Tennessee TECH

2020 University Design Challenge Presentation

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Concept

Our team will make a compact balloon that is attached separately to the pilot. Once the pilot lands in the ocean, the presence of water will trigger a release of CO2 from compressed CO2 canisters to inflate a decompressed balloon. From there, an electrical resistance heat source will provide heat inside of the balloon. This heat will create a temperature difference between the balloon and the ocean so the balloon can be discerned from its surroundings with an IR camera.

Assumptions

The following are essential assumptions made by our team to narrow the scope of the project:

1) There will be, in total, a 4-6-hour timeframe for the Search & Rescue (SAR) team to find the downed airman.

2) The airman will be in a lifejacket, raft, and/or similar items and will be floating in the water.

3) The airman will be injured (possibly unconscious) upon bailing-out into the ocean.

4) Rescue boats, planes, drones will have an infrared camera to use with our device.

5) All GPS signals are jammed.

Balloon Construction

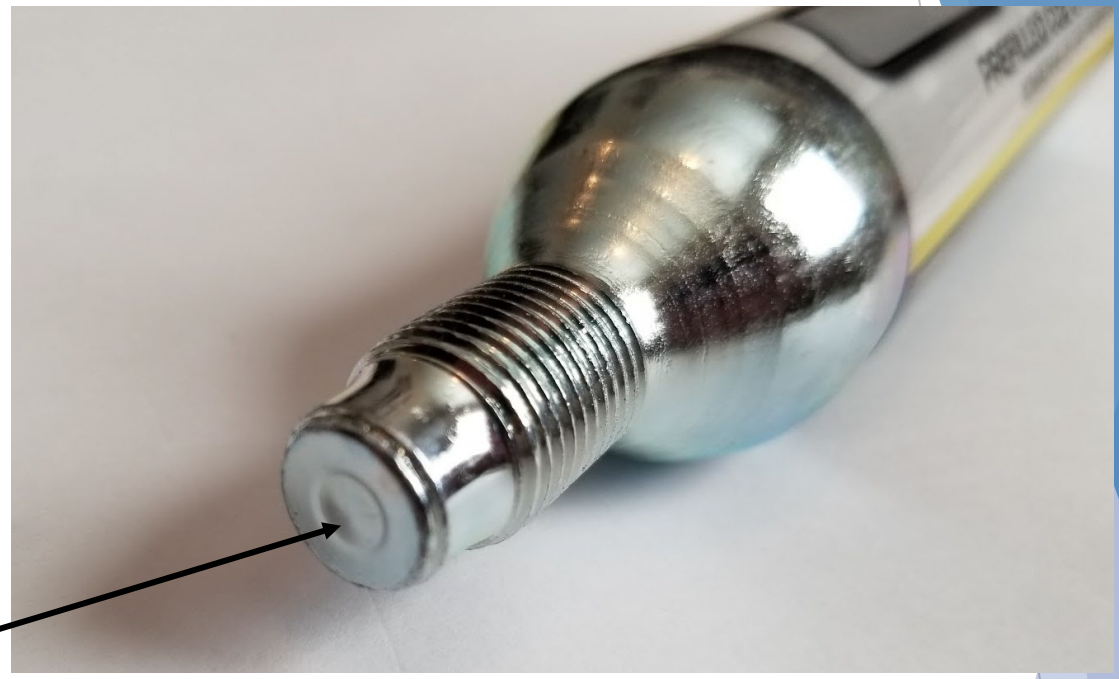
- Black TPU Coated Nylon
- Heat sealed at 220 degrees Celsius
- Advantages: Airtight & Waterproof
- Cylindrical construction inflates to approximately 3’ spherical balloon
- Collapsed size: 2”x 6”x 8”

