

**Level 3 Certification Project – May 24, 2008**  
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Project name: Apparent Motion

Advisors: Kent Newman  
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**Concept:**

This Level 3 certification project consists of a 6-inch diameter G10 fiberglass airframe, capable of accommodating up to 98mm M-impulse+ motors. It is a 3-fin booster design, with lower and upper payload sections for drogue and main chute recovery gear. Topped with a 5:1 conical nose cone, giving the rocket an overall length of 103 inches. Dry weight, including recovery gear and electronics, rounds out at ~446 ounces (27.8 lbs.).

Certification motor: Aerotech M1315W  
Projected Max Alt: 7300 ft. AGL (simulated)  
Drogue deployment: Apogee  
Main deployment: 1300 ft. AGL

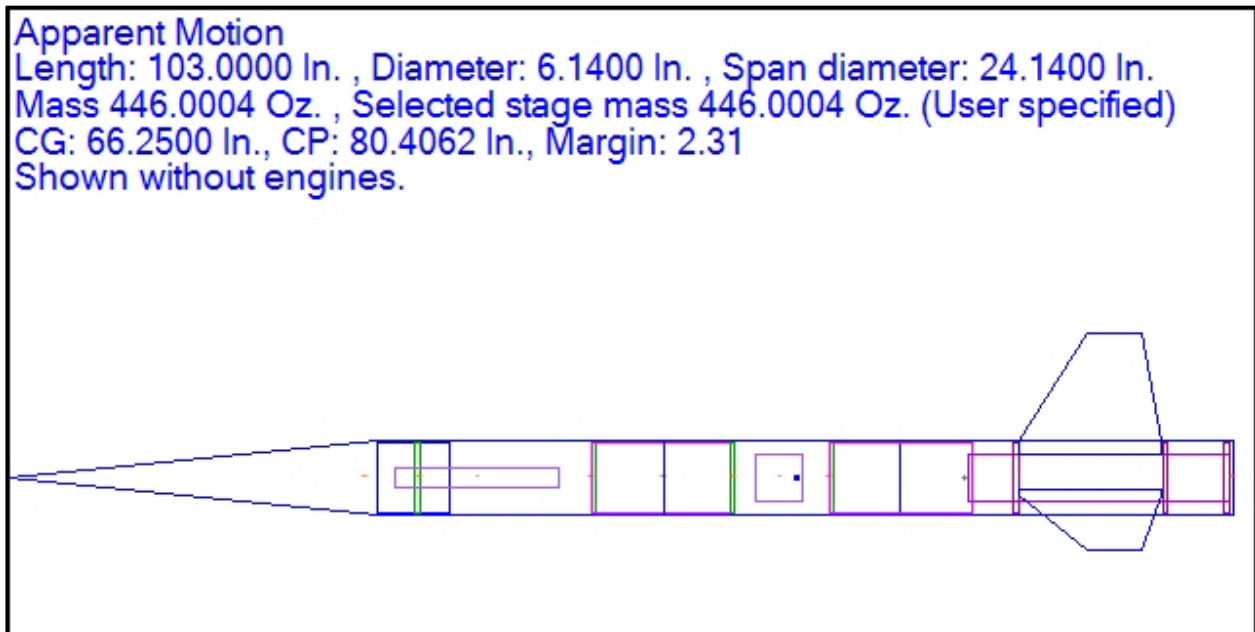


Fig. 1 – Dry weight

**Apparent Motion**  
 Length: 103.0000 In. , Diameter: 6.1400 In. , Span diameter: 24.1400 In.  
 Mass 645.1149 Oz. , Selected stage mass 645.1149 Oz. (User specified)  
 CG: 72.6551 In., CP: 80.4062 In., Margin: 1.26  
 Engines: [M1315W-None, ]

