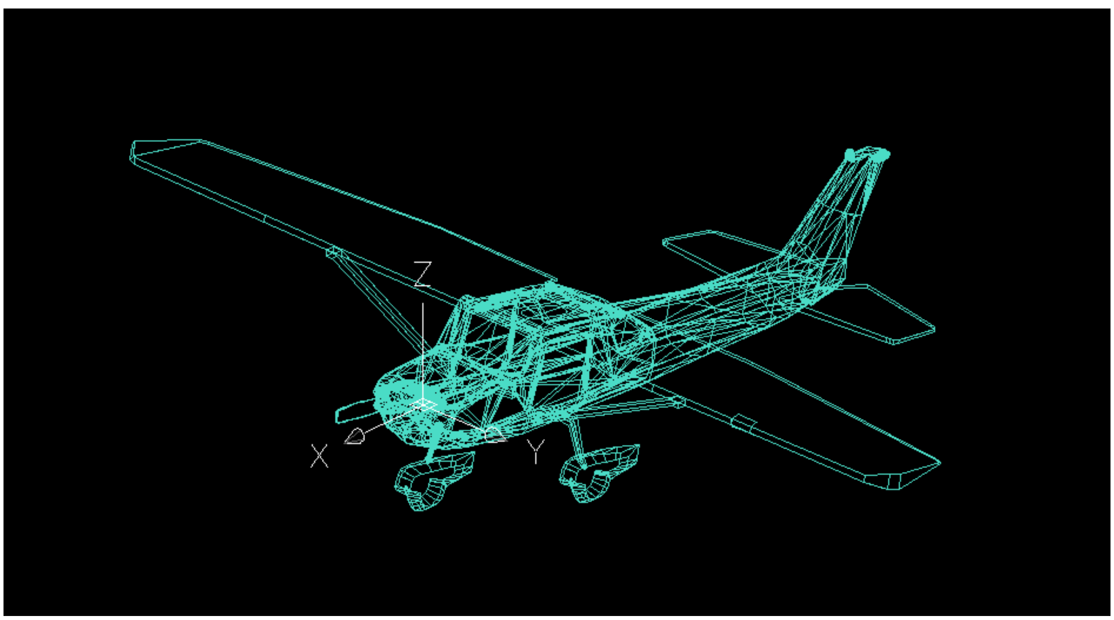
FY 2008 Progress Report
July 2009
Project No. THOM-08

Protective covers for aircraft, land vehicles and ground structures

Project Team:
Leader: Gwynedd A. Thomas
Team members: 1 Masters student (Vladimir Quinones Silva; **hired 18 August 2008**)
1 PhD student (Houmin Li; **hired January 8, 2009**)
Email: gat0001@eng.auburn.edu Phone: 334-844-5461

Objective:

A reasonable and logical device for protection of exterior aircraft or other vulnerable surfaces from ice formation, wind, blowing sand or falling hailstones is a cover, designed from a combination of appropriate polymer materials. A very novel approach for such a cover could consist of an individual inflatable/deflatable blanket system of a design, configuration and size to completely cover exposed surfaces of a flight vehicle, ground vehicle or ground structure. Our purpose in the research proposed herein is to determine and test a basic design to most effectively perform these and other requirements such as light weight and low storage volume to stow the material in an aircraft or ground vehicle. We also propose to design the optimized device for easy deployment and adjustment when placing it over the vehicle or ground unit. (Figure 1.)



General characteristics

- Crew: 1
- Capacity: 3 passengers
- Length: 27 ft 2 in (8.28 m)
- Wingspan: 36 ft 1 in (11.0 m)
- Height: 8 ft 11 in (2.72 m)
- Wing area: 174 ft² (16.2 m²)
- Airfoil: NACA 2412 (modified)
- Empty weight: 1,620 lb (736 kg)
- Useful load: 830 lb (376 kg)
- Max takeoff weight: 2,450 lb (1,113 kg)
- Powerplant: 1× Lycoming IO-360-L2A flat-4 engine, 160 hp (120 kW) at 2,400 rpm
- ■ Zero-lift drag coefficient: 0.0319
- Drag area: 5.58 ft² (0.52 m²)
- Aspect ratio: 7.32
- Lift-to-drag ratio: 11.6

