AIAA SciTech Forum
7-11 January 2019, San Diego, California
AIAA Scitech 2019 Forum

10.2514/6.2019-2100

Technology Demonstration of a 1-ton Single Use Disposable Glider

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The design and flight tests are presented for a low-cost, single-use, autonomous, folding truss-braced wing, glider-based airdrop system. The LG-2K glider could provide aerial delivery of supplies to distributed ground forces. The glider is a technology demonstration system funded by Defense Advanced Research Projects Agency (DARPA) Small Business Technology Transfer (STTR) awards under the Revolutionary Airlift Innovation (RAIN) program. Deployed from a variety of fixed-wing or rotary-wing aircraft including the MV-22, CH-53, or KC-130, each LG-2K glider could provide an affordable, 130 knot airspeed, all-weather resupply method with similar accuracy as low altitude airdrop. These disposable gliders could carry as much as 1,800 pounds of cargo to points of need located over 70 nautical miles away. A landing parachute deployed at low altitude could allow delivery of cargo into urban environments, small clearings, mountainous terrain, or through forest or jungle canopies.

Figure 1. LG-2K RAIN glider released from a Shorts SC-7 Skyvan cargo aircraft.

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I. Introduction

Defense Advanced Research Projects Agency (DARPA) Small Business Technology Transfer (STTR) contracts with Logistic Gliders Inc. support continued work on Logistic Gliders' Revolutionary Airlift Innovation (RAIN) LG-2K glider program to include manufacturing full-scaled prototypes. Six (6) 100% scaled prototype gliders have been built and flight tested using commercial helicopters and cargo aircraft to deploy the gliders. The gliders are disposable by design therefore a new glider must be built for each flight test. Tests include evaluation of (a) loading & carriage onto a cargo aircraft, (b) glider deployment (including glider wing unfold) from a cargo aircraft, (c) glider stability when towed by a helicopter, (d) glider release from a helicopter sling load, (e) autonomous flight control & navigation, (f) glide ratio determination, (g) inflight glider stability & control, (h) glider structural adequacy, (i) belly landing, and (j) parachute landing. Test results were either Satisfactory (Level 1) or Acceptable (Level 2). Future flight tests will involve deploying LG-2K RAIN gliders from military aircraft onto military test ranges under a fiscal year 2019 contract and will be reported later in a future paper.

Logistic Gliders has also been awarded contracts to develop and flight test a different air deployed glider called the LG-1K Tactical Aerial Delivery (TACAD) glider for the U.S. Marine Corps. This glider is smaller than the LG-2K RAIN glider and the results of its development and flight tests will be the subject of a future paper.

II. Background

Logistic Gliders Inc. has designed the LG-2K glider system in response to the requirements for a low-cost, disposable single-use, autonomous, glider-based naval Ship to Objective Maneuver (STOM) logistic resupply system. STOM consists of combined arms operating from over the horizon, with forces moving rapidly to operational objectives without stopping to seize, defend, and build up beachheads or landing zones. The LG-2K glider system supports STOM by delivering logistic supplies without the need for relatively fixed depots located ashore; instead supplies are delivered directly to the point of need. The LG-2K glider can deliver supplies anywhere a parachute airdrop can without endangering the carrier aircraft and the glider does not need an airfield-like landing zone.

The LG-2K glider is a folding truss-braced wing (TBW) glider design with a streamlined fuselage and the glider is designed to be disposed after a single use. Logistic Gliders has reinvented the military cargo glider concept using a novel design, modern fabrication methods, inexpensive materials, and newly available affordable unmanned avionics. The glider is sized to deploy from Marine MV-22B, KC-130, CH-53E, CH-53K; Navy MH-60S; USAF C-130, C-17, CV-22; Army CH-47 & UH-60; and many international fixed and rotary wing aircraft.

Logistic Gliders Inc. is developing gliders to provide the United States with an inexpensive means to accurately deliver supplies at very long offset distances. Rotorcraft operating from ships could lift our disposable gliders either internally or using an external sling and then release the gliders in a Global Positioning System (GPS) guided flight toward their point of need. Gliders could also be carried internally inside fixed winged cargo aircraft. One of the design features is the glider's wings are folded while the gliders are being carried and the wings unfold after the glider is released. Production versions of the gliders are expected to have a glide ratio approximately equal to 15 to 1.

