WHERE TECHNOLOGY TAKES FLIGHT

SPACE AND RECOVERY SYSTEMS
DELIVERING TECHNOLOGY, INNOVATION, AND SOLUTIONS
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BEST OF CLASS ENGINEERING SERVICES

Delivering Technology, Innovation and Solutions
Airborne Systems engineers bring unmatched technical skills and innovative capabilities to provide deceleration system solutions ranging from submunitions, personnel, cargo delivery, air launch, large spacecraft recovery and aircraft spin/stall recovery systems.

A Systems Approach to an Optimum Solution
Airborne Systems provides the most extensive range of engineering services to enhance the final product.

Fabric Design
Fabric design is central to all of our product development. Our engineers are experts in the design and specification of fabrics including broadcloth, tape, webbing, cords, ropes and coated fabrics. Airborne Systems is also expert in the joining of all classes of fabrics to create efficient structures for these dynamic fabric-based parachute systems.

Our Space and Recovery Systems engineers work with all modern fibers, and constantly track emerging technologies in fibers, fabrics, film, scrims and coatings.

System Engineering
Understanding Customer Requirements
Airborne Systems applies extraordinary levels of system engineering to each project, delivering value to customers from the system engineering process while containing unnecessary costs.

System engineering tools including integrated master schedule/integrated master plan, specification compliance, validation tracking and risk assessment are included in all of our programs.

In addition to the development of internal specifications for fabric, parts and equipment, Airborne Systems engineering process also includes programmatic test plans, test reports, final verification matrices and reports.

More rigorous system engineering programs such as technical performance measurements, risk item tracking/database, and multi-level specification requirements databases are used as required by the size of the program or when directed by the customer.
Predictive Capabilities Unmatched in the Industry

Multiple stress and structural simulation capabilities are an integral part of Airborne Systems engineering services.

Parachute Trajectory Modeling and Simulation

Extensive analysis capability exists within Airborne Systems trajectory modeling and simulation.

- Airborne Systems primary parachute deployment, inflation and trajectory application, Decelerator Dynamics (DCLDYN) has its original algorithm roots dating to the Apollo program. Significant capabilities and validation have been added over the years. Airborne Systems parachute trajectory simulation includes all of the higher order terms of parachute deployment and inflation including:
  - Time dependent parachute drag area, including highly nonlinear responses
  - Parachute mass growth during inflation
  - High order cargo body aerodynamics
  - A variant that assesses vehicle reorientation events
- Modeling of aircraft floor for aerial delivery application, including ramp tip-off simulation
- Inputs for variable atmospheres, Earth or off-planet
- Wind profiles
- Temperature/density variations
- Ejection seat modeling with crew acceleration exposure computations
- Deployment forces such as mortar or tractor rocket
- Landing brake parachute modeling for the aircraft
- High quality parachute simulation for coupling with a customer vehicle
- Development of a trajectory Monte Carlo simulation, implemented as scripts, which provide outer loop execution of the basic DCLDYN application, this capability includes:
  - Primary model inputs which the user can vary, such as:
    a. Parachute drag area
    b. Inflation characteristics
    c. Vehicle aerodynamics
    d. Deployment initial conditions such as airspeed and position
  - Flight atmosphere conditions
    a. Prevailing winds
    b. Density profile
Finite Element Analysis of Metal Parts

Stress and structural linear and nonlinear analysis of metal parts improve designs, reduce costs and shorten time to market for many of Airborne Systems customers. Airborne Systems engineers provide quick and accurate linear analysis and a capability for structural optimization in both topology and topography. Airborne Systems has used this analysis to quickly assess potential improvements to baseline designs. These analysis results, further reviewed in product testing, produced significant results in the optimization of the final design solution.

Airborne Systems expertise also exists in nonlinear analysis of materials and design geometry. Airborne Systems has successfully analyzed load cases with metal parts and their dynamic loading in the parachute deployment train and successfully implemented design changes to compensate for potential load cases.
Airborne Systems engineers can simulate small modifications in canopy size and form to optimize the design and improve performance instead of unnecessary cost and time consuming flight tests.