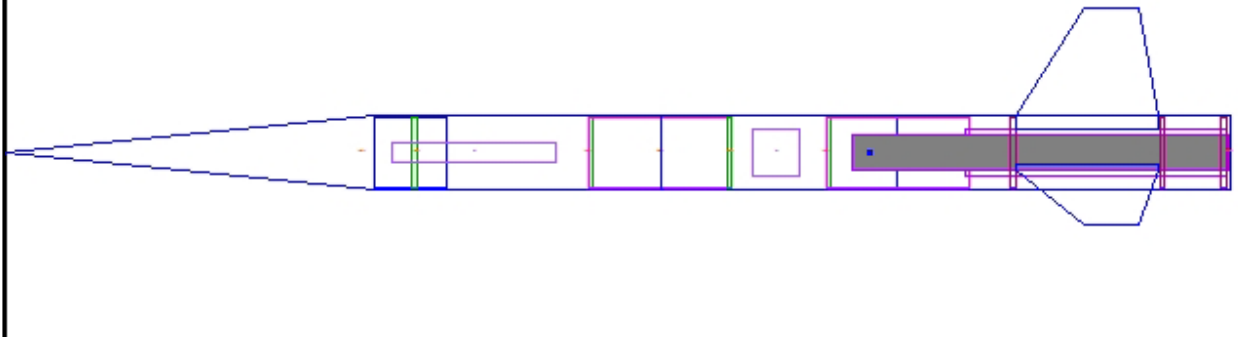
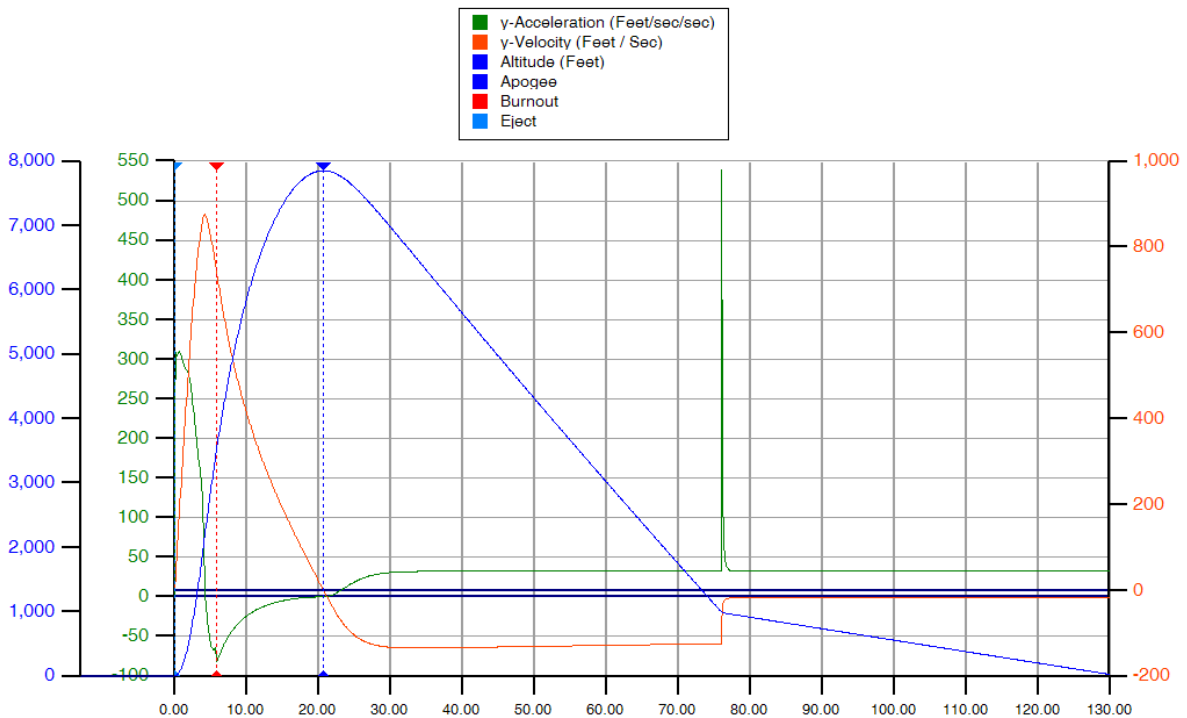


Fig.2 – Loaded weight (M1315)

**Preliminary flight simulation data:**

Center of pressure: 80.4 inches from nose (Rocksim V8.01)  
Center of gravity: 72.6 inches from nose (Rocksim V8.01) [Loaded with motor]  
Mass at liftoff: 40.3 lbs. (Rocksim V8.01)  
Total impulse: 6645 N-Sec.  
Burn Time: 5.95 Sec.



