainty margins. In addition to the normal flight loads, the payload must be designed for a 4.5 g lateral load in the event of a carrier aircraft emergency landing. Yielding of the payload under this emergency load is acceptable but ultimate failure is not.

Table 1 specifies the maximum quasi-static accelerations (i.e. both steady state and transient) at the payload center of gravity during various mission phases. These accelerations envelope all accelerations whether induced by static loads or transient loads. The ground operations loads are derived from AirLaunch's operational experience with similarly-sized GSE and conventional transport speed limitations. In-flight loads were predicted using worst-case trajectory simulations and carrier aircraft flight limitations.

Table 1: QuickReach™ Quasi-Static Accelerations

Mission Segment	Axial* (X Axis)	Lateral* (RSS of Y,Z Axis)
Ground Operations	±2.0	±3.0
Captive Carry	±2.0	±2.8
Powered Flight	-4.5	±2.3
Coasting and On-Orbit	±0.02	±0.02
Emergency Landing**	±2.0	-4.5

* Referenced to QuickReach™ Coordinate System

** Payload is not required to survive emergency landing, however, it must not pose a danger to the aircraft or flight crew.

Natural Frequency Requirements

The first bending frequency of the payload should be above 25 Hz assuming a fixed base attachment. This will ensure that payload loads and deflections are minimized and will also minimize the potential for coupling of the payload modes with the launch vehicle guidance system. AirLaunch understands that these requirements may be difficult to meet and will work with the customer to recommend practical solutions toward addressing these issues. Should the need arise, AirLaunch can provide a spacecraft isolation system as a non-standard service in order to mitigate the effects of resonant burn excitation.

Random Vibration

For ground launched vehicles, the launch acoustic environment will usually generate the worst-case payload random vibration environment. The acoustic environment excites the launch vehicle external skin panels, which in turn transmit a vibration to the payload adapter cone and thus to the payload. The conversion of acoustic energy into a vibration response at the payload interface is very sensitive to spacecraft mass, geometry and stiffness, requiring a mission-by-mission analysis. The air launch method used by QuickReach™ eliminates the ground reflected acoustic environment, although aeroacoustic levels during the high-α conditions at drop or during Max Q have the potential to result in relatively high vibration levels.

Table 2 and Figure 10 specify the maximum predicted flight random vibration spectrum at the QuickReach™/Payload interface, which occurs during captive carry and Stage 1 operations. The spectrum was derived using the maximum expected acoustic environment, which occurs during Stage 0 operations. The effects of internal blankets and fill effect are included.

To improve mission responsiveness and to minimize requirements on the payload, a commercial flight-proven payload isolation system is available from CSA Engineering as an option.

Table 2: QuickReach™ Maximum Predicted Random Vibration Environment

Frequency Band (Hz)	Acceptance Level
20	0.004 g^2/Hz
200	0.004 g^2/Hz
400	0.004 g^2/Hz
630	0.004 g^2/Hz
800	0.004 g^2/Hz
2000	0.0011 g^2/Hz
Overall:	2.6 Grms
Suggested Duration:	1 min/axis