Balloon Features

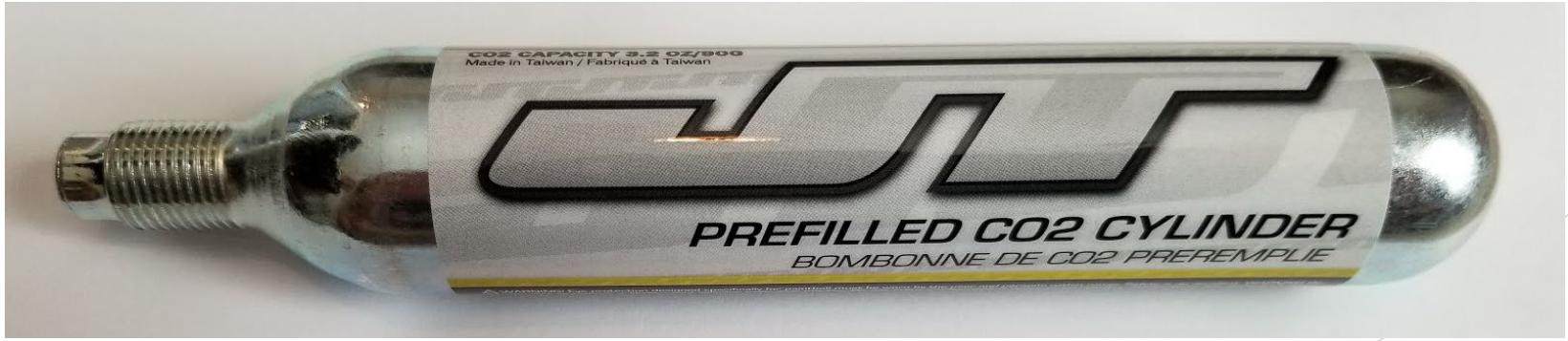
- 8’ Tether cable to connect downed airman to balloon (green as shown)
- Magnetic switch to trigger inflation and heating upon balloon release (housed inside bright green box)
- Screw-on cap to interface with inflation system, allows for quick deflate if required

Air Supply

- 90-gram CO_2 paintball tank
- Tank can be used one time
- End is punctured to release air
- \$6 per CO_2 tank
- Weight is approximately 1 lb.