■ Wing loading: 14.1 lb/ft² (68.8 kg/m²)
■ Power/mass: 15.3 lb/hp (9.25 kg/kW)

Performance
■ Never exceed speed: 163 knots (187 mph, 302 km/h)
■ Maximum speed: 123 knots (141 mph, 228 km/h) at sea level
■ Cruise speed: 122 knots (140mph, 226 km/h)
■ Range: 610 nm (790 mi, 1,272 km) at 55% power at 12,000 ft (3,040 m)
■ Service ceiling: 13,500 ft (4,116 m)
■ Rate of climb: 720 ft/min (3.7 m/s)

Figure 1. Cessna 172, the intended aircraft for cover design prototype

Proposed solution design:

The bottom layer of the protective cover may be inflatable/deflatable with a layer of soft material suitable to protect an aircraft or other damage prone surface.

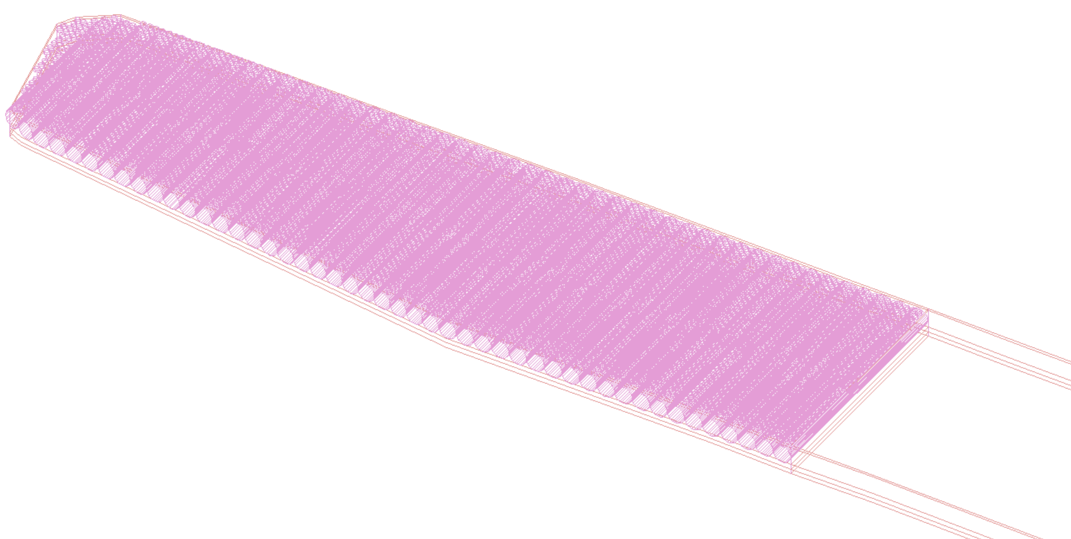
Progress to date: We have modified this part of the concept based on the suggestions and practical experience of Dr. Thomas. Her approach is to have an innermost (or bottom layer) that is static dissipating and electrical spark inhibiting. Cold weather can exacerbate the occurrence of static discharge spark generation where certain polymeric materials are in contact with polymer film paints and where a high dielectric constant exists between the two surfaces. Removal of the aircraft cover in those or similar conditions can cause a dangerous spark near fuel tanks that could result in an explosion.

The middle layer or layers of the cover could be designed so they have numerous individual air or air-and-fiber filled pockets within the structure as shock absorbing and/or temperature insulating layers. The number of rows and layers within will be determined to protect an aircraft, vehicle or structure from damage from hail and other foreign objects striking it.

