Modularity Concepts for a 30,000 lb Capacity Ram-Air Parachute

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The U.S. Army Natick Soldier Research Development & Engineering Center (Natick) has contracted Para-Flite, Inc. to design and develop a 9,000 sq ft, low cost, slider reefed, Ram-Air parachute as part of a 30Klb Precision Aerial Delivery System. A primary design requirement for the system is the modularity concept. Under this requirement, all components of the system must weigh less than 250 lbs. A modular canopy has the logistical benefit of ease of material handling and an economic benefit of the replacement of individual damaged sections. The challenge of modular design is to incur minimal disassembly of the system when disengaging the modular pieces. The content of this paper discusses the implementation of the modularity concept to all the primary components of the 30K decelerator system; canopy, lines, slider, and risers.

I. Introduction

The U.S. Army Natick Soldier Research Development & Engineering Center (Natick) contracted Para-Flite Inc. to design and develop a 30,000 lb capacity Ram-Air canopy and deployment system as part of a 30K Joint Precision Aerial Delivery System (JPADS) Army Technology Objective (ATO). Under Natick's direction, the requirements of the Ram-Air (parafoil) design were relaxed, compared to past NASA efforts, since the parafoil was delivering cargo instead of personnel. The modified requirements would result in a more affordable design for the Army. Para-Flite was allowed freedom to experiment with canopy designs and to explore new and novel packing techniques and procedures. The parafoil, designed by JC Berland and Bill Gargano, is a 9,000 sq ft elliptical canopy that is slider reefed. It is the world's largest documented parafoil and has been dubbed the Megafly.

Figure 1: Maiden Flight of Megafly

Large parafoil canopies are known to require significant time and involve considerable complexity during the manufacture, assembly, packing, and recovery of the system. These negative properties of large parafoils are a direct result of increased mass, volume, and number of parts. Natick recognized these drawbacks and established a modular design requirement which restricted the

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maximum component weight to be no more than 250 lbs. This weight limit would ensure that the system could be moved without material handling equipment on the DZ. In addition to the ease of use and handling, the modular construction has an economic benefit, whereby a section that is damaged beyond economical repair can be replaced at the section level, saving 80% the cost of the system.

The Megafly is comprised of approximately 35,000 sq ft of nylon fabric, 4.5 miles of various spectra suspension lines, 560 sq ft of a spectra composite slider, and a suspension line confluence hardware assembly. The combined weight of the materials is 960 lbs. The Nylon fabric used in the Parafoil subassembly is the largest contributor to the system weight.

Figure 2: Canopy divided into 5 Sections

One major challenge in designing the modular concept was to incur minimal disassembly of the system when disengaging the modular pieces. The design selected for full scale manufacture has 5 pie-shaped pieces (Figure 2), the minimum number of divisions necessary to satisfy the 250 lb/section requirement.

The modular design does not disconnect the suspension lines from the canopy or the suspension line confluence hardware assembly. The removal of lines can be extremely labor intensive as the lines are uniquely attached to the canopy and the confluence hardware and have individual operations per line removed / installed. The slider is also modular into 5 sections. Each slider subsection is designed to remain with the corresponding parafoil section. The pairing between the canopy and slider sections serves to maintain continuity and organization of the lines when sections are disconnected.

Figure 3: Three Sections Ready for Joining

Figure 4: All Sections Joined

II. Modularity Concepts

To achieve the desired pie-shaped modularity, connectivity concepts were developed between canopy sections, slider sections, and suspension line confluence hardware sections.

A. Canopy Sections

The canopy sections are joined only at common Line Attachment Points (LAP's) of adjacent connecting cells. Connecting cell LAP's are constructed similar to all other LAP's. The joining of connecting cells between canopy sections is accomplished by installing a soft-link on the LAP of one section and capturing a matching soft-link already installed on the LAP of the adjacent section. A single suspension line then joins to the soft link assembly (Figure 5). Due to the modular design, there is a discontinuity of cross port venting between sections. The lack of cross ports between sections creates a technical challenge to achieve an even, symmetrical inflation of the parafoil.