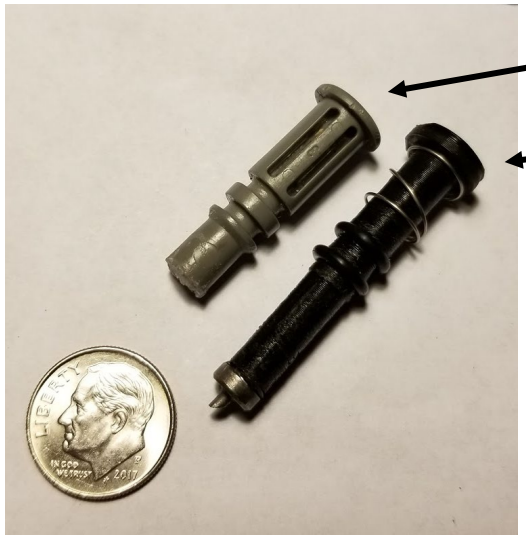


Needle punctures here



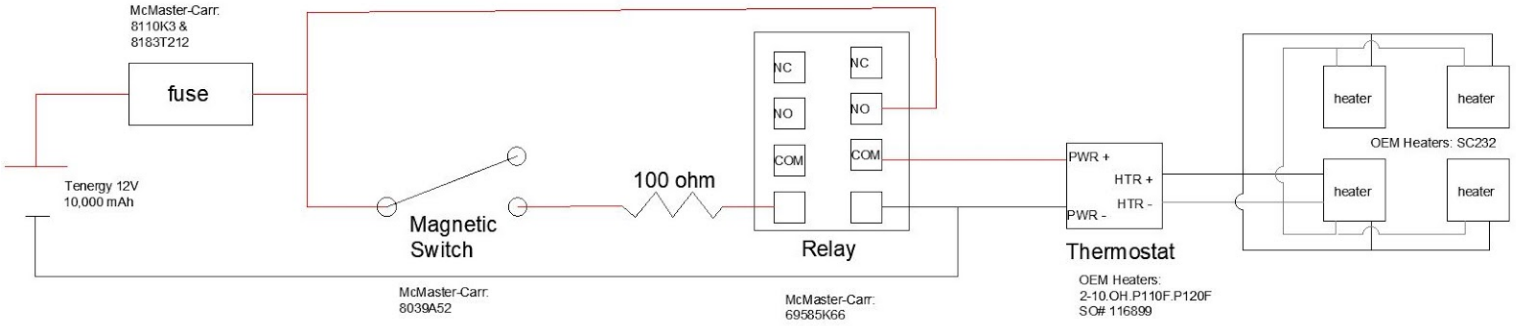
Valve Modification

- Valve taken off a Mustang self-inflating PFD
- Valve was originally used with 16-gram CO_2 tank
- Reverse engineered bayonet to adapt to 90-gram tank
- 3D Printed, self-tapped threads
- $0.22 per bayonet
- $50 per valve
- 0.16 lbs.
- $7 per dissolving tablet - “Bobbin”
- Testing Bayonet: https://youtu.be/Sb4x22SzBoI



Wiring Schematic

- Protected against shorts with 5A fuse
- Fuse doubles as emergency stop switch
- Thermostat regulates temperature of balloon between 110°F & 120°F
- Thermostat helps conserve energy, extending battery life
- Estimated minimum 6-hour battery life
- Circuit is completely encased in balloon making it having zero contact with water



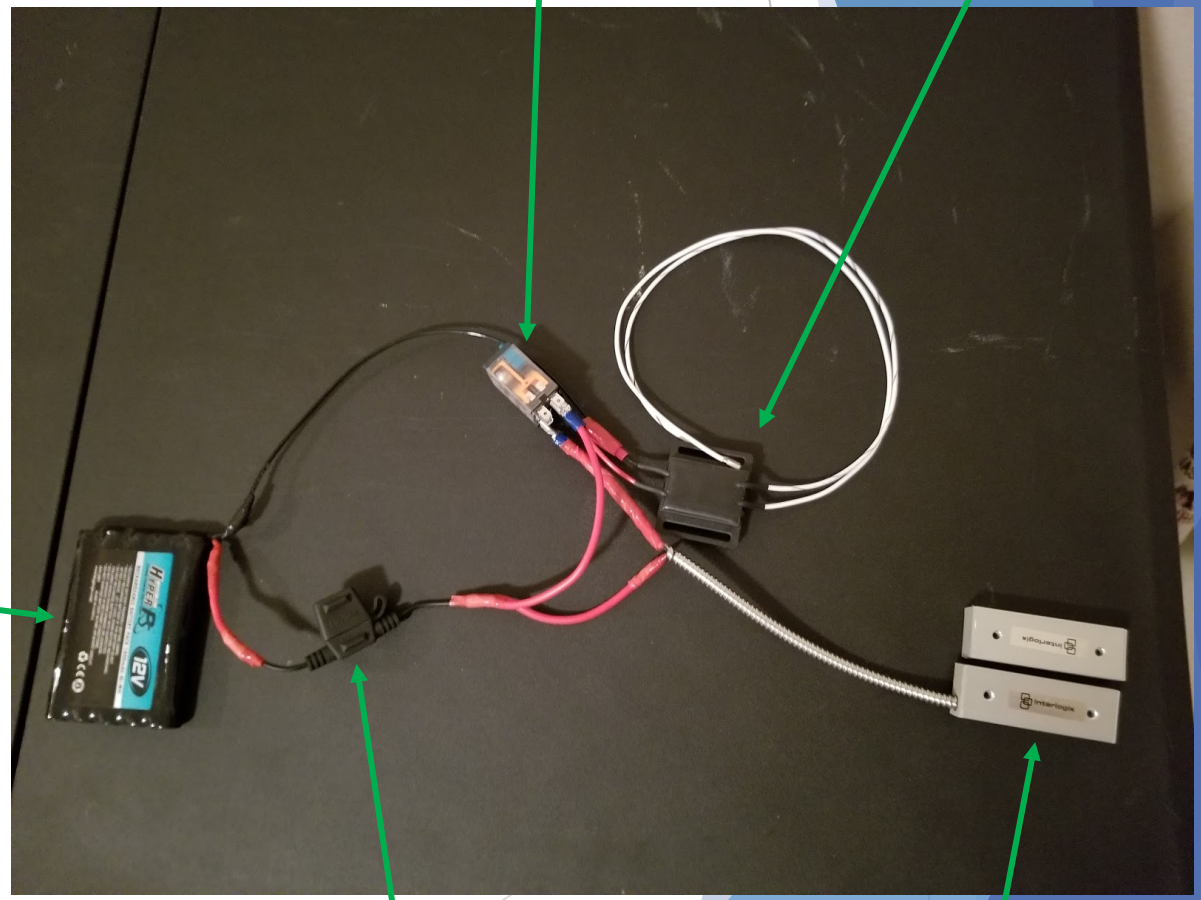
- Optimal battery
- 12V 10,000mAh
- 6.3” x 2.6” x 2.4”
- 3.7 lbs.