The ability to visualize the airflow around this personnel parachute provides the designers with a new perspective and the ability to optimize the design.
Fabric Structure and Impact Dynamics Analysis

Airborne Systems capabilities in the analysis of fabric structures and impact dynamics are unmatched. Airborne Systems expertise provides analyses and solutions to large deformations found in both fabric structures and fabric impact dynamics. Airborne Systems is a leader in the analysis of impact dynamics with airbags for landing of aircraft and spacecraft.

In the area of inflated structure design, Airborne Systems has advanced the technique of using quasi-steady results from its explicit Finite Element Analysis (FEA) capability. Airborne Systems engineers can analyze the steady state loading conditions and analyze and manage the challenges associated with large deformations of structures, such as the transition from constructed to inflated shape of a fabric structure.

Fluid Structure Interaction

Airborne Systems couples Computational Fluid Dynamics (CFD) and Finite Element Analysis to create a Fluid Structure Interaction (FSI) analysis capability. Space and Recovery Systems engineers were the first to use FSI analysis for parachute engineering solutions. The purpose of these simulations is to analyze systems where the loading mechanism and the structural deformation are linked and largely inseparable. The parachute is the perfect example of this application. Airborne Systems provides analysis of the shape of the parachute and its interaction with the flow field as it varies with flight condition; yet the flight condition is dependent upon the performance and shape of the parachute.

Airborne Systems work with this analysis includes two primary value-added capabilities:

- The simulation of parachute structures in steady state and transitional flight
- The landing dynamics of spacecraft and other vehicles including fabric structures in a water landing condition

As part of its engineering solutions, Airborne Systems engineers identify, analyze, and correct random glide flight modes of otherwise non-gliding parachute systems.

In the field of water landing, Airborne Systems provides validation analysis comparing landing simulations to test data and can predict landing loads.

Flotation Stability—A Unique Capability

Airborne Systems flotation stability analysis is unique in the industry, providing automated processing of vehicle buoyancy plane and moment. Airborne Systems FloatStab analysis allows the rapid analysis of basic vehicle shape and augmented shapes, with deployed flotation or stabilization devices for planned and emergency water landings. Airborne Systems FSI capability also allows analysis of post-landing static and dynamic performance.
Metal parts and mechanisms are key parts of all recovery systems. These include metal fittings in the parachute structure, servo actuated devices, adaptive structures to interface with the customer vehicle, parachute compartmentation, and integration with pyrotechnic class controls and actuators. Airborne Systems engineers are expert in the mechanical design of these critical components.

Airborne Systems engineers work with a wide range of tools for stress analysis, including linear, non-linear and topology and topography optimization.

**Pyrotechnic Devices**

- **Parachute Deployment Mortars**
  Airborne Systems proven mortar family capabilities range from parachutes of 1 lb or less to parachutes of approximately 185 lbs. The average parachute deployment speed is approximately 120 fps, providing excellent penetration of vehicle wake flowfields and results in high deployment reliability. In the 20 to 100 lb range, multiple mortar designs exist, providing flexibility in designing parachute installation.

- **Parachute Release Cutters**
  Airborne Systems has a wide variety of existing designs for pyrotechnically activated parachute cutters. These are often used for parachute sequencing, such as drogue parachute release, main parachute deployment and spin and stall recovery systems.

- **Inflation Systems**
  Multiple designs are available for the inflation and pressure control of inflatable structures such as airbags.

- **Other Devices**
  Door thrusters, drogue guns and tractor rockets are also part of Airborne Systems design capabilities.

Airborne Systems controllers fly daily in aircraft spin and stall recovery systems for many customers. These systems control both pyrotechnic and servomotor devices. Built-in-test (BIT) systems have both enhanced flight test safety and reduced system maintenance between flights.

In addition, customers can count on Airborne Systems knowledge of recovery system controller design to support their own designs. Our full knowledge of BIT integration and pyrotechnic device safety and testing is available to support our customers’ controller design and development requirements.
PRODUCT TESTING

Airborne Systems engineers are fully versed in all aspects of product testing, from seam and joint element testing to highly complex supersonic wind tunnel testing.

