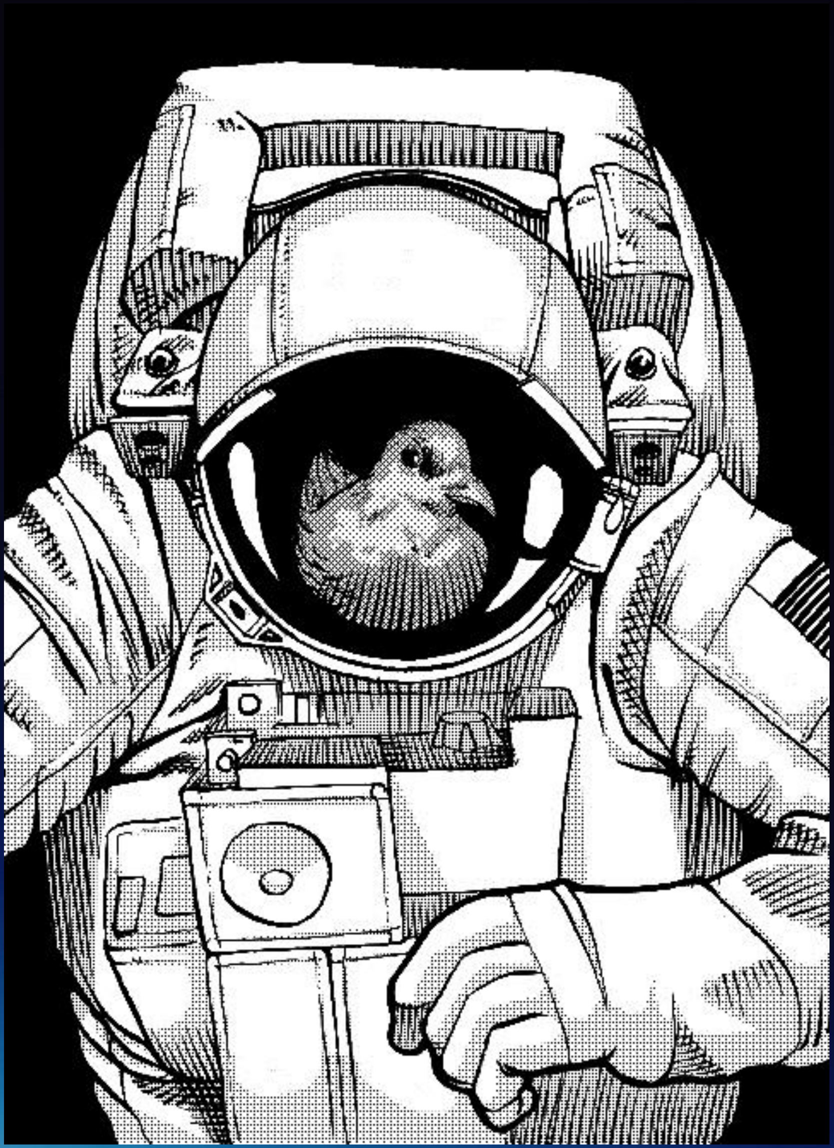
PIGEON

Precision Integrated GEOgraphical Navigation



A Near Space Recovery Technology Team

Photos courtesy Grisso, deviantart.com

Mechanical Engineering

- Students
  - Craig Amundson
    - UASE Researcher
    - RC Hobbyist
  - Wyatt Shallbetter
    - UASE Researcher
    - Private Pilot
  - Crystal Kelly
    - DRS Tactical Systems Internships
    - Former HASP Team Member
- Faculty Advisor
  - Dr. William Semke

Electrical Engineering

- Students
  - Evan Andrist
    - Microprocessor Experience
  - Crystal Kelly
  - Pericles Tsellos
    - UASE Researcher
- Faculty Advisor
  - Dr. Naima Kaabouch