Heater max current: 2 amps
Relay max current: 0.12 amps

2.12 amps x 6 hours= 12.24Ah = 12,240mAh

Physical Circuit

- Soldered circuit to be mounted inside balloon
- When magnets are misaligned, relay closes and energy flows to the thermostat
- $330 per circuit ($97 per battery)
- Total weight: 8 lbs.
- Testing of Circuit: https://youtu.be/TFETVrBUnVQ



Desired Next Steps

- Determine contents of aircraft ejection kits to develop plan to add balloon device
- Test the balloon's heat output for the recommended six hours with the IR camera
- Determine maximum distance balloon is detectable with IR camera
- Ensure CO_2 pneumatics are accurate and consistent with balloon's full duration
- Conduct at least three thorough tests from start to finish of the balloon prototype

Subject Matter Experts' Concerns/Advice (1/2)

1. **Michael Starr** (Air Force Pilot, F-15C, E-11, F-22, & F-16)
    a) Assume pilot is injured; Ensure heat can be controlled; Prevent damage to wires
2. **Chelsea Bush** (SERE Instructor) & **Logan Jeffery** (Navy Communications)
    a) Pilots typically have raft and/or auto-expanding life jacket
3. **Maj. Daniel Coughlin** (AIRCOM Watch Officer)
    a) Use balloon even after heating life to help find downed airmen in recovery to exceeds 6 hours; The steady and solid infrared signal of the heating element used is preferred over an alternating signal (i.e. signal mirrors)
    b) Coloring the balloon a bright orange color would help in recovery effort if designed to be punctured when threatened by enemies
    c) Part of balloon could be colored orange so that the airmen can decide which side is seen
    d) Batteries will need to be accessible so that they can be changed out after shelf life expires

Subject Matter Experts' Concerns/Advice (2/2)

4. **Colin Chessor** (Air Force Pilot, C-17 Cargo Plane)
    a) Avoid premature inflation; Simple yet effective solution; A constraint is line of sight; Drones and planes see infrared imaging quite well
5. **Ryan Sealy** (AIRCOM-Rescue)
    a) A large target such as this is ideal; Consider a way to manually inflate in the event there is no water; Even small heat sources are detectable with FLIR
6. **Steve May** (Former USAF Pararescueman)
    a) Make the device as small and light as possible; Strive for six hours of heat
7. **Adam Kawatski** (Former Aircraft Commander for Rescue Missions)
    a) Consider being in non-friendly water; Would be great for carrier ops; Determine maximum distance; Avoid inflation puncture

Hazard Analysis Key

				Probability					
				A	B	C	D	E	F
SEVERITY	Category	Descriptive Word	Physical Injury/Illness	Frequent	Reasonably Probable	Occasional	Remote	Extremely Improbable	Impossible
	I	Catastrophic	Fatality or Permanent Disability				Spotted by the enemy	Overinflation	
	II	Critical	Severe injury, severe occupational illness			Electrical Shock	Burned by Heater		
	III	Marginal	Minor injury, minor occupational illness				Premature Inflation		
	IV	Negligible	Less than minor injury or illness			Inflation Failure			