Gliders provide numerous advantages.

For <u>Ground Combat Units</u>:

- Gliders could provide rifle squads located at widely separated points of need with single day sustainment.
- Gliders would not telegraph a ground unit's location like a helicopter or a parachute airdrop might. The glider's small size, low radar cross section (RCS), low infrared (IR), and low acoustic signature all make the gliders difficult to observe.
- Gliders do not further burden the rifle squads by requiring them to bring back glider components.
- Glider resupply would not be stopped by Improvised Explosive Devices (IED) as a ground resupply might.
- Gliders resupply would not be stopped by Air Defense Systems (ADS) as either helicopter or airdrop resupply might. Even if the gliders are shot down by an ADS, the gliders should cost less than the ADS assets required to shoot the gliders down.
- Gliders would be able to operate in all weather conditions including high winds.
- Gliders would be able to deliver supplies anywhere a parachute airdrop can.
- Gliders do not need an airfield-like landing zone.

For the <u>Carrier Aircraft</u>:

- Gliders improve cargo aircraft survivability by providing standoff from ADS.
- Gliders reduce flight hours needed to fly a logistic mission by over an hour, thus reducing aircraft maintenance and increasing the availability of aircraft & flight crew for other missions.
- Gliders could eliminate rotorcraft landing in a landing zone (LZ) – potentially dangerous even in peacetime.

• Gliders save carrier aircraft limited airframe life for future use.

For Amphibious Ships:

• Gliders increase ship standoff distance from shore-based threats such as cruise missiles.

• Gliders improve carrier aircraft's radius of action – e.g., 20% increase for MV-22 missions to a single point of need and more than 50% increase for MV-22 missions to multiple points of need.

• An amphibious ship's Air Combat Element (ACE) could deploy up to 50 gliders an hour because the MV-22 and CH-53 aircraft could carry multiple gliders simultaneously.

For Humanitarian Aid:

• Gliders could transfer humanitarian aid across political borders.

For Logisticians:

• Gliders could greatly outdistance any ground based unmanned aerial vehicle (UAV) designed for cargo logistics since the actual cargo delivery distance is the sum of the carrier aircraft's range plus the glider's range.

• Gliders could bypass shore-based Reception, Staging, Onward Movement, and Integration (RSOI) logistics depots that have been traditionally used to deliver supplies to multiple points of need.

• Gliders could improve the throughput (tons-miles of cargo per hour) for a carrier aircraft. For example, since the MV-22 could carry up to four gliders at a time there are concept of operations (CONOPS) in which the gliders enable one MV-22 to do the job of four MV-22's.

• Gliders could save carrier aircraft fuel – this is fuel that does not need to be transported into the operating theater (for example about 2,300 lb (six 55-gallon drums) for MV-22).

• Gliders stow in standard intermodal (ISO) shipping containers at the point of use and can be assembled quickly using only small hand tools.

For the Taxpayer:

• Glider's innovative design and unique choice in materials and manufacturing methods can make it lower in cost as compared to other precision airdrop systems.

• Gliders could be less expensive for many missions as compared to other means of aerial supply when considering the cost of both the carrier aircraft plus the glider.

• Gliders are always less expensive when the probability of carrier aircraft loss to ADS is considered.

III. Glider Design and Specifications

A summary of the glider design and its specifications are presented here. Further details can be found in Logistic Gliders' 15-page U.S. Patent, US 10,040,549 B2 "Single Use Logistic Glider".

A. Overall Description

The LG-2K glider is a high wing design with a streamlined fuselage and a truss-braced wing (TBW). It has a single horizontal tail with twin vertical tails. The prototype gliders for the RAIN program weigh 400 pounds (lb) empty without the optional landing parachute. The glider is 12.7 feet (ft) long with a 23.2 ft wingspan. An extended range (ER) version has a 27.2 ft wingspan which provides a 14% improvement in glide ratio, but adds 37 lb to the glider empty weight, see figure 2. The glider cargo volume is about 42 cubic ft without the landing parachute installed and 36 cubic ft when it is installed. Payload capacity is up to 1,800 lb. The cost of this glider is envisioned to be comparable to a standard air-dropped Container Delivery System (CDS) due to the similar cost of materials and similar labor hours required for glider manufacture. CDS costs $4,500 to $11,000 a unit, depending upon parachute used, and 90% of all US military airdrops in the last 40 years have used CDS.