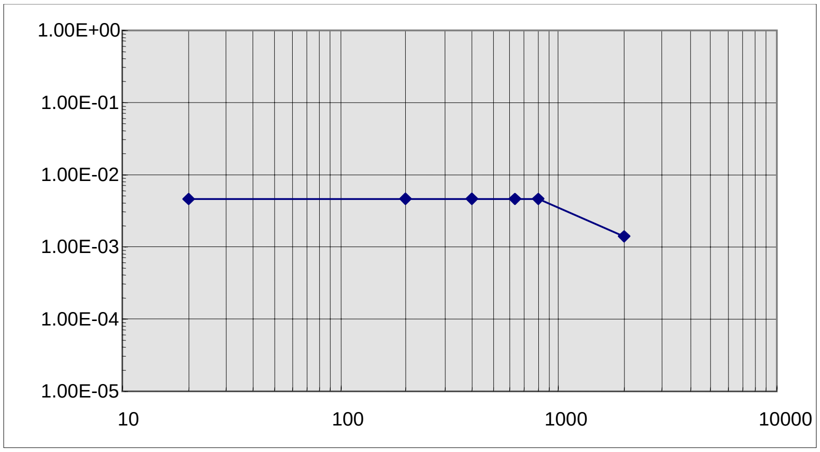


Figure 10: QuickReach™ Maximum Predicted Random Vibration

Acoustic Environment

With conventional ground-launched vehicles, the payload internal acoustic environment is primarily a function of the reflected ground acoustic environment at launch and the aeroacoustic environment near Max-Q. Orbital's Pegasus vehicle has demonstrated that air launch eliminates the reflected ground acoustics and thus dramatically reduces the payload acoustic environment. The worst-case acoustic environment on that vehicle occurs at carrier aircraft takeoff. Unlike Pegasus, AirLaunch's QuickReach™ vehicle is carried internally in the cargo aircraft resulting in a payload internal acoustic environment that much lower than even the 124.8 dB OASPL of the Pegasus vehicle. Also unlike Pegasus, the QuickReach™ vehicle will fly at a near 90° angle of attack for a brief period immediately following extraction from the carrier aircraft. While this high-α flight regime could result in high aeroacoustic levels, the airspeed is extremely low.

Powered flight aeroacoustic levels are expected to be equally benign. Composite honeycomb panels previously fabricated by Delta Velocity have shown a 10 to 30 dB acoustic attenuation from exterior to interior, with the larger reductions coming at the higher frequencies. Fairing internal acoustic levels are dependent on spacecraft geometry (fill factor) and, to a lesser extent, upon acoustic absorption characteristics, and will vary on a payload-unique basis. Fairing interior noise levels for the fairing are expected to be well below 125 dB OASPL during all phases of the mission. The use of acoustic blankets to supplement the attenuation of the fairing shell is not expected to be necessary but blankets are available as an option.

Pyro Shock

Shock inputs to the payload are a function of both source shock level and distance from the payload interface. For separating payloads, this usually means that the payload separation system imposes the worst-case shock levels due to its proximity to the payload. Non-explosive separation systems eliminate pyrotechnic shock sources, but often the majority of the shock source comes from the rapid relaxation of stored energy in the separation system. Motor-driven release systems such as the motorized Lightband system, help mitigate this shock. A typical payload separation system shock environment is shown in Figure 11.

After the payload separation system, the next closest shock sources to the payload are the fairing separation rails and the bolt cutters at the base of the fairing. While pyrotechnic bolt cutters have been baselined, we will assess the shock inputs of these devices and investigate lower-shock alternatives if necessary. The separation rail ordnance is actually a mild detonating cord contained in a steel tube and the pyrotechnically generated shock levels are low. The expansion of the tube and shearing of the rivets holding the fairing halves together is likely the greater shock source, but the fairing base joint will already have released at that point, attenuating the transfer of this shock into the payload cone.