## Launch guide data:

- Launch guide length: 96.0000 In.
- Velocity at launch guide departure: 65.8911 ft/s
- The launch guide was cleared at : 0.301 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 44.1161 In.

## Max data values:

- Maximum acceleration: Vertical (y): 1518.433 Ft./s/s Horizontal (x): 3.809 Ft./s/s Magnitude: 1518.433 Ft./s/s
- Maximum velocity: Vertical (y): 875.7196 ft/s, Horizontal (x): 10.1018 ft/s, Magnitude: 876.5459 ft/s
- Maximum range from launch site: 457.37211 Ft.
- Maximum altitude: 7852.20431 Ft.

## Landing data

- Successful landing
- Time to landing: 128.729 Sec.
- Range at landing: 437.65285
- Velocity at landing: Vertical: -18.7266 ft/s , Horizontal: 6.5344 ft/s , Magnitude: 24.1469 ft/s

## Component descriptions:

### Nose cone:

Type:	Performance Rocketry fiberglass
Shape:	5:1 Conical
Length:	31.000 inches
Shoulder:	6.000 inches

### Upper airframe (main payload) tube:

Type:	Performance Rocketry G10 fiberglass
Outside diameter:	6.145 inches
Inside diameter:	6.000 inches
OAL Length:	24 inches

### Main recovery:

Chute type:	Skyangle Cert3XL with pilot and deployment bag
Chute size:	96.000 inches
Harness:	1.000 inch tubular nylon x 25 ft. long

### Avionics Bay:

Type:	Performance Rocketry G10 fiberglass
Outside diameter:	6.000 inches
Inside diameter:	5.900 inches
Length:	12.000 inches

Bulkheads: 0.125 inches G10 thick x 6.000 inches DIA  
backed with 0.250 inch birch recessed inside coupler.

Flight computers:

Primary: Perfect Flight HA45K  
Backup: Perfect Flight MAWD

Switches:

Flight computers: Missileworks rotary type  
Deployment charges: Missileworks rotary type

Midship airframe (drogue payload) tube:

Type: Performance Rocketry G10 fiberglass  
Outside diameter: 6.145 inches  
Inside diameter: 6.000 inches  
OAL Length: 20 inches

Drogue recovery:

Chute type: Sperrachute with spill hole  
Chute size: 30.000 inches  
Harness: 1.000 inch tubular nylon x 25 ft. long

Aft coupler:

Type: Performance Rocketry G10 fiberglass  
Outside diameter: 6.000 inches  
Inside diameter: 5.900 inches  
Length: 12.000 inches  
Bulkheads: 0.125 inches G10 thick x 6.000 inches DIA  
backed with 0.250 inch birch recessed inside coupler.

Fincan airframe tube:

Type: Performance Rocketry G10 fiberglass  
Outside diameter: 6.145 inches  
Inside diameter: 6.000 inches  
OAL Length: 28 inches

Motor mount:

Type: Performance Rocketry G10 fiberglass  
Size: 98mm  
OAL Length: 20 inches  
Centering rings: 3x 0.125 G10 fiberglass