Airborne Systems experience and knowledge base ensures that tests are conducted with the precision required to validate product performance to federal standards.

**Tensile Test**

Airborne Systems computer controlled tensile test machines are capable of testing the lightest sewing threads up to the highest tensile elements. This test capability is also used for parachute seam and joint testing to validate and verify assumptions made in our design analysis process.

**Flight Testing & Qualification of Parachute Systems**

Airborne Systems flight testing and parachute system qualification is unsurpassed in the industry. Our engineers regularly design and conduct parachute flight tests with payloads ranging from 2 lbs up to 6,000 lbs in weight. We can configure any required weight or mass property. Test equipment includes programmer parachutes, time delay cutters and electronic sequencers that enable engineers to conduct testing at the highest fidelity possible.

Airborne Systems experienced team conducts all aspects of aircraft drop testing, including drop zone control, load masters and test jumpers. We also have proven experience working with a number of government agencies in the design and execution of drop tests with payloads up to 42,000 lbs in weight.

Airborne Systems maintains dedicated test and drop facilities in several locations. Typical test measurements include video, photo and on-board instrumentation (loads, pressure, altitude, acceleration and GPS). Design enhancements and modifications are made on-site as part of our continuing product development. Several delivery aircraft are available for parachute testing including Twin Otter, Skyvan, B-25, C-123 and L-39. Test vehicles with a wide range of payloads are available and utilized as part of the parachute test and qualification. Depending on requirements, several drop zones are available with locations in Eloy, Yuma, and Kingman, Arizona and Lake Elsinore, California.

**Airbag Drop Testing**

Space and Recovery Systems engineers are expert in scaled and full-scale testing of airbag landing systems. Local drop test facilities are available for testing of scaled and full scale vehicle models to 6,000 lbs depending on vehicle geometry. Other facilities are available for larger size and weight vehicles up to 42,000 lb weight class and full scale spacecraft/aircraft geometry.

Our engineers are fully versed in the scaling of test results and relevant scaling laws. Airborne Systems has published detailed comparisons between scaled testing and full scale simulation.
Water Landing Systems Testing

Airborne Systems is expert in the testing of water landing systems, including direct entry and airbag landing attenuation for water landing. Space and Recovery Systems engineers are fully conversant in requirements for full scale testing and the application of sub-scale testing for both water entry and post-landing flotation and stability.

Environmental Testing

Airborne Systems conducts a full range of environmental testing of components and recovery systems. Qualification tests include:

- Vibration and Shock
- Thermal
- Vacuum
- Thermal/Vacuum
- EMI/EMC
- Explosive Atmosphere
- Sand and Dust
- Salt Fog
- Rain Environment
- Impact Testing

Acceptance Testing

Space and Recovery Systems engineers are fully versed in the development and execution of acceptance tests for a specific component or part. Tests are developed and reviewed with the customer during program execution. Equally important, the procedures and test articles are typically maintained and updated over the life of the product. A new product that requires additional tests typically results in an update to the acceptance test, resulting in further observation of that product feature for future years.

Installation Testing

As required, Airborne Systems provides detailed installation and checkout procedures. These are often finalized in the field as Airborne Systems engineers complete equipment installation on the aircraft or system. Recovery system installation, checkout procedures, and detailed packing instructions are completed with the operator technicians during a hands-on training process.

Wind Tunnel Testing

Airborne Systems engineers design and operate a wide range of wind tunnel tests ranging from low speed, full size tests in the NASA Ames tunnel through supersonic scale model testing in the AEDC Transonic Tunnel.

Data Collection

Airborne Systems employs the finest data collection and analysis tools. Airborne Systems test vehicles are typically instrumented with field computers collecting multiple channels of data with rates up to 5,000 Hz or higher. A typical instrumented drop will measure 3 axis accelerations, riser loads, pilot/static pressure, vehicle inclination and GPS position and velocity. The drop also includes an on-board camera to film deployment events. Data collected is typically available for review within two hours of the test.
Airborne Systems recognizes that effective program management is one of the key elements required to ensure successful execution of any program.