Background and Problem Statement

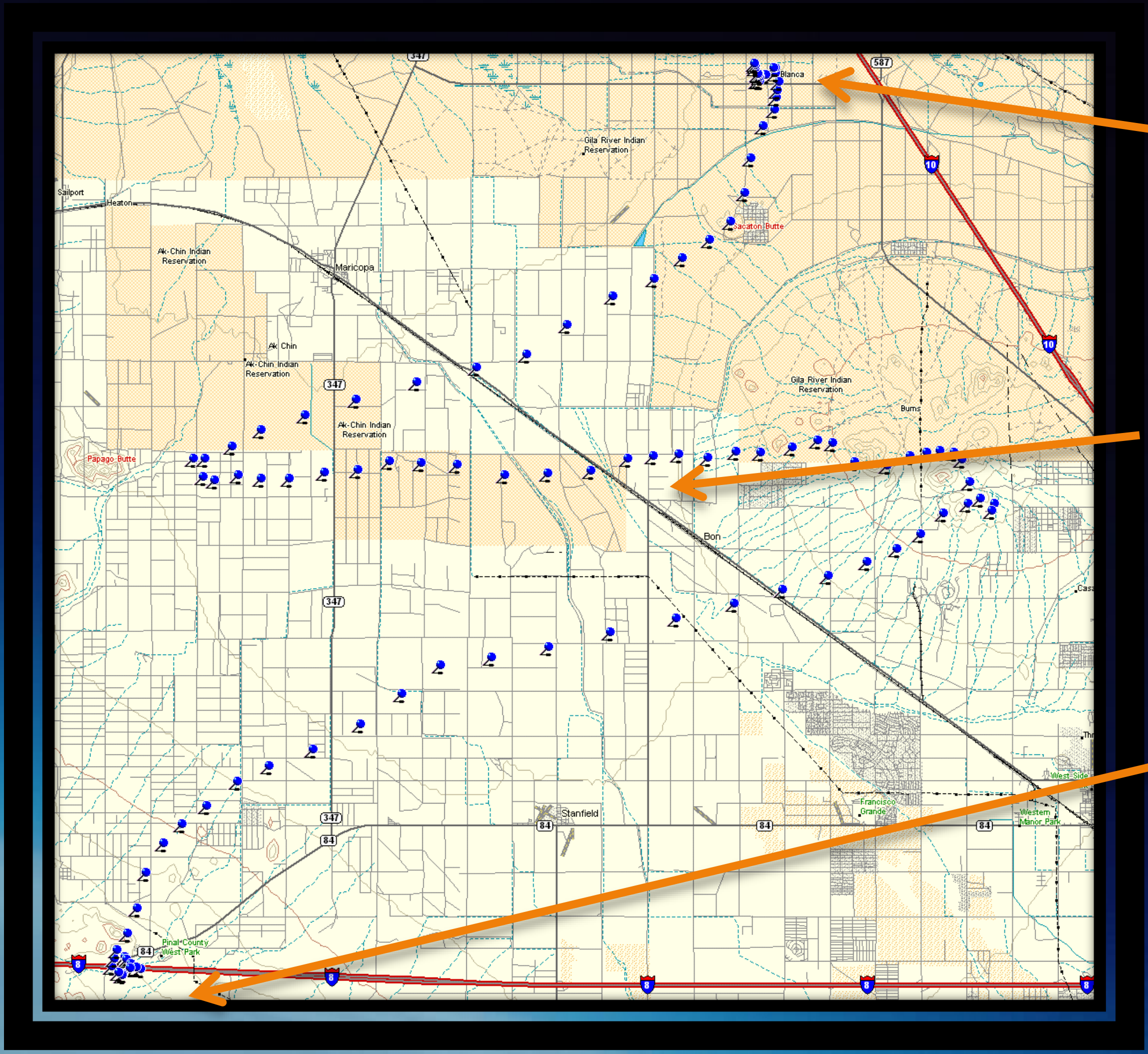
- Increase recovery rate of high altitude balloon payloads
- Enable near-space research opportunities
- Diminish hazards to people and property

Photos courtesy UND High Altitude Balloon Project

Problem Statement

Design a recovery system that will accompany scientific payloads on high altitude balloons. System must be capable of guiding payloads to a user designated “safe” landing zone in order to successfully recover payloads intact, and prevent damage to people and property.