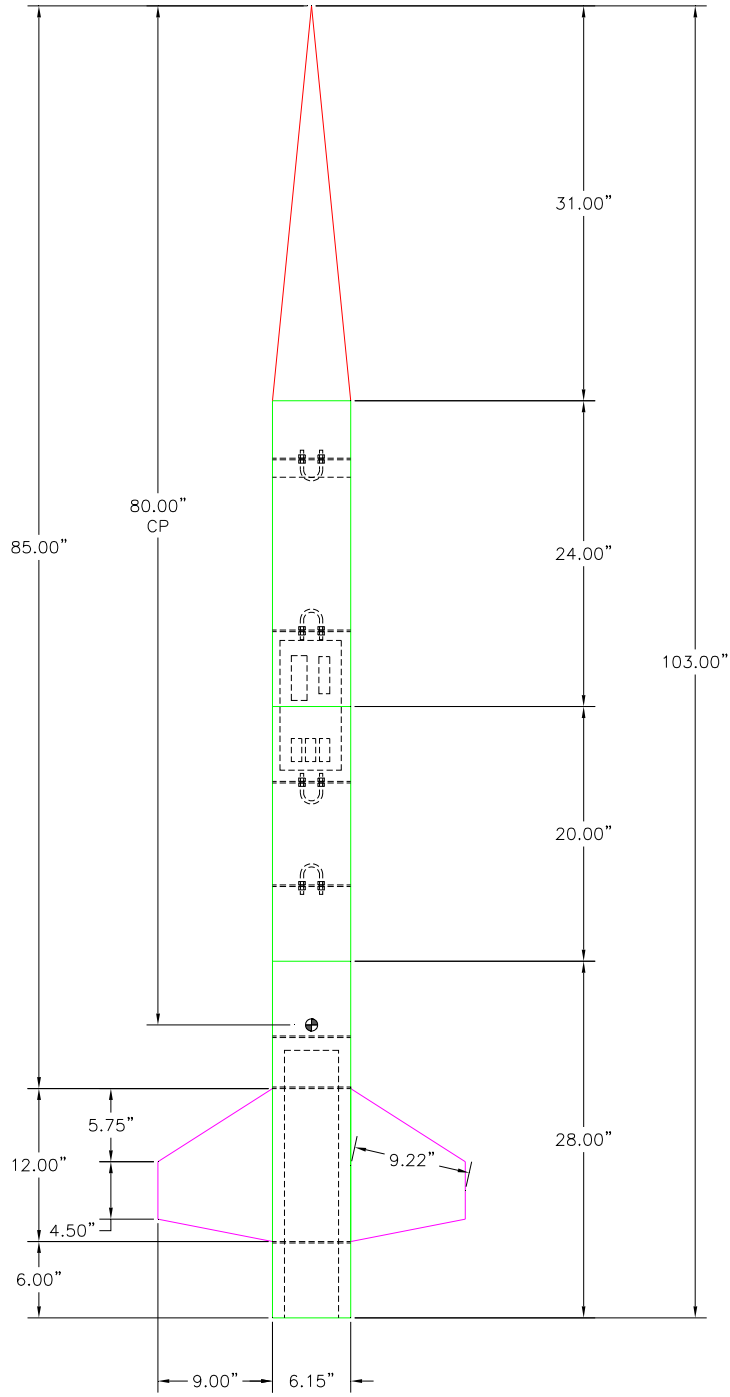
Fins (3 each):

Core: 0.125 inch G10 fiberglass  
Second layer: 0.093 inch balsa with birch center spur  
Third layer: 5.7 oz 3K carbon fiber (vacuumed)  
Fourth layer: 6.0 oz. S-glass (vacuumed)  
Final layer: 2.0 oz. E-glass (vacuumed)  
Dimensions: See below