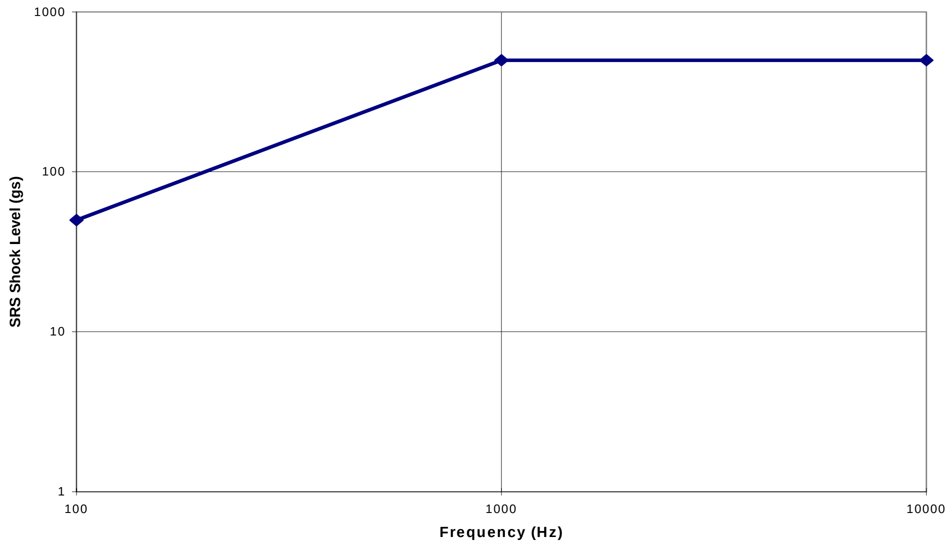


Figure 11: Payload Pyroshock for AirLaunch Provided Separation System

Thermal and Humidity

<u>During Payload Processing</u>

Prior to payload encapsulation in the ECE, payload thermal environments will be maintained by a payload-provided environmental control system. It is assumed that temperature shall be maintained at 65 - 75° F and controllable to ±3° F of the setpoint. Relative Humidity shall be 40-60% and controllable to ±5% of the setpoint.

If an optional payload environmental control system (ECS) is required, AirLaunch can provide a service to maintain the payload environment during and after encapsulation. The portable ECS shall maintain the fairing inlet conditions at a temperature setpoint selectable between 55-85°F and controlled to ±3° F. Dew point temperature is maintained between 38-62°F and relative humidity is maintained at a setpoint between 35-55%, controllable to ±5%. The portable ECS shall remain connected to the ECE during encapsulation and transport. If the ECE is to be placed in storage, a facility environmental control hose will be connected in place of the portable ECS.

Ground Operations and Captive Carry

Upon leaving the payload processing facility or storage facility and for the remainder of ground and captive carry operations, the payload environment will be maintained by the optional QuickReach™ portable environmental control unit (if selected) to the conditions noted in Section 4.3.2.2. The portable ECS is palletized and is loaded in the carrier aircraft along with the SLC and launch vehicle. Payloads that do not select the optional ECS will see ambient temperature and humidity levels.

Payload Power Dissipation

Limits for payload power dissipation at any time following encapsulation will be established and coordinated with the customer.

Powered Flight

During flight, thermal protection coatings on the fairing will ensure that the fairing backwall temperature is held well below 240°F. The bare graphite surface has an emissivity of about 0.92. This value can be tailored if the payload requires by applying foil or other coatings on the interior surface of the fairing.

The fairing is retained in flight until free molecular heating falls below 360 $BTU/ft^2/hr$ (1134 W/m^2), which is equivalent to the solar heating rate that a satellite will receive in low earth orbit. Since the satellite is designed to survive in orbit, no additional analysis or testing is required by this fairing jettison point. Fairing jettison will typically occur at approximately 400,000 ft.

Coast and On-Orbit

During the coast phase between the first and second burns of the second stage and/or prior to payload separation, the QuickReach™ attitude control system can impart a slow roll to the stack to control payload solar heating in the stowed condition. The ACS has the capability of pointing the launch vehicle +X axis at a predetermined angle to the sun and/or initiating a barbeque roll, not to exceed 2 RPM. Coast period thermal maneuvers must be terminated prior to Stage 2 restart.

Cleanliness

The QuickReach™ vehicle, all payload integration procedures, and AirLaunch's contamination control program have been designed to minimize the payload's exposure to contamination from the time the payload arrives at the payload processing facility through orbit insertion and separation.

Ground Operations

The customer-furnished payload processing facility is assumed to be a FEDSTD-209 Class M6.5 (Class 100,000) clean room environment. The QuickReach™ assemblies that affect cleanliness within the encapsulated payload volume include the fairing and the payload adapter cone. The inner surface of these assemblies and the blanket exterior surface are all cleaned and verified to Visibly Clean Highly Sensitive (VC-HS) per JSC-SN-C-0005.

If the optional payload ECS described above is selected, it will be connected to the ECE from payload encapsulation through vehicle lift-off. The fairing and payload cone assemblies are graphite reinforced epoxy composite structures with a total mass loss (TML) value of approximately 0.54% by weight and collected volatile condensable material (CVCM) value of approximately 0.02%. Other materials used within the payload encapsulated environment have an outgassing characteristic of less than 1.0% TML and less than 0.1% CVCM.