The gliders have a plywood fuselage strengthened in key areas by minimal amounts of aluminum. The wings are made using a stock aluminum extrusion as a spar, which is covered with injected molded plastic "panel-ribs". The glider is equipped with an optional landing parachute system that allows cargo delivery into urban environments, small clearings, mountainous terrain, or through forest or jungle canopies. The parachute adds 45 lb to the empty weight.

The first noticeable feature of the glider is its blunt nose, similar to those found on World War II fighter aircraft. Blunt noses have no adverse impact on glide ratio because they have the same drag as pointed noses for the flight speed the gliders will encounter. A blunt nose maximizes the amount of glider volume for cargo and also could allow the glider to be stored on its nose, thus reducing the amount of storage space required. Additionally, the nose contains two layers of honeycomb paper that are used to protect the cargo during landing.

The next design feature is the glider wings fold in a stowed configuration and extend only after release from the carrier aircraft. A static line attached to the carrier aircraft releases the glider's wings from the swept aft position as the glider exits the cargo compartment. The glider wings unfold due to the force from gas springs which are located inside the wing's spar, a patented feature of the LG-2K glider design, thus leaving the glider's fuselage cargo

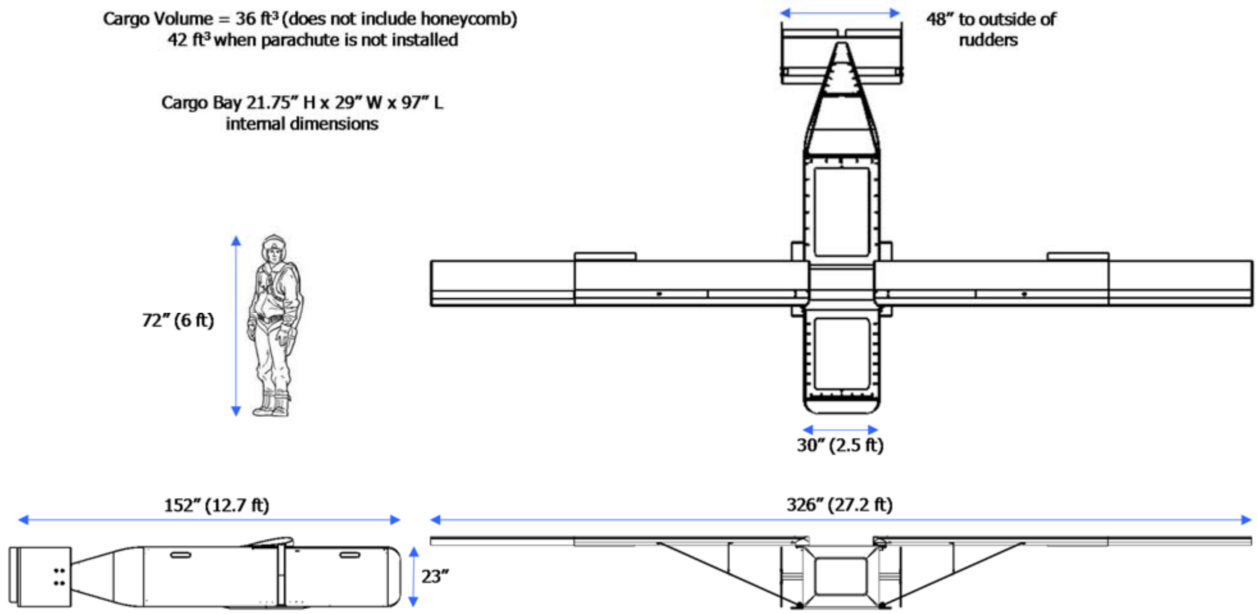

Figure 2. Dimensioned 3-view of the DARPA LG-2K RAIN Glider.

compartment unobstructed for payload. The gas springs take 3 seconds to extend and their opening force is transmitted via a bicycle chain. A wing unfold stop pin brings the wing to a stop after the wing is unfolded and the bicycle chain tension holds the wings open against the stop pin.