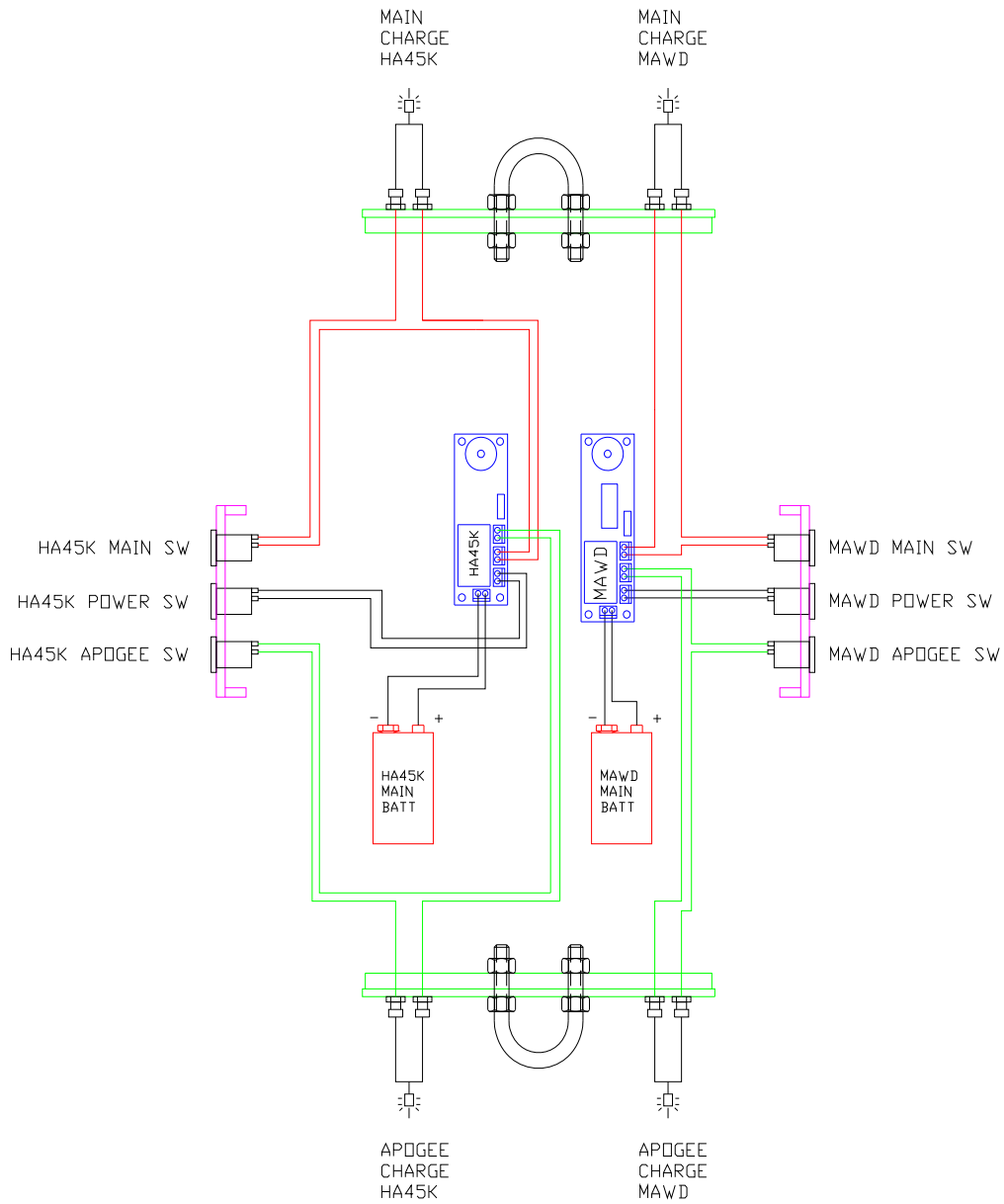
Tracking:

Type: Walston Retrieval  
Secondary: Beeline GPS

**Overall Dimensional drawing:**



**Avionics wiring diagram:**



## Construction Details:

The entire airframe is composed of 6.14" DIA. Performance Rocketry G10 fiberglass tubing, with a wall thickness of 0.14 inches.

The nose cone is a Performance Rocketry, 5:1 conical shape, made from fiberglass, with gel coat exterior.

The fins are 1/8" G10 fiberglass core, sandwiched between 3/32" balsa for shaping. Fin layup consists of 1 layer of 3x 5.7oz carbon fiber, and one layer of 6 oz. S-glass with a 2 oz. e-glass sanding veil.

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### Fins:

I began by cutting out two 3/32" balsa pieces for each fin. Using Aeropoxy, I laminated the balsa to the G10. Next, I prepared the carbon fiber fabric and glass, and laminated it to the fin layup using a vacuum process.



### Motor Mount and fin attachment:

The motor mount is a 98mm x 20" long G10 fiberglass setup, with 1/8" G10 centering rings. Two each 1/4" aluminum tubes were incorporated for future air starting in a two-stage configuration. Motor retention is accomplished by an aluminum aft bulk head with 3x #8 PEM nuts. An aft retaining ring is secured to the aluminum bulkhead with screws once the motor is installed.

Birch "pockets" were used to mate the fins to the MMT tube. Heavy epoxy fillets reinforced with carbon fiber hairs were used to attach the birch pockets to the MMT. 1/8" holes were drilled through the fins and the birch to create epoxy "pins" for added strength.



The fins were then attached to the MMT tube assembly with large external epoxy fillets with milled glass additive.