The outer layer of the cover is a part of the concept that was not originally considered critical, but based on Dr. Thomas' recommendations, we have expanded the concept to include a lightweight layer of highly reflective material to allow for greater protection in extreme heat environments such as the desert. (Figure 2)

Cover Design (unit in inches)

Perspective view



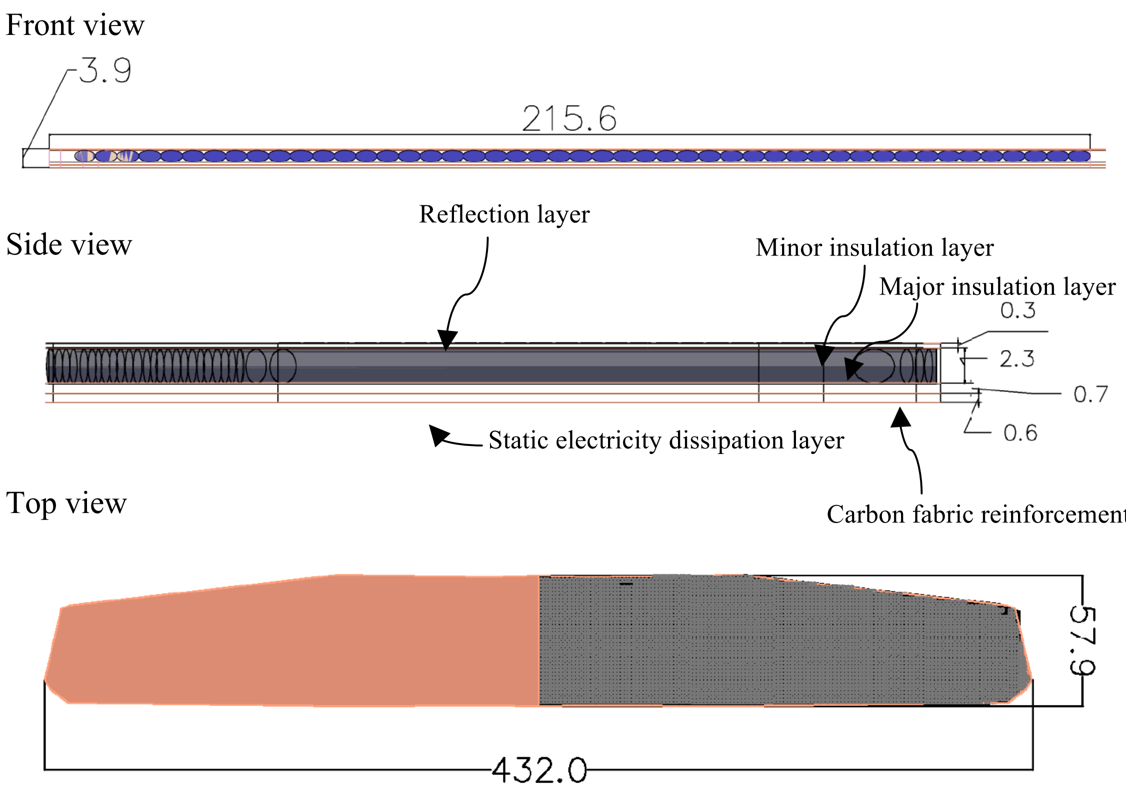


Figure 2. Depictions of multilayer protective cover design (units in inches)

Our total plan of development and testing consists of numerous required steps, many of which have been completed already. Those steps are as follows:

<u>Step I (Characterization of layers)</u>

1. Base layer requirements:
    a. Light
    b. Folding/Bending compliant (crease/ bending recovery)
    c. Static charge resistant
    d. Flame resistant

Material candidates: 50% Kevlar and 50% Carbon Fiber
100% Carbon Fiber

2. Outside layer requirements:
    a. Light
    b. Folding/Bending capable
    c. Light reflective
    d. Infrared/heat reflective

3. Inner (air pockets) layer requirements:
    a. Light
    b. Folding/Bending *by segmentation*
    c. Burst/rupture resistant
    d. Minimum strength and elongation requirements to be determined
    e. Air or specific gas filling capability

Step II (Characteristics of composite)

1. How to seal the structure
2. Will it still pass all the test in step I
3. Impact absorbing?

Step III (Field Test)

1. Fit to airplane
2. Testing to be conducted at Auburn Aviation

To this end we have performed research into this requirement in the following manner:

Inner (base) layer

1- We have collected various representative aircraft parts with the help of Auburn University Aviation Department that will allow us to measure dielectric constants of various polymeric materials against both painted surfaces (aircraft grade acrylic paints) and unpainted aircraft aluminum.