Our Space and Recovery Systems team is composed of experienced program managers who prepare a detailed report of cost, schedule, and technical performance on a regular monthly basis. This cost, schedule and technical performance reporting can be a method to achieve significant cost improvement.

Airborne Systems routinely utilizes schedule management tools such as MS Project to develop an integrated master schedule and then monitor and track progress. As required, Airborne Systems can provide program control and reporting using an Earned Value Management System.

In addition to tracking against the agreed contract cost, the Airborne Systems program manager regularly reassesses progress against each Work Breakdown Schedule (WBS) item and compares the expenditures against the work completed. This data is presented via Estimate to Complete / Estimate at Complete reports. These data, when combined with the progress tracking and the integrated master schedule allows Earned Value to be assessed and reported.

Airborne Systems has an established supplier base to support its engineering and large-scale manufacturing operations. All suppliers of parts and materials are assessed against Airborne Systems requirements before being entered onto an approved suppliers list.

Configuration Management
Airborne Systems has a well-established configuration management program, documenting over 90 years of parachute design and manufacture. Configuration control is used to manage all changes to design and documentation throughout the life of a product, from the initial release of sketches for sample manufacture to the final technical data package.

Packing and Rigging
Airborne Systems maintains a full parachute rigging and packing capability that includes packing tables, rams for pressure packing and an autoclaving capability.

These capabilities allow pressure packing of decelerator systems to world-class packing densities. Packing tables can be configured to provide a clear run of over 280 feet of table length allowing the largest parachutes to be rigged and packed.
Through its engineering specialists, Airborne Systems delivers a systems approach to launch and recovery system design. Best of class systems solutions include:

**Parachute Deployment Devices**
- Parachute Mortar
- Drogue Gun
- Tractor Rockets

**Parachute Compartmentation**
- Includes Structural Analysis and Testing
- Deployment Bags
- Compartment Door Thrusters
- Parachute Compartment / Container

**Sequence Cutters and Related Controls**
- Servo Mechanisms
- Pin Locks
- Cutters

**Sequence Control Electronics**
- Various Recovery Applications
- Integrated Built in Test
- Well Developed Ground Support Equipment and Manuals
- Timed Cutter Releases

**Recovery of Large and Manned Spacecraft**
- Government
- Commercial

**Full Flight Test Support for Demonstrations**
- Private Drop Zones
- Government Drop Zones
- Test Site Selected for the Application

**Inflatables and Fabric Structures**
- Design
- Fabrication
- Test / Qualification / Acceptance
- Integration
- Inflation Systems

**System Engineering & Analysis**
- Full Support During Concept Development
- Specification Development, Review and Refinement
- Statement Of Work Definition
- The Most Advanced Simulation Tools in the Industry
The Space and Recovery Systems business unit is dedicated to space-based applications and is the world’s leader with respect to Entry, Descent and Landing Systems (EDLS) for manned space flight applications, booster recovery systems, and planetary exploration missions.

Airborne Systems has extensive experience in the design and development of EDLS for various space applications and has the distinction of providing the recovery system for Discoverer 13 (Project Corona), the first man-made item ever recovered from orbit on August 11, 1960. Since that time Airborne Systems has designed and developed EDLS systems for a multitude of manned and unmanned, planetary, and terrestrial space applications.

**MANNED SPACE FLIGHT**

**Multi-purpose Crew Vehicle**

Airborne Systems is supporting the NASA Johnson Space Flight Center (JSC) with the design, development, and qualification of the Orion EDLS. The recovery system consists of three 116 ft modern concept ringsail main parachutes, two 23 ft mortar deployed variable porosity conical ribbon (VPCR) drogue parachutes and three 9.85 ft mortar deployed conical ribbon pilot parachutes.

**SpaceX Dragon Capsule**

Airborne Systems developed the EDLS for the Dragon Crew Capsule; the commercial crew module developed by Space Exploration Technologies (SpaceX). The Dragon EDLS consists of three 116 ft modern concept ringsail main parachutes – and, two 19 ft VPCR parachutes which are mortar deployed.