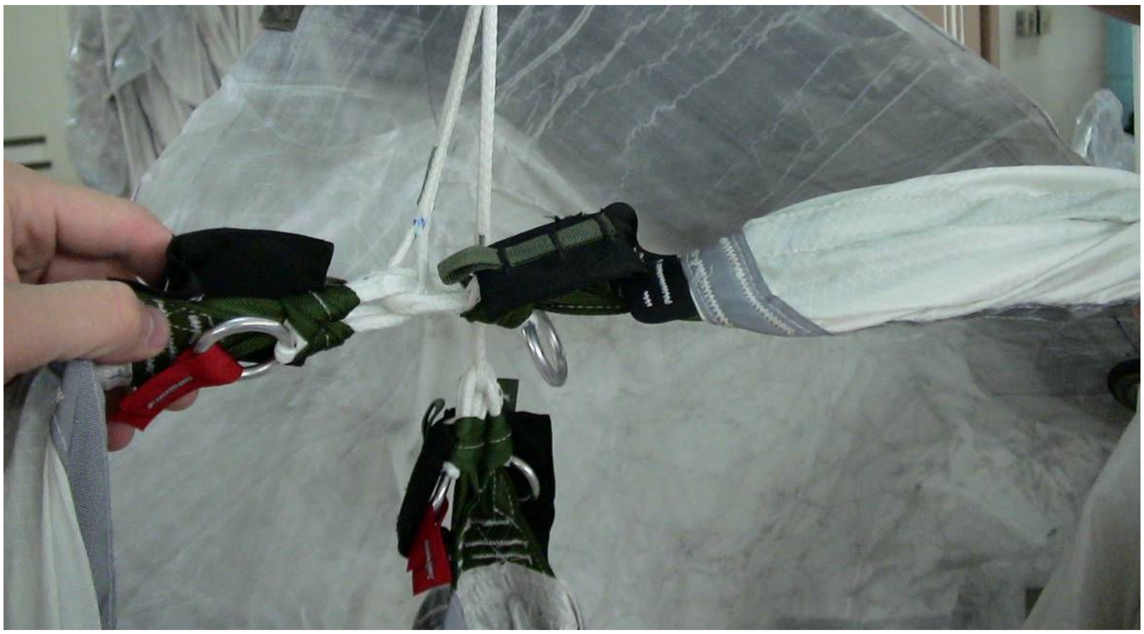

Figure 5: Connecting Cell LAP's Joined Together and to a Suspension Line

B. Slider Sections

The slider for the Megafly is produced from a Spectra composite material to protect the canopy and withstand the high dynamic pressures expected during the early deployment phase. This slider has reinforcements both spanwise and chordwise. Divisions of the slider are chordwise and match the division locations of canopy subassembly. The slider sections are joined only at common spanwise reinforcement locations and are protected with a cover to prevent line interference / contact during deployment.

Figure 6: Slider Connection at Spanwise Reinforcement

C. Suspension Line Confluence Hardware Sections

Instead of risers, a hardware solution was designed to distribute the suspension line load and location of line attachments. The suspension lines belonging to a canopy section pass through the slider section and finally attach to a single confluence hardware section. The confluence hardware sections are then assembled to each other with nuts and bolts.

Figure 7: Single Confluence Hardware Section

Figure 8: Five Confluence Hardware Sections Assembled w/ Lines Installed

III. Assembly and Recovery

The time to assemble the canopy sections together is approximately 24 man hours completed in 1.5 days, and the time to disassemble on recovery is approximately 4 man hours completed in 1 hour. Figure 9 shows the canopy sections being disconnected and prepared for vehicle pick-up.