Powered Flight

The fairing longitudinal separation joints are contained joints that maintain the Class 100,000 environment throughout the separation event.

Active control of the QuickReach™ second stage both pre- and post-deployment of the payload mitigates risk of undesired contamination or loading of the payload components due to the attitude control engine plumes. Gaseous Oxygen (GOX) is used as the Reaction Control System (RCS) cold gas propellant. Following payload deployment the second stage will perform a C/CAM to ensure that no plume contamination or outgassing from can impinge on the satellite. This is important not only from a contamination standpoint but also to preclude the possibility of a thruster plume impinging on the satellite and causing an attitude change.

Pressure

Ground Operations

If the optional portable ECS is selected, it will maintain positive pressure inside the fairing following encapsulation, providing a minimum airflow rate of 300 ft^3/min.

Powered Flight

If the optional ECS is selected, the payload volume (fairing interior) shall have a positive pressure at QuickReach™ release from the carrier aircraft and shall be vented during ascent. During flight, the maximum fairing pressure decay rate shall be 0.5 psi/sec and the payload volume shall be vented such that the internal pressure at fairing deployment is below 0.2 psia.

Electromagnetic Compatibility

Payload Processing Facility RF Environment

The maximum field strength inside the payload processing facility (PPF) with all doors closed must not exceed 1 V/m during payload encapsulation. The QuickReach™ payload fairing system is RF-opaque. Once the payload is encapsulated, the minimum attenuation through the fairing is
29 dB. The maximum field strength inside the QuickReach™ payload fairing will not exceed 1 V/m.

Integration Site Radio Frequency

The payload must be compatible with the electromagnetic environments at the integration site as will be defined with the customer. The RF environment at the integration site will be controlled to less than 10 V/m.

Payload Deployment Attitude Options

Following orbit insertion, the QuickReach™ avionics subsystem can execute preprogrammed ACS maneuvers to provide a specific payload attitude prior to separation. This capability also allows Stage 2 to independently orient and release multiple spacecraft on a multiple manifest mission. Either an inertially-fixed or spin-stabilized attitude can be provided. The maximum available spin rate for a specific payload will depend on the moment of inertia about the spin axis and the amount of ACS propellant needed for other attitude maneuvers.

OPERATIONS AND PROCESSING

The encapsulated cargo element design allows payloads to be prepared and stored in flight-ready condition for rapid integration with the launch vehicle. A preliminary payload processing timeline has been generated to develop schedule and manpower requirements for payload encapsulation. Payload encapsulation equipment includes a buildup stand to support the adapter cone, handling fixtures and shipping containers for fairing components, encapsulation carts to allow positioning of the fairing halves around the payload, and an ECE handling and rotation fixture for mating the encapsulated payload to the QuickReach™ vehicle.

Mission-specific payload mating and test procedures will be developed by AirLaunch and Delta Velocity in conjunction with the payload provider through the mission integration process. These procedures must coordinate with corresponding procedures created by the payload provider to successfully mate the payload to the adapter and encapsulate it. The actual payload integration, test, and encapsulation process is jointly performed by AirLaunch, its team members, and the payload provider. Responsive payloads should require substantially less integration effort than today's satellites, but the QuickReach™ system is able to accommodate both in an effort to maximize the potential customer base. Payloads requiring a higher level of mission integration effort will incur a non-standard charge for the launch service.

The ECE remains in storage until transport to the staging site is required. If the optional payload environmental control is required, a commercial mobile ECS is attached to the fairing to control payload temperature, humidity, and contamination during storage and prior to launch. The ECS would be installed in the carrier aircraft along with the SLC and would remain connected to the payload at all times prior to release from the aircraft. An ECE handling and rotation fixture allows for aligning and mating to the ECE the launch vehicle prior to installation in the carrier aircraft. A final post-transport health test is performed and the QuickReach™ vehicle is now ready for fueling and aircraft installation.