**Orion Pad Abort 1 (PA-1)**

As part of the Orion program, Airborne Systems supported the Pad Abort 1 (PA-1) test from White Sands Missile Range. This mission was designed to test the Orion Pad Abort System in the event of a launch system mishap. The Orion EDLS for PA-1 consists of three 116 ft modern concept ringsail main parachutes, two 23 ft VPCR mortar deployed drogue parachutes and three 9.8 ft ringslot mortar deployed pilot parachutes.

**Max Launch Abort System (MLAS)**

The Max Launch Abort System (MLAS) is a launch abort escape system for the Orion spacecraft developed to demonstrate alternate approaches to the heritage escape tower concept. The concept was successfully demonstrated in a July 2009 flight test at NASA Wallops Flight Facility. The flight test utilized nine separate parachutes to jettison and recover four system components including the 29,000 lb unmanned Orion crew module. Airborne Systems developed and integrated the parachute systems for the MLAS flight test vehicle for NASA’s Engineering and Safety Center under a rapid demonstration project.

The capsule simulator was then released and two more 27.6 ft conical ribbon parachutes were static line deployed to serve as the drogue stage for the capsule. Finally, the drogue parachutes removed the forward bay cover of the capsule and deployed four 64 ft military cargo parachutes that were modified by Airborne Systems to withstand the flight environment and to fit in the available packing volume.
NASA Pad Abort Demonstrator (PAD)
The NASA PAD program selected the Airborne Systems 156 ft ringsail parachutes as the final descent system for the Orbital SpacePlane-era Pad Abort Demonstrator. This program included a very successful test that was completed in December 2003. The cluster of four parachutes successfully recovered the 25,000 lb test vehicle after release from a C-17 at Yuma Proving Grounds.

Mid-Range UAV Parachute Recovery System
Teledyne Ryan contracted with Airborne Systems for mid-air retrieval of their jet-powered Unmanned Aerial Vehicle (UAV) using a parafoil-based parachute recovery system for the 1,600 lb UAV. The extraction system was initiated by a reefed drogue parachute at speeds of up to Mach 0.9. A time-delayed cutter then transitioned the recovery system from the drogue to a slider-reefed parafoil.

Airborne Systems developed a two-tiered parafoil system, with the lower canopy being large enough to support the UAV and slow its forward velocity to less than 25 kt, and a smaller parafoil connected above the large parafoil and oriented in the same direction. The recovery helicopter was outfitted with a recovery winch system and retrieval hook and this was used to hook the smaller parafoil while the system was in flight resulted in a successful mid-air retrieval.

Boeing Crew Space Transportation (CST-100)
Airborne Systems is providing the spacecraft recovery system for the Boeing Crew Space Transportation (CST-100) spacecraft and on May 2, 2012 completed a series of risk reduction test drops at the Delamar Dry Lake Bed near Alamo, NV. The CST-100 is a reusable spacecraft that uses a demonstrated capsule architecture, as well as proven materials and subsystem technologies. The CST-100 can transport up to seven astronauts, or a combination of astronauts and cargo. Boeing has designed the spacecraft to be compatible with a variety of expendable rockets. The company has selected the United Launch Alliance Atlas V launch vehicle for initial CST-100 test flights in 2015-16.

Pioneer Venus
The Pioneer Venus Probe was one part of a “multi-probe” spacecraft designed to send four probes from a courier “bus” down through the atmosphere of Venus. The probe contained seven science experiments to collect samples and readings about the atmosphere’s composition as it parachuted down to Venus’ surface. Entry forces on the probe exceeded 300g, but the probe performed perfectly, sending data back to Earth until its planned crash into the planet’s surface, less than an hour after it entered the atmosphere. Pioneer Venus EDLS used special materials to survive the acidic nature of the Venus atmosphere.
European Space Agency (ESA) Atmospheric Re-entry Demonstrator (ARD)
The Atmospheric Re-entry Demonstrator was launched on 12 October 1998 on Ariane 5-3, the third Ariane-5 qualification flight. The ARD performed a sub-orbital flight with a maximum altitude of 830 km, and landed in the Pacific Ocean. Airborne Systems designed and built the mortar system, pilot parachute, drogue parachute and the main parachute cluster which flew on the mission. The terminal descent parachutes were a modified version of the 75 ft polyconical parachutes that were designed by Airborne Systems for the Atlas booster recovery system.