Non-Steerable Flight – Balloon and Drogue



Payload Landing

Balloon Burst or Cut Down

Balloon Launch

Photo courtesy UND High Altitude Balloon Project

Steerable Flight – Ram Air Chute

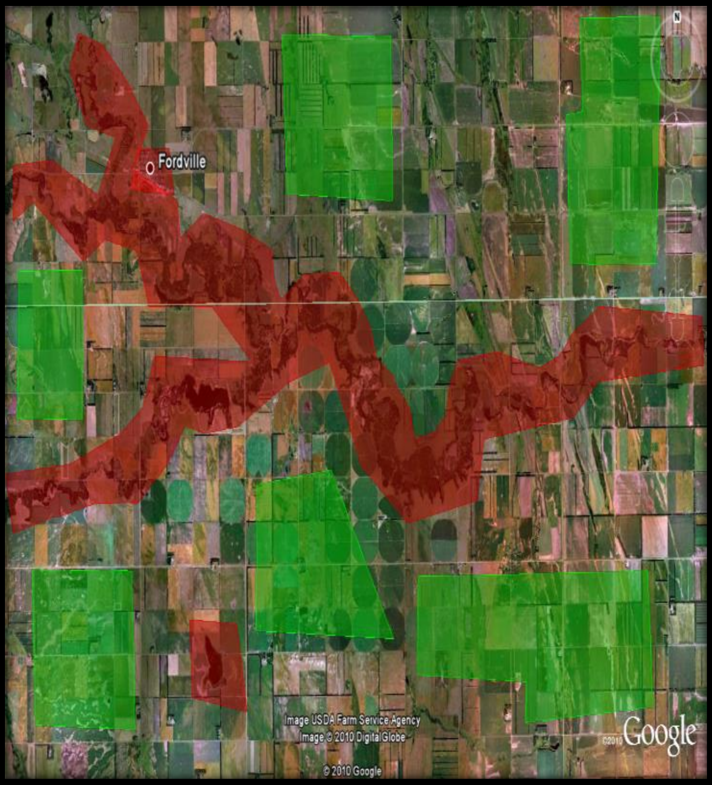
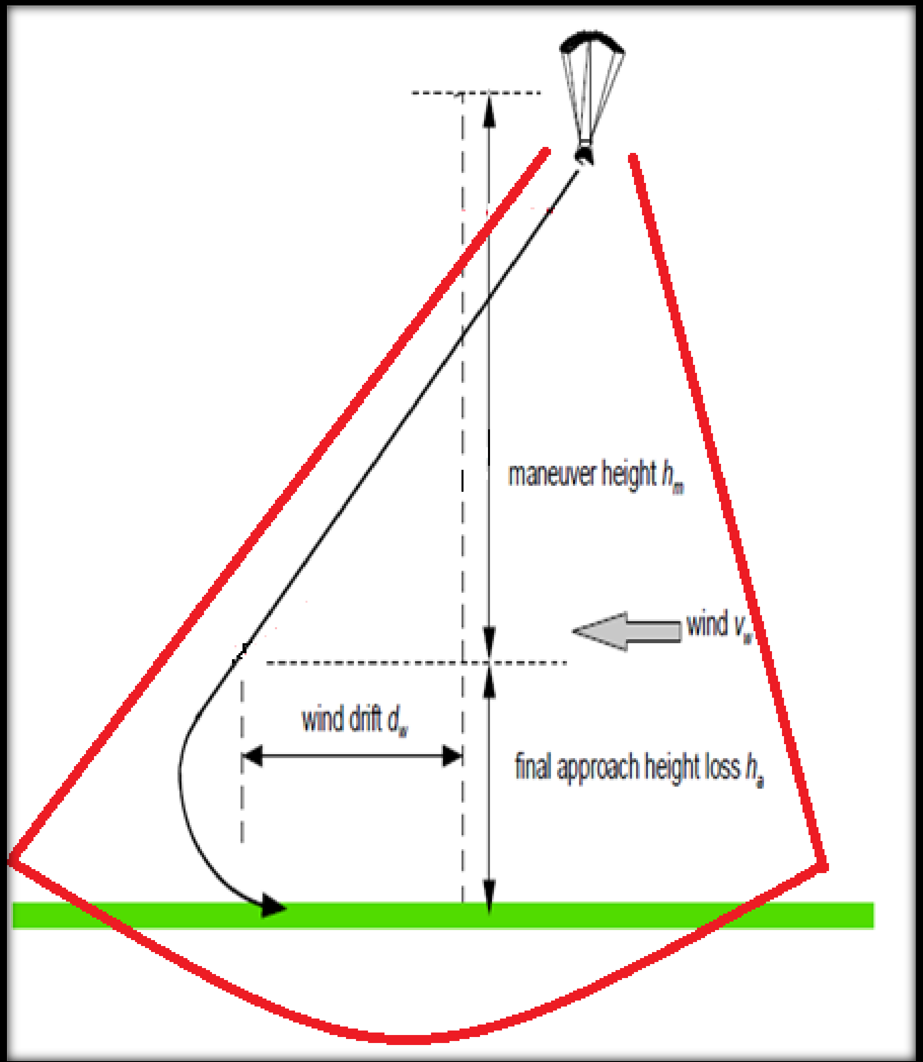


Photo courtesy Google Earth



Photos courtesy Martin-Baker Aircraft Co.

Our Solution

- Lightweight, portable, and versatile autonomous high altitude transport and recovery platform.