Payload Processing

AirLaunch's approach is based on the "ship and shoot" philosophy of operationally responsive payloads, in which payload processing is conducted separately and independently from the vehicle. Payload processing may occur at the payload's own facility or at an existing PPF at or near the launch site. The customer can directly integrate the payload into the ECE and present AirLaunch with a fully integrated ECE ready to launch.

Payload Encapsulation

The fairing and payload cone assemblies are delivered to the PPF cleaned, bagged, and installed in their associated GSE. Once inside the PPF, the bags are removed and cleanliness is verified (as required). The payload cone is placed in the PPF to facilitate both payload attachment and fairing installation. Once the payload cone has been positioned, the payload separation system is installed if used. When ready, the payload is lifted from its payload stand using payload provided lifting fixtures, and mated to the payload cone/separation system assembly. Payloads with propulsion systems can be fueled either before mating to the payload cone or after, at the customer's discretion. The payload encapsulation process is detailed in Figure 12.

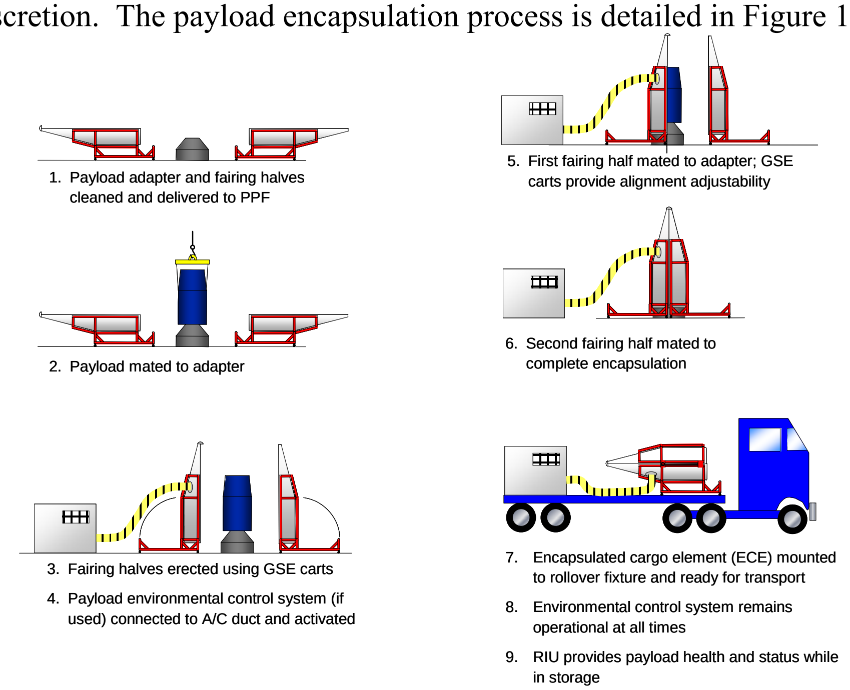


Figure 12: Payload Encapsulation is Decoupled from Launch Vehicle Processing

Following mechanical/electrical mating and any required testing, the payload is ready for encapsulation. The fairing halves are rotated from horizontal to vertical using the rotation and handling carts. If required by the payload, the optional payload environmental control system hose is connected to the first fairing half (the 0° - 180° half, which includes the nose dome and ECS umbilical fitting) and the system is activated. If the optional enhanced cleanliness is exercised, a HEPA filter box is installed in the hose as well. The ECS is allowed to operate for a period of time while to blow out any contamination in the duct as well as to verify proper system operation.

The first fairing half is then rolled into place using the fairing handling cart and the base joint is aligned, as shown in Figure 12. The cart provides vertical and tilt adjustment capability to ensure that the fairing half is properly aligned with the payload cone base ring. Following any final payload operations, the second fairing half is rolled into place, aligned, and the separation rail bolts are installed as shown in Step 6. Aerodynamic covers are installed over the initiation manifolds at each end of the separation rails and the thermal protection layer is touched up as required. Structural attachment of the two halves of the payload handling fixture completes the ECE.