Huygens Descent Control Sub-System (DCSS)
Airborne Systems was selected by the DCSS prime contractor to provide design, analysis and manufacturing support in the development of the Huygens DCSS. Airborne Systems manufactured all of the development, qualification and flight models for the program. Airborne Systems also provided test support and developed all of the cleanliness procedures necessary to meet the planetary protection requirements of the program. Airborne Systems was also responsible for the design and manufacture of the wind tunnel models that were tested at the Defence Research Agency Bedford, UK low speed wind tunnel and the Arnold Engineering Development Center (USA) 16T transonic wind tunnel. Huygens completed a successful entry and landing at Titan on January 14th, 2005. The probe and DCSS completed a 9 year spaceflight and 2 hours and 15 minutes of descent through Titan’s atmosphere.

Beagle 2
The Airborne Systems team provided early definition of parachutes and airbags for the Beagle 2 mission and worked to define the first order physics and to understand the challenges involved in the Entry Descent and Landing of this very ambitious mission. Later in the program, Airborne Systems designed, manufactured and qualified a 10 meter ringsail parachute in 4 months to replace the program baseline disc gap band parachute. The main parachute was replaced, to literally double the drag area provided while continuing to meet the weight and volume requirements.

Mars Guided Parachute (MGP) Program
The MGP program was sponsored by the JPL-led Mars Technology Program. Airborne Systems designed the parachute system and developed the control algorithms. The program culminated in one open-loop and two closed-loop high altitude flight tests in Tillamook, Oregon. These tests were very successful and demonstrated that parachute guidance was indeed possible in Mars equivalent environments. The program also used a 10 meter ringsail parachute.

Support Infrastructure
Airborne Systems maintains all the necessary infrastructure to support its projects, including parachute packing / rigging services, on-site equipment installation and user training, ground and flight test capabilities as well as a strong capability in project, configuration and data management.
SpaceX Falcon 1 and Falcon 9
Airborne Systems has developed the recovery systems for all of the SpaceX launch vehicles. This includes the first stage of both Falcon 1 and Falcon 9.

Both systems use a mortar deployed drogue stage followed by a main parachute stage. Falcon 1 lands under a single 75 ft slotted polyconical parachute. Falcon 9 lands under four 116 ft ringsail parachutes. Airborne Systems also provides the deployment mortars, sequence control and parachute systems sequencer.

Boeing Evolved Expendable Launch Vehicle (EELV)
Airborne Systems developed the 136 ft Ringsail for the recovery of a 20,000 lb propulsion module for the Boeing EELV. The 136 ft parachutes were based on the Airborne Systems-designed 85.6 ft F-111 Crew Escape Module parachutes. The parachutes were tested in the single canopy and in the 3-parachute cluster configuration. The canopies exhibited excellent performance in terms of managing opening loads, load share, drag coefficient, and stability.

Demonstration tests off the coast of NASA Stennis demonstrated suitable performance for recovering a Space Shuttle Main Engine.

Kistler K-1
Airborne Systems developed the 156 ft diameter ringsail for the terminal descent phase for both stages of the Kistler K-1 vehicle. The Launch Assist Platform (LAP) weighed 52,000 lbs and employed a cluster of six canopies. The Orbital Vehicle (OV) weighed 27,000 lbs and employed a cluster of 3 canopies. The canopies were extensively tested in the single, 3-parachute, and 6-parachute configurations and exhibited similar drag efficiencies as the EELV class canopies.