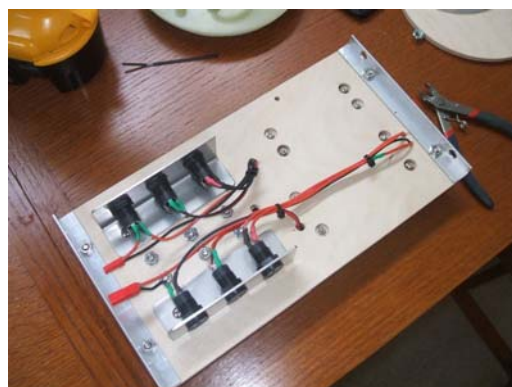
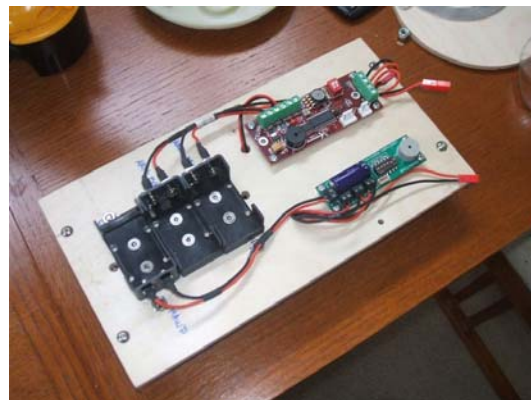
### Avionics Bay:

The avionics bay is comprised of a 6" x 12" G10 coupler, with ¼" birch bulkheads recessed inside the coupler, and G10 bulkhead plates on the exterior. Two each 3/16" stainless u-bots are provided as anchoring points on both ends of the avionics bay, and the top coupler of the booster.

The avionics sled is made from ¼" 7 ply birch ply, with ½"x 1/16" aluminum angle. The angle slides on the 2 ea. ¼-20 all thread, which acts to secure the avionics bay bulkheads in place.

The Perfect Flight MAWD and HA45K\* altimeters are secured to the board with supplied hardware from the manufacturer, and all wiring is multi-stranded 22 gauge wire, and male/female locking connectors for the deployment charge connectors. Deployment charge terminals are brass knurled thumb-screws.

*\*(Note that at the time of construction, an ARTS2 was planned for deployment. However, in the final design, the Perfect Flite HA45K was chosen for the L3 certification flight).*



Nose cone:

The nose cone bulk head is an aluminum two-piece setup, where the U-bolt plate can be removed via 8 ea. #8 screws. This allows access into the NC for flight computers and/or tracking devices. The aluminum ring holding the plate has been secured with epoxy.



Final Assembly:



## Deployment Details:

Deployment charge equation:  $n = 0.00052FL^*$

Where:            n = Grams of 4fg BP  
                      F = Force desired (PSI)  
                      L = Length of deployment bay

*\*Courtesy of Vern Knowles*

### Drogue Deployment Charge:

- Drogue Bay volume: 8" L x 6" DIA. = 226 in<sup>3</sup>
- Desired drogue deployment force: 350 psi
- Equation:  $n = 0.00052 \times 350 \text{ psi} \times 8 \text{ inches}$ 
  - Yields 1.456 + 20% safety factor = 1.75g BP
- Ground tested and verified accurate

### Main Deployment Charge:

- Main Bay volume: 12" L x 6" DIA. = 339 in<sup>3</sup>
- Desired drogue deployment force: 350 psi
- Equation:  $n = 0.00052 \times 350 \text{ psi} \times 12 \text{ inches}$ 
  - Yields 2.18 + 20% safety factor = 2.75g BP
- Ground tested, but results where "borderline"
- Increased charge size to 3.25g with better results. Will use 3.25g BP

### Shock Cords:

- Both shock cords (drogue and main) are 1" Military Tubular Nylon
- "Y" harnesses are 1" tubular nylon with Kevlar protection sleeves

### Main Chute:

- Skyangle Cert3XL with pilot chute and deployment bag
- Safe decent weight (according to Skyangle testing) for rockets weighing 32-70 lbs.
- Verified by Brad Wrights L3 flight FITS 2007

### Drogue Chute:

- 30" Spherachute with spill hole
- Projected decent rate under drogue 50-60 fps



Main Recovery Gear



Drogue Recovery Gear