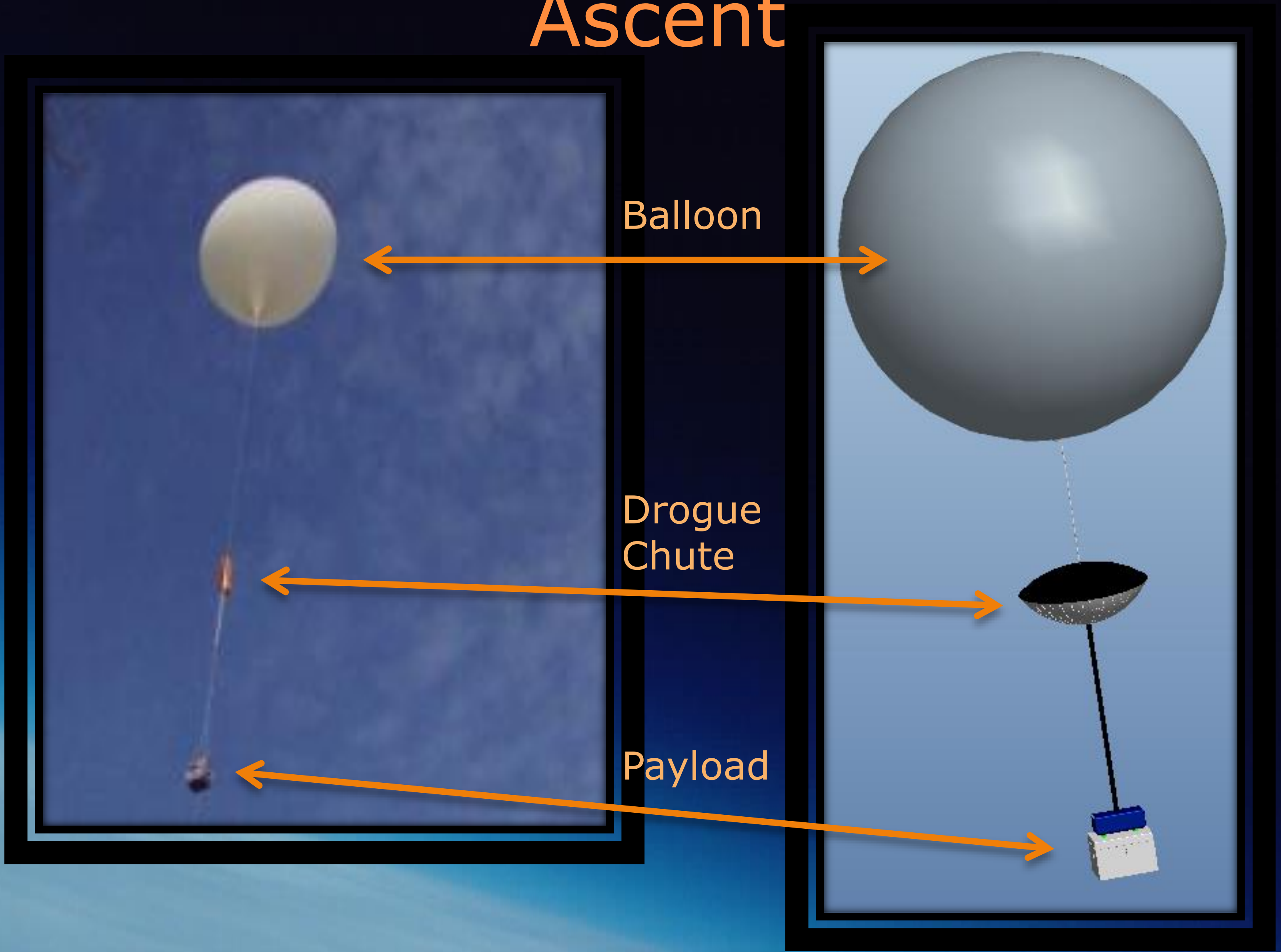
- Able to carry 3 lb pound payload
- Dimensions 7”x9”x12”
- Weight 3 lb

Photo courtesy UND High Altitude Balloon Project

Constraints of Project

- Balloon flights often reach altitudes of 100,000 ft or more
- FAA constraints on weight < 6 lbs
- Simple, guidable system
- Budget