Mars Airplane High Altitude Deployment Demonstration 2 (HADD2)
Airborne Systems designed and delivered descent stage and deployment drogue parachutes in support of the Aurora Flight Sciences/NASA Langley Research Center HADD2 balloon flight-test program. This system was based on the Beagle 2 baseline design that flew on the MGP program. The system was extremely demanding in terms of mass budget and required high-fidelity stress analysis to optimize weight and deliver an absolute minimum mass solution that met the extremes of the deployment conditions.
**INFLATABLE SYSTEMS**

**Airborne Systems capabilities include design, analysis, simulation, fabrication, and testing of inflatables and fabric structures.**

We have developed a wide range of inflatable products starting with production of hundreds of thousands of BSU-85 Air Inflatable Retarders in the 1960’s to the recent development of large scale Inflatable Aerodynamic Decelerators (IADs) for NASA. This experience provides a significant capability to design, analyze, develop and fabricate inflatable and fabric structures including IADs for supersonic and hypersonic applications, impact attenuation airbags for space and aircraft applications, flotation and recovery devices for naval applications, inflatable deployable wings for light aircraft, pneumatic muscle actuators, and deployable/transportable structures for a variety of applications.

**Inflatable Aerodynamic Decelerators**

Airborne Systems is heavily engaged in the study, analysis, design and fabrication of large scale IADs, including supersonic and hypersonic decelerators for high mass aerocapture and re-entry for applications including Titan and Mars Landers for NASA. Current activities include NASA-sponsored development of an inflatable 8 meter diameter isotensoid (ballute) for supersonic deceleration and design and fabrication of large scale aeroshells for NASA wind tunnel testing. We also fabricated the 3 meter flight IAD for the NASA Langley Research Center Inflatable Re-Entry Vehicle Experiment (IRVE-3) was successfully launched in the summer of 2012.

**Inflatable Wings**

We have been at the forefront of inflatable wing development for over a decade, starting with the Gun Launched Observation vehicle with an inflatable wing to the DARPA Extended Range Aerial Delivery System (ERADS) with a 28 ft inflatable wing.

**Airbags**

Airborne Systems has been involved in a broad range of airbag programs for both spacecraft landing applications and emergency aircraft crash and landing attenuation including the Orion CEV airbags, the Rapid Inflation Emergency Airbag Landing System for a helicopter, and the Kistler K-1 reusable booster recovery airbags. Our systems can include rapid inflation systems and active or passive venting and we have analysis capability to simulate bag inflation and dynamic interactions during impact.

**Floats**

We have developed several float and recovery devices for naval operations. The floats have extremely low leakage rates and are very durable and have long life in the severe conditions experienced at sea. A subsurface float was developed to support a deployable communication system and a toriodal float device was designed for recovery of the Mk 54 exercise torpedo.

**Pneumatic Muscle Actuators**

The Pneumatic Muscle Actuator (PMA) is designed to decrease in length and increase in diameter when inflated. Retraction strokes of 25% to 35% of the deflated length are achievable based on materials, braid configurations, and pressure. The PMA is currently being qualified for use as a helmet restraint system for military aircraft use. Our PMA design has also been utilized in two successfully demonstrated Natick Soldier Systems Center cargo airdrop programs and a commercial inflatable sailboat batten program for BMW Oracle Racing.
Airborne Systems is the world premier provider of aircraft spin/stall recovery parachute systems.

Airborne Systems

"Airborne Systems has extensive experience and expertise in a variety of applications related to aircraft safety and effectiveness, weapons delivery and delivery of personnel and cargo to the warfight.

Aircraft applications include spin/stall recovery systems for flight test, aircraft escape systems – ejection seat and walk around, and aircraft landing brakes. Weapons systems include decelerators for conventional, submunitions and special weapons. Military systems include gliding and non-gliding personnel parachutes for all class of air drop, as well as conventional and precision cargo delivery systems. Airborne Systems also supports our missile defense systems by providing a number of air launch systems to deliver targets to test missile defense systems.

Aircraft Landing Deceleration Systems

Airborne Systems has provided aircraft landing deceleration systems for a range of different aircraft over many years. Airborne Systems is the designer and the only original equipment manufacturer for F-16 deceleration systems, and continues to build systems for legacy aircraft including the F-5 and B-52.