The wing span is relatively large since glide ratio increases approximately linearly with the increasing wing span. The LG-2K's large wing span still achieves compact storage by folding its wings and also by allowing the wings to overlap the adjacent glider, see figure 3, when inside a MV-22, KC-130, or CH-53.

The final noticeable feature is the glider's fixed "H" tail. When the glider rolls out from the inside of a carrier aircraft, it will be subjected to large pitch and yaw motions. A glider with a conventional tail configuration may enter a spin. Fortunately, the H-tail is effective at all angles of attacks and all angles of sideslip and as a result aircraft with H-tails are considered resistant to spins. The two vertical fins at the ends of the H-tail also increase the effectiveness of the horizontal tail by about 30%. In other words, a 48 inch (") wide H-tail is as effective as a 62" wide conventional tail. Finally, the most important benefit is that the H-tail is the most compact fixed tail for carriage inside a cargo aircraft since the vertical fins do not project above or below the fuselage.

B. Cargo Accommodation

The cargo compartment's internal volume for the cargo is 97" long by 29" wide by 21.75" high, equal to 36 cubic ft. The volume available to cargo is almost 70% of the entire internal volume of the glider – this is a very high cargo volume fraction. If the parachute is not installed, then another 6 cubic ft of cargo volume is available in the tail cone. To get a sense of the size of the cargo compartment, twenty-four (24) 20-liter (5 gallon) Gerry cans totaling 900 lb with gasoline or 1,100 lb with water could be carried. Another example is thirty-six (36) cases of Meals Ready-to-Eat (MREs) – 432 meals totaling 800 lb could be carried.

The glider can actually carry up to 1,800 lb payload. Heaver weights do not affect the glide ratio, but merely increase the glide speed. The heavier weights also do not affect the empty weight or the structure of the glider. The glider's structure is designed to withstand the aerodynamic loads when the glider is perpendicular to the airstream after it exits the KC-130. It is these aerodynamic loads that size the glider's structure and not the payload weight.

The cargo is loaded via doors located forward and aft of the wing. The forward door is 22" x 28" while the aft door is 22" x 35". Each door is a flat piece of 3/8" thick panel. At 3.7 to 4.5 lb, the doors can be easily lifted and installed by one person. There are several methods to secure the cargo inside the cargo compartment. Options include using straps or netting, Novus or AirSaver biodegradable air cushions, honeycomb paper, foam in place packaging, or bubble wrap.

C. Glider Sizing

The LG-2K glider is sized to fit inside the Marine Corps MV-22B Osprey. This means it could also fit inside the larger aircraft. The MV-22B cargo compartment's allowable cargo length of 250" (out of about 280" actual) determined the length of the glider. The glider's 23" height is such that the stacked height of two gliders are inside the tip-off curve for MV-22 airdrop cargo. The 48" width of the glider's H-tail is set to the allowable width for MV-22 cargo and the 48" width of Container Delivery System (CDS) rails on KC-130.

The MV-22B could carry 2 gliders in a single layer, and 4 gliders in two layers. The MV-22B can execute a vertical takeoff with full internal fuel onboard with up to 5,600 lb of cargo, thus if the MV-22B does carry 4 gliders, the gliders cannot be at their full gross weight of 2,200 lb each if the MV-22 is also carrying full fuel. In addition, the MV-22 cargo ramp is limited to a 2,500 lb airdrop limit. This means the weight of two gliders stacked on each other cannot exceed this weight.

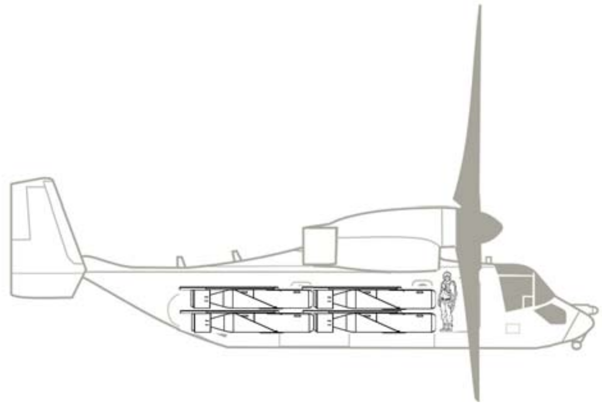

Figure 3. Four (4) DARPA LG-2K Gliders can be carried internally by the MV-22B.