Controllable Parachute System - Ascent

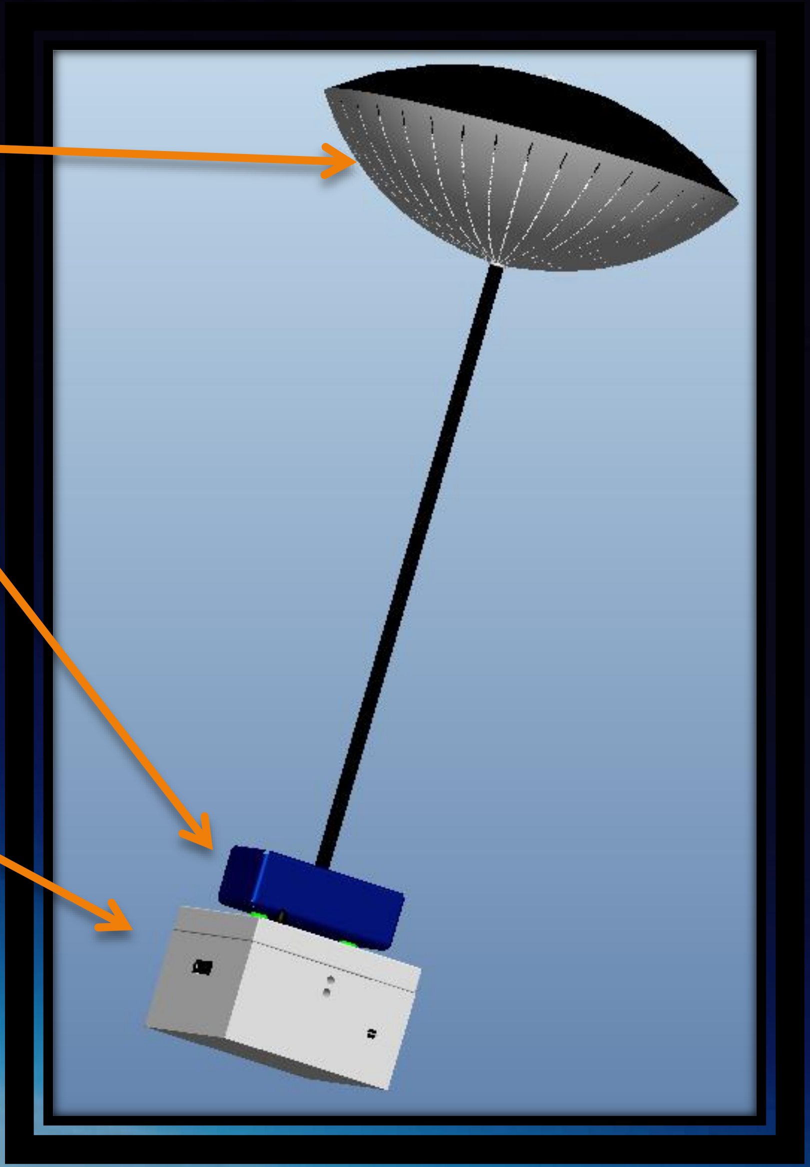


Controllable Parachute System - Descent

Drogue Parachute

Ram-Air Parachute

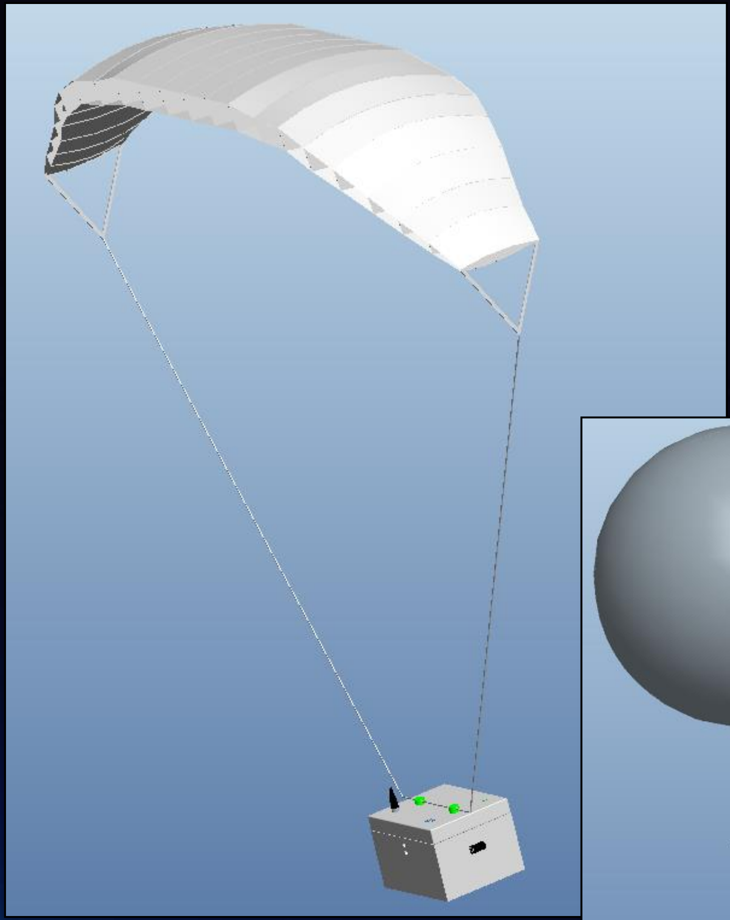
Payload Bus

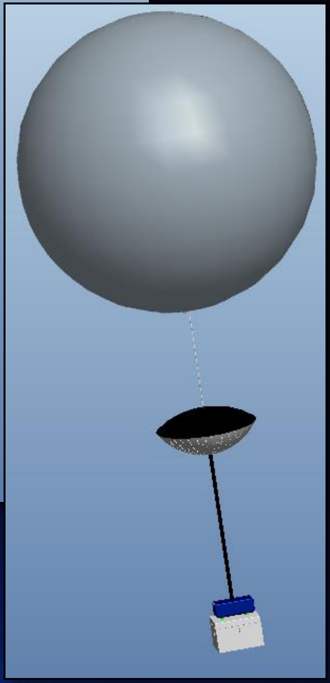