2- We procured samples of seven promising base material samples for the experiment, including

a- 100% woven polytetraflourethylene (Teflon® brand) fabric
b- 100% stitchbonded carbon fiber fabric
c- 50% carbon fiber / 50% aramid (Kevlar® 49 brand) stitchbonded fabric
d- 100% woven Kevlar
e- TempShield™ Single Bubble/Double Foil
f- TempShield™ Single Bubble/White Foil
g- Aluminum double
h- Aluminum single

3- We have conducted vertical flame resistance testing in a fire chamber by Standard Test Method for Flame Resistance of Textiles D 6413.

a- The 100% PTFE fabric failed the test with a > 1" char and melt pattern upon exposure to open flame for 20 seconds. Considerable smoke generation accompanied the charred sample.
b- The 100% carbon fiber fabric exhibited no damage and minor smudging from the flame
c- The 50/50 carbon/aramid blend exhibited nearly the same result as the carbon fiber sample, but more smudging and a small amount of charring could be observed
e- Burned for 6 seconds before extinguishing
f- Burned completely
g- Partially burned for about 4 seconds
h- Partially burned for about 7 seconds
A combination of Materials e and g together did not burn
A combination of Materials f and h together burned completely
A combination of Materials e and h together burned for 2 seconds before extinguishing

4- We researched the databases of ASTM standards for measuring static dissipation and dielectric constants and found no relevant methodologies apply to this end use.

5- In collaboration with the department of Electrical Engineering (Auburn University), we have been able to obtain the use of a static measuring device and initiated testing of the inner (base) layer of the composite structure. The 100% PTFE fabric was eliminated from the testing because it had failed the flame test (above).

The prepared sample was attached to a buffer, and the buffer rubbed at high rpm against the painted and unpainted aircraft's surface. Then, using an electrostatic voltmeter, the aircraft's surfaces electrostatic were measured. Results are shown in Table 1 and materials are referenced according to the letter designation in item 2 above.

Table 1. Electrostatic Charge of Materials Tested (volts or potential)

	Painted Aircraft Aluminum			Unpainted Aircraft Aluminum		
rpm	Material b	Material c	Material d	Material b	Material c	Material d
1330	-21	-8	-40	-17	-7	-25
2330	-22	-20	-28	-22	-6	-26
2980	-10	-50	-42	-16	-29	-36

The rest of the materials will be tested using the same method.

Outer layer
The most critical characteristics of the outer layer will be light and heat reflectance and tear and puncture resistance after multiple occurrences of folding.
Progress to date: Material samples were ordered and received from two different suppliers for evaluation. One of the materials was thin, light and flexible enough to meet the bending and recovery requirement and pass reflectivity tests required for the concept.

Middle layer
The inflatable middle layer is a highly critical step because of the difficulty of producing a damage free, compartmentalized structure that can be deployed and reused in daily operating conditions.

Progress to date: Cocoon Corporation, subcontractor on this project for materials consolidation and procurement, has entered into negotiations with aircraft shelter manufacturers and with Winnebago for samples of the final, consolidated product. Current reports from them confirm that Winnebago is the likely supplier of the processes and product we require.

Combined layers and weight
By measuring each sample's weight, dimension, and the knowing the area of the airplane, It can be predicted the total mass of the aircraft's protective cover depending on the combinations of the materials are being used. (Table 2.)

Table 2. Properties of Materials Tested

Material	Thickness (mm)	Area (m^2)	Weight (g)	(g/m^2)
b	0.783	0.020450	9.136	446.7183
e	4.317	0.023978	4.267	177.9547
f	3.244	0.024345	3.785	155.4728
g	0.179	0.023146	2.959	127.8417
h	0.387	0.021912	2.111	96.34

Outreach to Industry and Target Market:
Our materials supplier and procurement source is a start-up operation in the aircraft covers industry. We are in very regular contact with the president and owner of the company for input, idea validation and for purchase of materials and/or fabrication of test designs in the proposed project. Winebago is confirmed as the most likely primary supplier of the finished product. Contact has been established and further input is being obtained from United States Army Soldiers Systems Labs, Natick, MA (7-14-2009)