The CH-53E can carry 4 gliders while the CH-53K has a wider cargo compartment so it could carry double the number of gliders, i.e., 8 gliders. The fact that these aircraft can carry multiple gliders makes it possible for the 12 MV-22 and 4 CH-53's in an amphibious ship's Air Combat Element (ACE) to launch 50 gliders in an hour. The KC-130 could carry 6 gliders in a single layer, and 18 gliders in three layers. Finally, the C-17 could carry 42 gliders in three layers.

The glider's 23" height also allows shipping gliders to the point of use inside either 20 ft or 40 ft long intermodal shipping containers (also known as ISO or International Organization for Standardization containers). Twelve (12) LG-2K gliders can fit inside the 20 ft container while thirty-six (36) gliders can fit in the 40 ft long container. The gliders are stacked 4 high and 3 wide. The glider wings, integrated skid board, and tail surfaces are removable. All of these parts are stored inside the fuselage cargo compartment. Thus, the fuselage acts as the glider's shipping container.

D. Glider Manufacture

The glider has a very small parts count – about 400 parts for the production glider (which includes every screw and washer). This compares to World War II era gliders such as the Waco CG-4A, which had 70,000 parts, and modern automobiles, which have over 30,000 parts.

The glider's streamlined fuselage structure is a wooden box made primarily from Medium Density Overlay panel, or MDO panel. MDO is plywood with a weather-resistant resin overlay bonded to the wood by heat and pressure. The overlay, which has at least 27% resin content, resists water, weather, wear and degradation. The cargo floor is made with 3/4" thick MDO, while the sides and top are made from 1/2" thick MDO. The cargo compartment constitutes almost half of the empty weight of the glider and it is designed to protect the cargo during landing.

The top and the bottom sides of tail cone are made from 1/8" thick plywood. In contrast to the cargo compartment, the tail cone is made as light as possible. This is to ensure that the overall glider's center of gravity (CG) is located under the wing's quarter chord point. The quarter chord point is 25% of the wing chord measured from the wing's leading edge. The glider's CG must be close to wing's quarter chord point for lowest trim drag.

The nose cone is made from crushable concrete. The crushable concrete in the nose provides the mass to balance the much longer but lighter tail cone and tail surfaces. In the center of the nose cone are two layers of 3" thick honeycomb paper. The crushable concrete and honeycomb paper crushes during landing and provide energy absorption to protect the cargo.

The LG-2K glider has an integrated skid board located on the bottom of its fuselage. This allows the glider to roll on and mate with the existing roller and rail system installed in the carrier aircraft. The skid board is sized for the MV-22B rail system which ensures that the skid board is always in contract with more than 3 rows of the aircraft rollers. The skid board measures 28" long by 40" wide and is 1.125" thick.

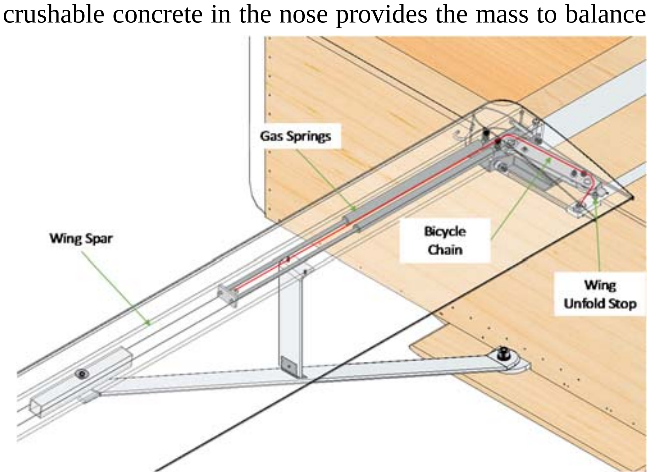

Figure 4. Truss-braced wing is unfolded using two gas springs that pull a bicycle chain.

The wing is divided into two outer wing panels while the fuselage itself provides the remaining span. The wing structure employs a "panel-rib" consisting of mass-produced plastic ribs. The wing is progressively built up by gluing these rib sections over the wing spar. A symmetrical airfoil was selected because it allows the use of the same tooling for both the upper and lower panel-ribs. A symmetric airfoil also has a zero-pitching moment about the quarter chord point which means only a single wing spar located at the quarter chord point can be used. There is no need for a rear wing spar because the center of flexure for the wing coincidences with the center of lift. For the same reason, a symmetric airfoil allows the use of a single wing strut.