Hazard Analysis (1/6)

Hazard	Probability	Severity	Matrix Value	Reasoning	Risk Management
Balloon Failure:					
Overinflating	Extremely Improbable	Critical		The strength of nylon/TPU is such that it would take a much larger pressure differential than we will be using to cause the balloon to burst. However, it's possible that a tear may cause the balloon to let in sea water, which could cause an electrical short	Based on calculations, the amount of air released should produce a relatively low pressure in the balloon to prevent bursting. Testing will also allow us to confirm the safety of the pressure.
Not Inflating	Occasional	Negligible		If the balloon fails to activate it will essentially be an inert object. However, if the balloon fails to inflate and the heating element activates, it may be conducive to overheating.	We will include a manual pull mechanism in the valve, which will mitigate the risk of it not inflating automatically.

Hazard Analysis (2/6)

Hazard	Probability	Severity	Matrix Value	Reasoning	Risk Management
Balloon Failure:					
Premature Inflation	Remote	Critical		This won't happen unless salt tablet is destroyed or removed, but could cause a nuisance to the pilot if the system were to prematurely activate somehow. Cutting the balloon would remove this nuisance, and there won't be enough pressure in the balloon to cause a hazard to the pilot.	We will include splash protection in the design so that water may only enter from the bottom. Also, salt tablets will be lab tested to make sure they can handle realistic acceleration and jerk without disintegrating.

Hazard Analysis (3/6)

Hazard	Probability	Severity	Matrix Value	Reasoning	Risk Management
Heater:					
Causing Burns	Remote	Critical		Normal operation would have the airman surrounded by cold water. It is unlikely they would be burned under such circumstances.	The balloon will be on a leash, not fixed directly to the airman, allowing for a safe distance between the airman and the hot balloon.
Electrical System:					
Electrical Shock Due to Short Circuit	Occasional	Critical		If the balloon is punctured, torn, popped or is burned through, it could expose the heating source to salt water and conceivably short circuit. There would be risk of electrical shock.	The electrical system will be insulated as well as possible to reduce the possibility of short circuit. The power source will be placed inside a separate waterproof compartment to eliminate zero resistance current.

Hazard Analysis (4/6)

Hazard	Probability	Severity	Matrix Value	Reasoning	Risk Management
Visibility:					
Visually Spotted by Hostile	Remote	Catastrophic		The balloon will be relatively small (3ft), and painted to blend in with the ocean. It's unlikely to increase the downed airman's visual profile, however it is conceivable that an enemy may spot it if he has access to an IR camera and is searching for the airman.	We will utilize camouflage paint to reduce the visual profile. In addition, the device may be modified in such a way that the auto inflate feature could be deactivated, but would still allow for manual inflation.

Hazard Analysis (5/6)

Hazard	Probability	Severity	Matrix Value	Reasoning	Risk Management
CO2 Cartridge:					
May Rupture	Extremely Improbable	Marginal		These canisters are designed for use in ambient temperatures in excess of 120°F. Since the cockpits have environmental conditioning systems it is unlikely that the ambient temperature would ever get so high. Injury is unlikely even in the event of a rupture, as CO2 gas is nontoxic and the energy released would be minor.	Canisters must be stored at a temperature below 120°F, and if it is expected that the ambient temperature may exceed 120°F the device may be removed from the cockpit and stored elsewhere.

Hazard Analysis (6/6)

Hazard	Probability	Severity	Matrix Value	Reasoning	Risk Management
Leash:					
Choking Hazard	Extremely Improbable	Catastrophic		It's possible that a tether used to connect the airman to the device could wind around a limb or the neck reducing circulation or even causing strangulation.	The leash will be kept short enough that it cannot strangle the airman, while maintaining enough length to provide protection from burns as mentioned above.

Cost of a Single Unit

Balloon Construction- $20

90 Gram CO_2 Paintball Tank- $6
Extended Bayonet- $0.22
Valve- $50
Dissolving Tablet - “bobbin”- $7
Circuit- $330

Total= $413.22