Aircraft Spin and Stall Recovery Systems

Airborne Systems is the world premier provider of aircraft spin/stall recovery parachute systems. Airborne Systems experience in this field extends for nearly 50 years, starting with the early DC-9 aircraft and continuing through to systems for most of the current major aircraft manufacturers.

Airborne Systems provides complete systems including the parachute system, typically mortar-deployed, the attach / release mechanism (ARM) systems, the cockpit control avionics and support structures. The Airborne Systems team provides ground support equipment including on-site support to the initial installation and rapid response to customer support enquiries.

Spin recovery systems are currently being provided for the F-16, F/A-22, Korean Aerospace T-50, Aermacchi M-346 and the F-35 Joint Strike Fighter, as well as smaller ‘light’ aircraft such as the Cessna Caravan.

Stall recovery systems, typically used to recover ‘T’-tailed aircraft from a deep stall condition, are used by most of the major aircraft manufacturers, including Bombardier, Cessna, Hawker Beechcraft, Embraer, Gulfstream and Honda Aircraft.

Airborne Systems provides a range of parachute systems suited to each aircraft application. These parachutes are combined with the standard ARM, cockpit control systems and ground support equipment. Airborne Systems uses a range of in-house designed mortar systems for parachute deployment.

Weapon Systems

Airborne Systems continues to provide and support many different parachute systems for weapons products. On-going product development programs are focused on the next generation of systems, and Airborne Systems continues to support the existing inventory of equipment, including the Air Inflatable Retarder (AIR) system for the BSU-49/BSU-85 series of weapons.
Aerial Targets
Airborne Systems has been a supplier of parachute recovery systems for aerial targets for many decades, including the original equipment designer for the MQM-107 aerial target. Airborne Systems is the designer and sole source supplier for the Composite Engineering Inc. BQM-167A Air Force Subscale Aerial Target (AFSAT). This system comprises a 9.85 ft conical ribbon drogue parachute and a 62.2 ft polyconical main parachute, and the system is configured to remain as a single element to aid in water recovery and to allow re-use of all significant components. The water recovery system includes an Airborne Systems designed and built parachute flotation system.

As well as supporting legacy systems like the MQM-107, Airborne Systems is working with Composite Engineering to provide reliable parachute recovery systems for the next generation of targets for the US Navy, US Army and overseas applications.

Flight Termination Systems
Airborne Systems has provided a range of flight termination systems for a number of different unmanned vehicles. These flight termination systems are designed to be able to terminate the unmanned vehicle’s flight, e.g. when required to keep a vehicle within a defined test range boundary. Airborne Systems is currently providing and supporting systems for the AGM-86 cruise missile, the NASA X-37 flight demonstrator and for the Korean Aerospace Research Institute’s tilt-rotor unmanned aircraft.

Aircraft Escape Systems
Airborne Systems produces a range of aircraft escape systems for use on ejection seats. These systems are in service on thousands of aircraft around the world. Airborne Systems continues to develop modern design systems intended to allow safe and survivable escape by aircraft personnel over a wider range of weight classes than current systems. These modern systems are being developed for use in the F-35 Joint Strike Fighter and for retrofit into the fleet of existing aircraft ejection seats.

Personnel Parachute Systems
Airborne Systems continues to develop modern high-performance personnel parachute systems. Modern steerable and non-steerable systems are being developed as successors to the current systems, e.g. SF-10A/MC-6, in-service around the world. These parachutes utilize modern planforms to give excellent stability and low rates of descent. The next generation of non-steerable systems (T-11) is in full-rate production and these show significant improvement over the current and legacy systems.

Cargo Delivery Parachute Systems
As the new technology personnel systems allow safe and secure deployment of personnel from lower flying aircraft, Airborne Systems is applying these lessons learned to the next generation of low level cargo delivery systems. These will complement the guided cargo systems that are suited for the high threat environments. Airborne Systems has tested parachutes designed as replacements for the existing in-service G-11 and G-12 systems. These new designs are capable of operation at the same flight conditions as the new personnel systems that are entering service with the US forces.