The wing spars are inexpensive commercially available hollow rectangular aluminum extrusions with a ¼" wall. The center wing spar is solid piece of aluminum extrusion that is ½" thick by 4" wide. Two inexpensive ($25 retail) gas springs installed inside each wing spar are used to unfold the wings. The gas springs are attached to a standard bicycle chain which transmit the gas spring force, see figure 4. This concept is patented and leaves the cargo compartment open for payload.

The horizontal tail uses the same panel-ribs as the wing. The spar is the same as the wing spar, but with 1/8" thick walls. The vertical tail surfaces are made from 1/2" thick MDO panel.

In order to reduce cost in production, gliders could be left unpainted. In addition to the cost of the paint, painting requires extra labor. The unpainted glider is brown and tan in color and naturally blends in with the ground and should be relatively effective in not giving away the location of a squad of Marines.

The glider can be moved about the ship's flight and hangar deck using lightweight commercial off-the-shelf helicopter ground handling wheels. These wheels are 12 inches in diameter and take only a few seconds to attach and lift the glider. They lift the glider by about 2 inches using an over-center lever that can be operated by one person. The wheels have a very low rolling friction which means one person can push the glider to a desired location even when loaded with payload.

E. Flight Control

The prototype gliders have the following avionics installed: (a) a disposable low-cost autonomous flight controller (FC), (b) a long-range radio control (RC) system, (c) a camera & video transmitter to provide First Person Video (FPV), (d) recording of data onboard the FC, and (e) telemetry (TM) of that data. The TM data is shown on a laptop computer and also on an On-Screen Display (OSD) on the FPV. In contrast, production gliders will have only the disposable low-cost autonomous FC.

The autonomous FC is a custom FC based upon a commercially available FC. The FC has extensive features that include autonomous waypoint navigation. The FC also has flight data recording that includes GPS latitude & longitude, altitude, heading, groundspeed, and airspeed data which is both stored onboard the FC and TM to a laptop computer onboard the carrier aircraft. The RC system in the prototype gliders uses an FCC approved commercially available long-range RC system.

The LG-2K glider uses six electrically actuated control surfaces. On the trailing edge of each wing are ailerons, at the trailing edge of the horizontal stabilizer are two elevators (left and right with a gap between them), and at the trailing edge of both vertical stabilizers are rudders. The surfaces all have the same dimensions of 24" span and 3" chord, thus making them easier to mass-produce. These surfaces are flat sheets made from 1/4" thick plywood.

Since the control surfaces have very small control moments, the servos that operate them can be relatively small. The baseline servos are mass produced commercially available servos used in large 1/4 scale model airplanes and retail for only $13 each. Also, the glider has been proven to be very stable; hence the control surfaces need to move only slightly to maintain level flight. Thus, the battery needed to power the servos is also very small and costs less than $20.

The two moveable rudders can be used to slip the glider, thus reducing the glider's glide ratio. Slipping the glider can reduce the glide ratio by more than 1/3. Direct glide path control by slipping the glider with the rudders allows for flight directly to the point of need, without the need for circling or energy management maneuvers.

F. Landing Modes

There are two options for landing. One option is a belly landing, which is the same method used in World War II gliders such as the Waco CG-4 and in modern sailplanes. Belly landing would require relatively large open areas with smooth terrain.

The 2nd option is an optional parachute that can be installed in the glider that will allow the glider to land vertically on its nose and enables delivery of cargo to any location that a normal parachute airdrop is capable

Figure 5. Parachute Landing uses a GFE Low Cost High Velocity (LCHV) Chute.

of reaching. The glider uses a government furnished equipment (GFE) High Velocity Low Cost (HVLC) chute, see figure 5. The chute can be used for Class I supplies (such as rations and water) and Class II supplies (such as individual equipment, hand tools & maps). These parachutes are designed to be one-time-use parachutes that are disposed of and they are received pre-packed from the manufacturer. The glider deploys the chute about 200 ft above ground level (AGL) and the glider lands nose first. Landing impact is absorbed by multiple layers of 3" thick paper honeycomb located in the glider's nose. The parachute will provide a relatively vertical descent path that could provide precision airdrop to small clearings including confined urban areas with tall buildings (urban canyons), forested areas, canopy jungle, steep ravines, mountainous or hilly terrain, and swampy areas. Delivery accuracy is expected to be similar to any very low-altitude parachute airdrop, i.e., an accuracy at about 50 feet circular error probable (CEP). CEP is defined as the radius of a circle centered on the point of need that contains 50% of the actual landings.