Controllable Parachute System – Steerable Flight

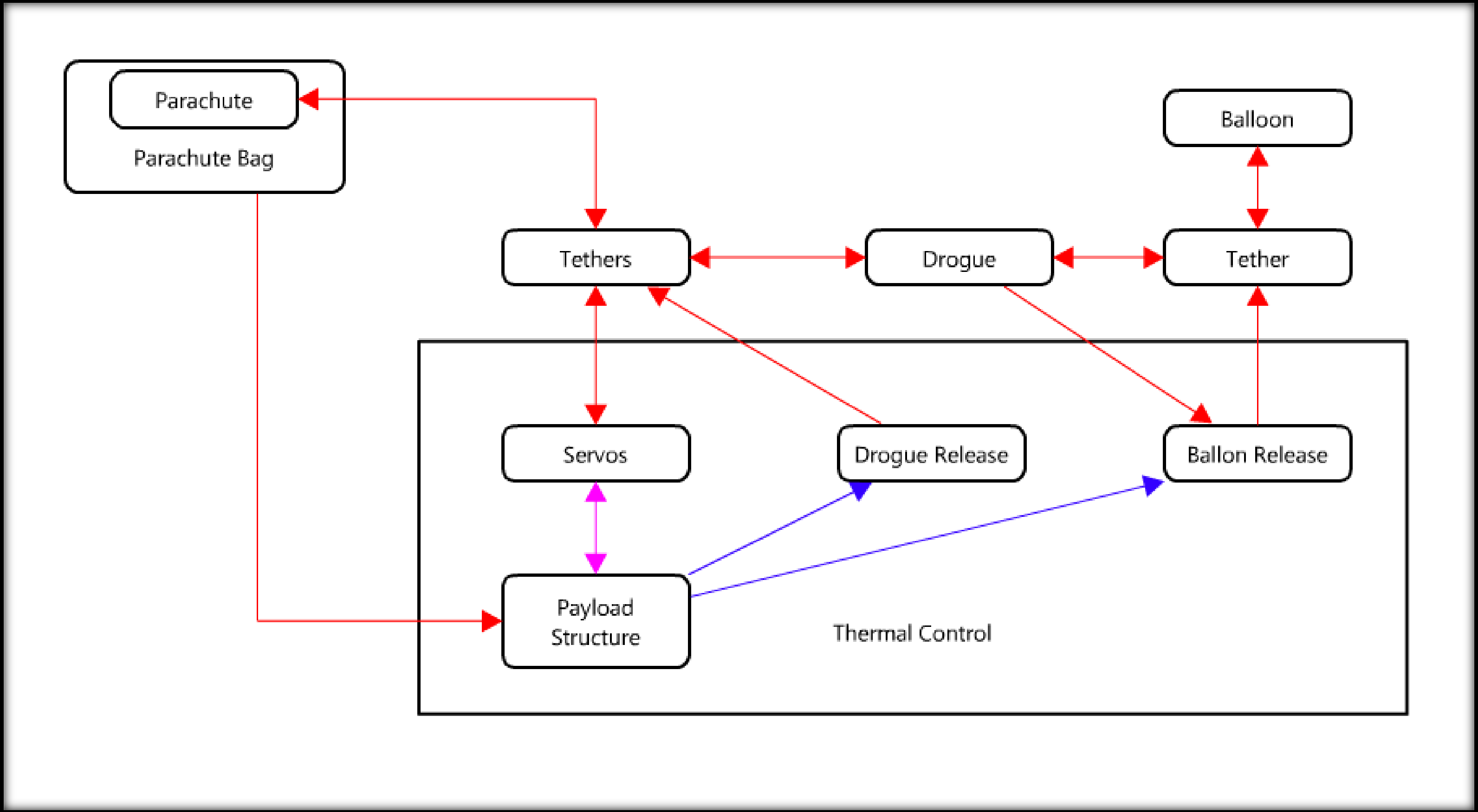
Engineering Approach

- Ram-air parachute controlled by servos
- On-board microcontroller monitors position, parachute deployment, steers vessel