Figure 9: Five Sections Ready for Pick-up

IV. Deployment and Opening

Depending on the aircraft and payload weight, the Megafly system is extracted from the aircraft with either one or two 28-ft extraction parachutes. Aircraft velocity can be up to 150 KIAS. After payload tip off, the extraction parachutes release from the Extraction Force Transfer Coupling device and then serve to deploy the parafoil with zero-delay. The initial inflation forces are taken by the slider. After a period of time, the canopy begins to pressurize. As the canopy spreads, the slider is forced down the suspension lines, allowing the parafoil to take flight. A significant achievement of the Megafly deployment system is that no pyrotechnic cutters are required to disreef the parafoil or to release the deployment brakes. The slider design is pressure driven and the deployment brakes are released by the Airborne Guidance Unit.

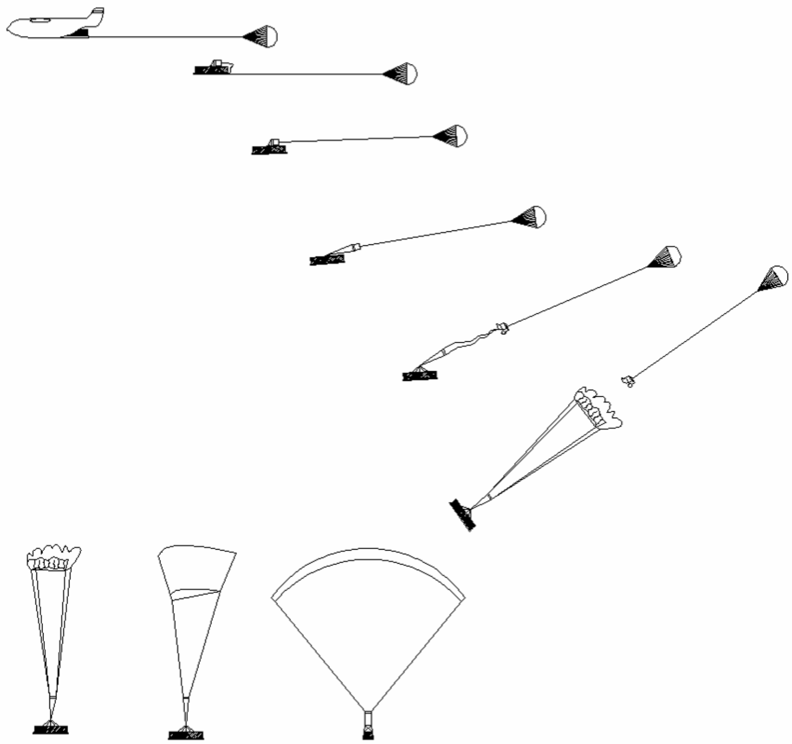

Figure 10: Deployment Sequence Illustration

As of May 1, 2007, the Megafly system has been successfully flown 3 times at Yuma Proving Ground, Arizona. On each drop, the Megafly was commanded by remote control for the entire flight. Autonomous flight is anticipated in May 2007. The Megafly system has demonstrated deployment and flight at 25,000 lbs from 18,000-ft MSL. The system will be tested at its designed operating weight of 30,000 lbs at an altitude of 25,000 MSL in 2007.

Figure 11: Megafly with Slider in Up Position

V. Summary

The successful deployments, inflations, and in-flight performance and navigation of the Megafly have validated the feasibility of Large Ram-Air modularity. Additionally, the inflation characteristics of individual Parafoil sections without cross port venting was demonstrated to be a viable concept for canopies of this size.

As a result of lessons learned during the Megafly project thus far, future advancements of modularity technology were opportunistically identified. Future modularity concepts for Large Ram-Air's will include connectivity designs that enable rapid rigging and de-rigging between sections and reduced complexity of assembly operations. As these modularity concepts mature and become more reliable and economical, they are expected to find their way into smaller versions of Ram-Air cargo systems. The logistical benefit of increased system service life, realized by offering the replacement of sections damaged beyond economical repair, would be a desirable quality for any delivery system.

References

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