IV. Flight Test Program

Six gliders have been tested to date. Four were released from a helicopter sling load and two were released from a SC-7 Skyvan cargo aircraft. Five were flown using remote radio control and the sixth was flown autonomously by the onboard flight controller. Note that the gliders are disposable, hence a new glider had to be built for each test. Details of these tests can be found in six (6) reports totaling 108 pages. Distribution of these reports are authorized to U.S. Government agencies only. Other requests for the reports must be referred to the Tactical Technology Office (TTO), Defense Advanced Research Projects Agency (DARPA), 675 North Randolph Street, Arlington, VA 22203-2114.

The glider tests were conducted in campaigns because the test locations were different than the location that the gliders were designed and built at.

A. Test Campaign One

The first test campaign was series of ground tests conducted during a 2-day period on 11 & 12 September 2016. A 50% scaled glider was installed on top of a truck mounted test stand that was driven across the El Mirage, California dry lake bed. Tests included evaluation of the (a) wing unfold system, (b) parachute door release, (c) wool tuft testing of the glider's aerodynamics, and (d) pitot-static airspeed system calibration. No noticeable difference in wing unfold dynamics was observed at wind speeds that varied from 0 to 30 miles per hour (mph). The parachute door successfully opened in 3 tests and the door's trajectory was well clear of the glider's tail. No separated aerodynamic flow was observed on the fuselage or wings. The calibration of the pitot-static system was satisfactory.

Figure 6. 100% scaled glider attached to 100 ft sling.

B. Test Campaign Two

Two 100% scaled prototype gliders were evaluated during two flight tests on 9 November 2016 at Spaceport America, New Mexico. The first glider was released in the morning from a Bell 206 helicopter at 1,400 ft AGL, see figure 6. Later that same afternoon, a second glider was released from 3,000 ft AGL. Flight times were 1.90 minutes and 4.37 minutes. After release, the gliders were controlled by remote radio control (RC). The gliders were not equipped with landing gear or a landing parachute, hence belly landings were performed. Tests included evaluation of (a) glide ratio, (b) flying qualities, (c) structural adequacy, (d) glider stability when towed, (e) glider release from helicopter sling, (f) tuft testing of glider aerodynamics, (g) inflight glider stability & control, and (h) belly landing. Tests results were satisfactory (Level 1) or acceptable (Level 2).

C. Test Campaign Three

A 100% scaled prototype glider was evaluated in a series of ground and truck tests over a 4-month period during the summer of 2017, see figure 7. In addition, a 25% scaled model was also tested. The wing unfold system was satisfactory upon the redesign of the wing unfold stop pin. The wing unfold release system and parachute door release system were satisfactory. Data obtained during truck testing was sufficient to understand the parachute deployment dynamics. Sling carriage of the glider with the wings folded was satisfactory with a 3-line suspension. Finally, the glider's directional stability was acceptable.

Figure 7. 100% scale prototype glider on top of a 7-ft high truck mounted test stand.

D. Test Campaign Four

Two 100% scaled prototype gliders were evaluated during two flight tests on 14 & 15 November 2017. The first glider was released from a Hughes MD-500D helicopter at an altitude of 4,520 ft AGL. The next day, a second glider was released from 4,583 ft AGL and its parachute was released at 1,220 ft AGL. Flight time for the 2nd glider was 4.40 minutes. After release, the gliders were controlled by a ground-based pilot via radio control. Tests include evaluation of (a) glide ratio, (b) glider stability when towed, (c) glider flying qualities, (d) glider structural adequacy, (e) parachute landing, and (f) autorotation landing. Glide ratio was measured at 12.4:1 to 14.4:1 depending on analysis method. All tests except autorotation landing were either satisfactory (Level 1) or acceptable (Level 2).