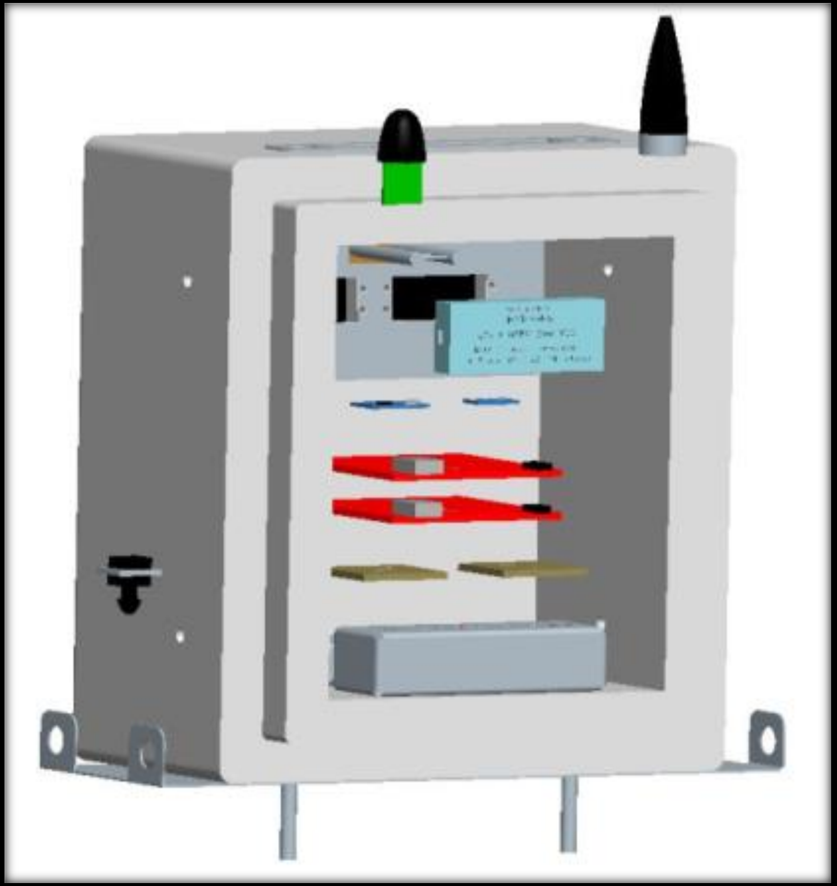


Mechanical Engineering Approach



Payload Bus Design

- Material Selection
  - Insulation Foam(2in. Thickness)
  - reinforced with aircraft grade aluminum
- Stress/Force Analysis
  - Impact Forces
  - Servo Imposed Forces
  - External Component Mounting