The ECE may remain in this configuration for any length of time until mission call-up. While in storage, a facility ECS replaces the transportable unit. “Y” fittings and gate valves in the hose allow this switchover without the need for disconnecting the ECS. In preparation for transporting the ECE, the transportable environmental control system is reattached. Fairing internal temperature and humidity levels will be controlled using the transportable unit for the remainder of ground operations. The ECE is lifted onto an air-ride trailer, secured, and prepared for transportation to the launch vehicle staging site.

ECE Mating to LV

Integrated processing activities are designed to streamline final QuickReach™ vehicle processing following call-up while providing a comprehensive verification of the payload interface. As described in the previous section, payload processing is conducted independently of vehicle processing. Following encapsulation, the encapsulated payload is moved to a storage facility to await responsive call-up.

The T-0 umbilical is installed to the ECE prior to transport to the flightline. This allows electrical connection of the payload to payload-unique airborne support equipment, if required. The payload ASE will be palletized and will be loaded on the carrier aircraft along with the SLC. Upon call-up, the encapsulated payload and ASE are transported to the staging site. Mating of the ECE to the QuickReach™ vehicle is facilitated by the folding cover on the transport trailer and the ability to roll the vehicle to the end of the SLC. The ECE rotation fixture rotates the payload to a horizontal position and incorporates sufficient degrees of freedom to allow alignment with the avionics skirt. Stray voltage tests are performed prior to electrical mating to verify that the interface is safe to mate.

Following these checks, the ECE-to-LV electrical interface is connected and a final interface verification test is performed in a flight configuration using internal power to verify that payload health was unaffected by the transport and that the ECE is properly connected. Following test completion the ECE is mechanically mated to the avionics skirt and final payload operations, such as arming, occur. The ECE handling and alignment fixtures are removed and the T-0 electrical umbilical and ECS hose are secured to the umbilical tower. At this point the payload is fully mated. The vehicle is now ready for fueling and installation in the carrier aircraft. The payload-unique mission data load is downloaded either from the control station or from the Vehicle Interface Module on the payload. The QuickReach™ system is now ready for launch authorization. This mating process is shown in Figure 13.

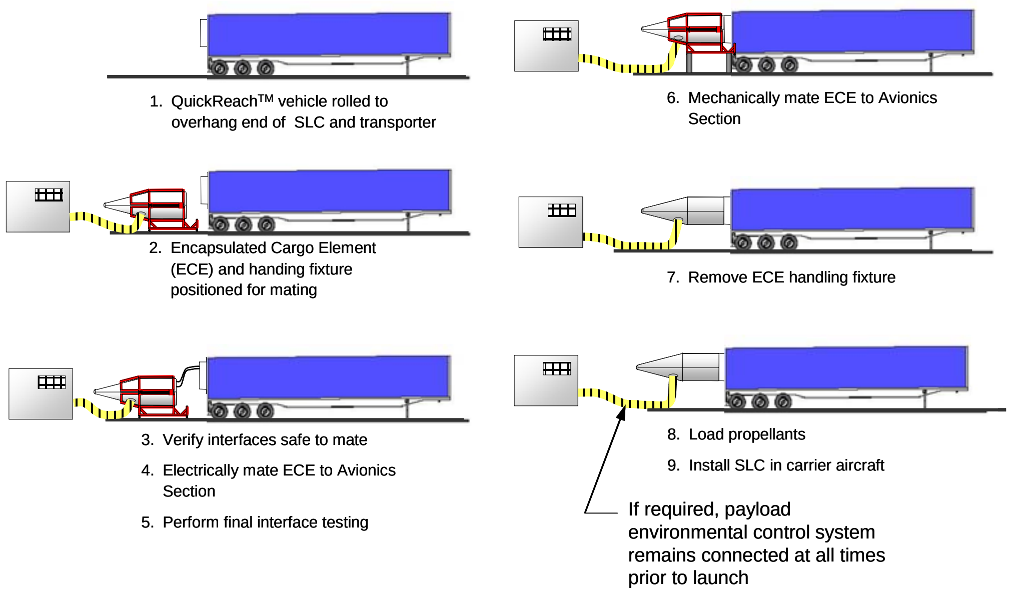


Figure 13: ECE Mate to QuickReach™ Vehicle is Performed Horizontally