E. Test Campaign Five

A single 100% prototype glider was evaluated on 23 April 2018. The glider was released from a Shorts SC-7 Skyvan aircraft at an altitude of 2,760 ft AGL, see figures 8 and 9. Glider flight lasted 3.20 minutes. Primary tests included evaluation of the loading, carriage, and safe glider deployment (including glider wing unfold) from a cargo aircraft, see figure 8. Additional tests included (a) wing spoiler operation, (b) glider structural adequacy, (c) belly landing, and (d) further evaluation of the glider's glide ratio and flying qualities. All tests were either satisfactory (Level 1) or acceptable (Level 2). A key discovery was the very low accelerations that the glider experienced during the glider deployment from a cargo aircraft – significantly less accelerations than what the glider was designed for.

Figure 8. Glider being loaded onboard SC-7 Skyvan.

F. Test Campaign Six (also known as Risk Reduction Demo 1)

A single 100% prototype glider was evaluated during a flight test at Marine Corps Air Station (MCAS), Yuma, Arizona. The glider was released from a Shorts SC-7 Skyvan aircraft on 22 October 2018 at an altitude of 8,000 ft AGL. Glider flight lasted 7.33 minutes, see figure 10. Primary tests included evaluation of (a) autonomous flight control & navigation, (b) glider deployment from the Skyvan at increased airspeed (130 knots true) and increased glider weight (860 lb), (c) a new concept of operations (CONOPS) of having a Flight Test System Operator (FTSO) onboard the Skyvan rather than on the ground, and (d) remote flight controller laptop computer access. Additional tests included further evaluation of (a) glider loading onto the aircraft, (b) glider carriage onboard the aircraft, (c) wing unfold operation, (d) glide ratio determination, (e) glider flying qualities, (f) glider structural adequacy, (g) parachute landing, (h) ground handling wheels capability, and (i) glider cargo capability.

Figure 9. Glider installed inside SC-7 Skyvan.

V. Future Development and Flight Tests

DARPA has awarded Logistic Gliders a fiscal year 2019 contract to manufacture and flight test 2 to 4 more full-scaled prototype gliders. The overall objective of this contract will be to further mature the technology of the LG-2K glider with the goal is to achieve Technology Readiness Level 7 (system prototype demonstration in an operational environment) by the fall of 2019. The full-scaled prototypes will be ground and flight tested using military aircraft (MV-22 or C-130) to load, lift, and release the gliders. Gliders will be released at full gross weight.

Figure 10. Glider being chased by SC-7 Skyvan.

VI. Summary

The DARPA LG-2K RAIN glider (see figure 11) is a folding truss-braced wing glider design with a streamlined fuselage and the glider is designed to be disposed after a single use. The glider is sized to deploy from numerous aircraft types including Marine MV-22B, KC-130, CH-53E, CH-53K; Navy MH-60S; USAF C-130, C-17, CV-22; Army CH-47 & UH-60; and many international fixed and rotary wing aircraft. The glider features 1,800 lb and 42 cubic ft cargo capacity, and an over 70 nautical mile glide range.

During the 2-year period of the STTR contract six full-scaled prototype gliders were manufactured and flight tested. Flight time totaled at 21.20 minutes. Four glider releases from helicopters were used to evaluate (a) glider stability when towed, (b) glider release from a helicopter sling, (c) inflight glider stability & control including glider flying qualities, (d) glide ratio determination, (e) glider structural adequacy, (f) tuft testing of glider aerodynamics, (g) belly landing, (h) parachute landing, and (i) autorotation landing.

Two glider drops from a Shorts SC-7 Skyvan cargo aircraft were used to evaluate (a) glider loading & carriage onto a cargo aircraft, (b) glider deployment (including glider wing unfold) from a cargo aircraft at increased airspeed (130 knots true) and glider weight (860 lb), (c) autonomous flight control & navigation, (d) further evaluation of the glider's glide ratio & flying qualities, (e) wing spoiler operation, (f) ground handling wheels capability, (g) glider cargo capability, (h) evaluation of a new concept of operations (CONOPS) of having a Flight Test System Operator (FTSO) onboard the cargo aircraft rather than on the ground, and (i) remote flight controller laptop computer access.

Under the a fiscal year 2019 award 2 to 4 more gliders will be manuafactured and flight tested. These are scheduled to be released from a MV-22 or a C-130.

Figure 11. LG-2K RAIN glider.