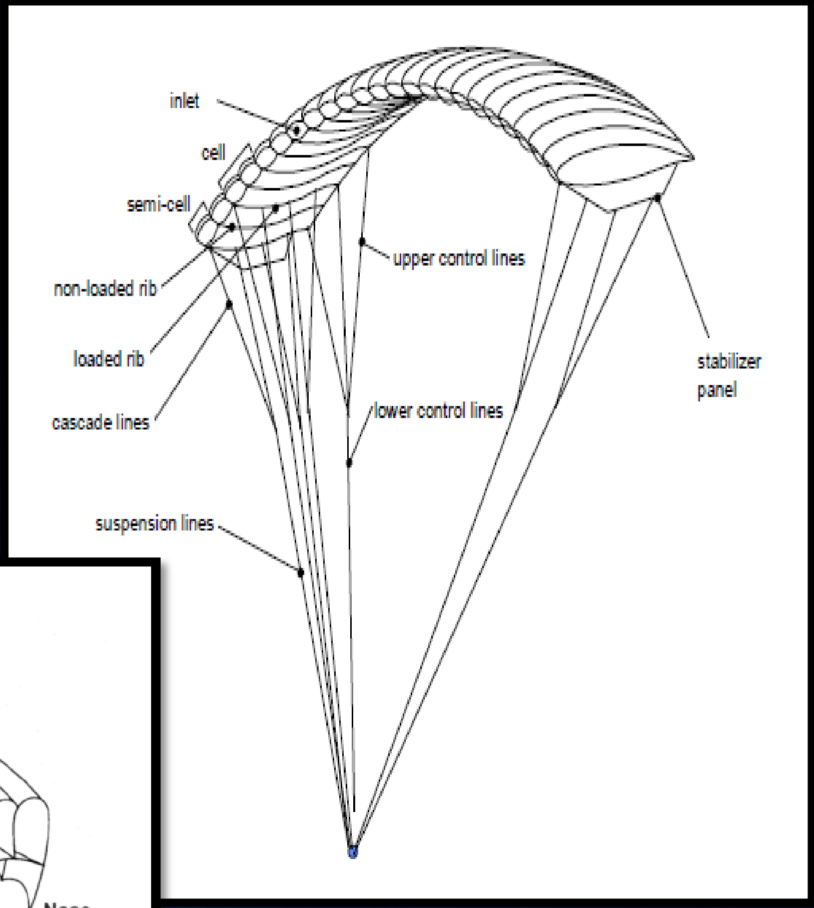


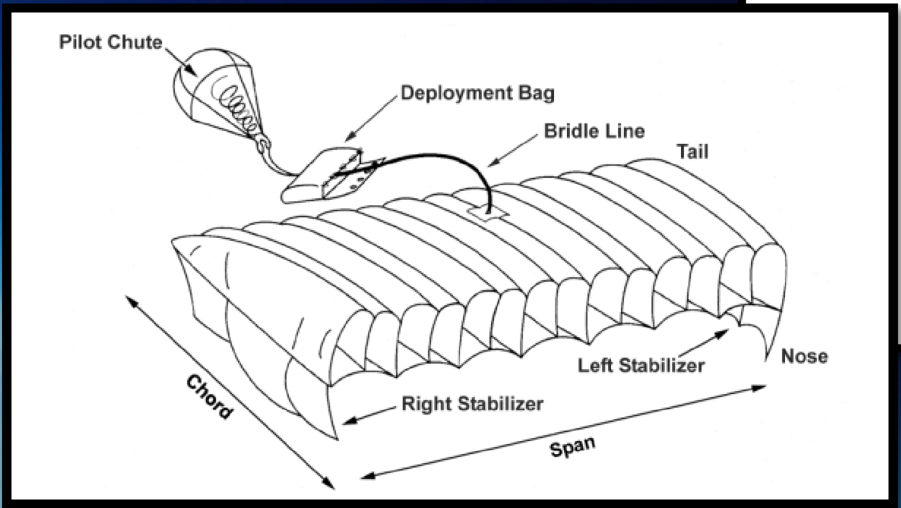
Platform Specifications

- Recovery Housing
  - Exterior: 11in x 9 in x 7.25in
  - Interior: 8in x 6in x 4.25in
  - Material: Rigid Foam
- Two Attachment Points Between Bus System and Scientific Housing
- Deployment Bag Rigging Attaches to Recovery System/Scientific Housing Mounting Plate
- Drogue Attaches to the Ram-Air
- Ram-Air Chute 2 Attachment Points Through Overall System

Ram Air Parachute Components

Steerable parachute with two layers of fabric
Airfoil shaped cross-section
Cellular design with slots cut between cells
Leading edge of parachute is open





Photos courtesy Martin-Baker Aircraft Co.

Parachute Specifications

Drogue Parachute: 3 ft Diameter

Descent Rate: 27 mph

Main Parachute

Descent Rate: 15 mph

Coefficient of Lift: 0.65

Coefficient of Drag: 0.2

Flight Characteristics

Turn Rate: currently undefined

Photo courtesy Hobbyking.com

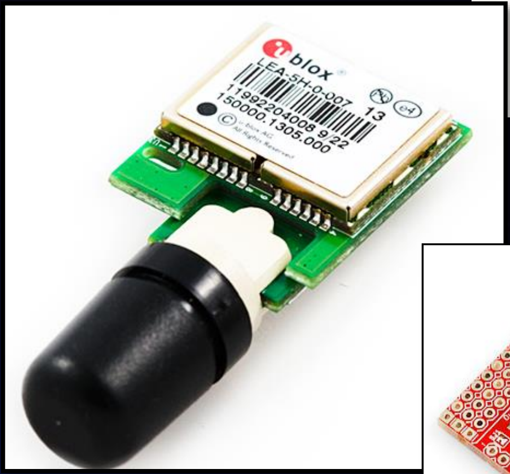
Servos

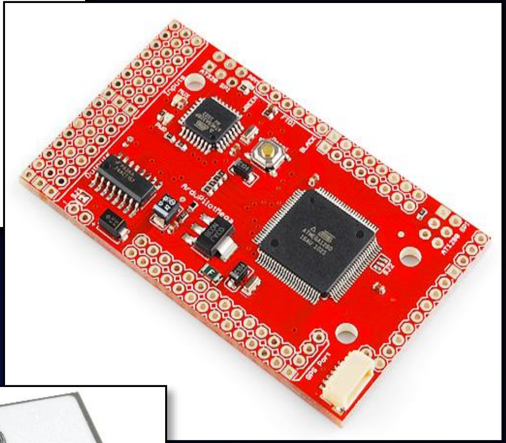
- Selection
  - Futaba 9650
    - Torque 62.5 oz. in.
    - Size 1.4 x 0.6 x 1.1(in.)
    - Weight 0.9(oz.)
    - Operating Voltage 6.0(Volts)
    - Price $60(each from Tower Hobbies)
- Stress Analysis
  - Servo arm
  - Mounting Components
- Current Draw
  - 1.5A

Photos courtesy Futaba

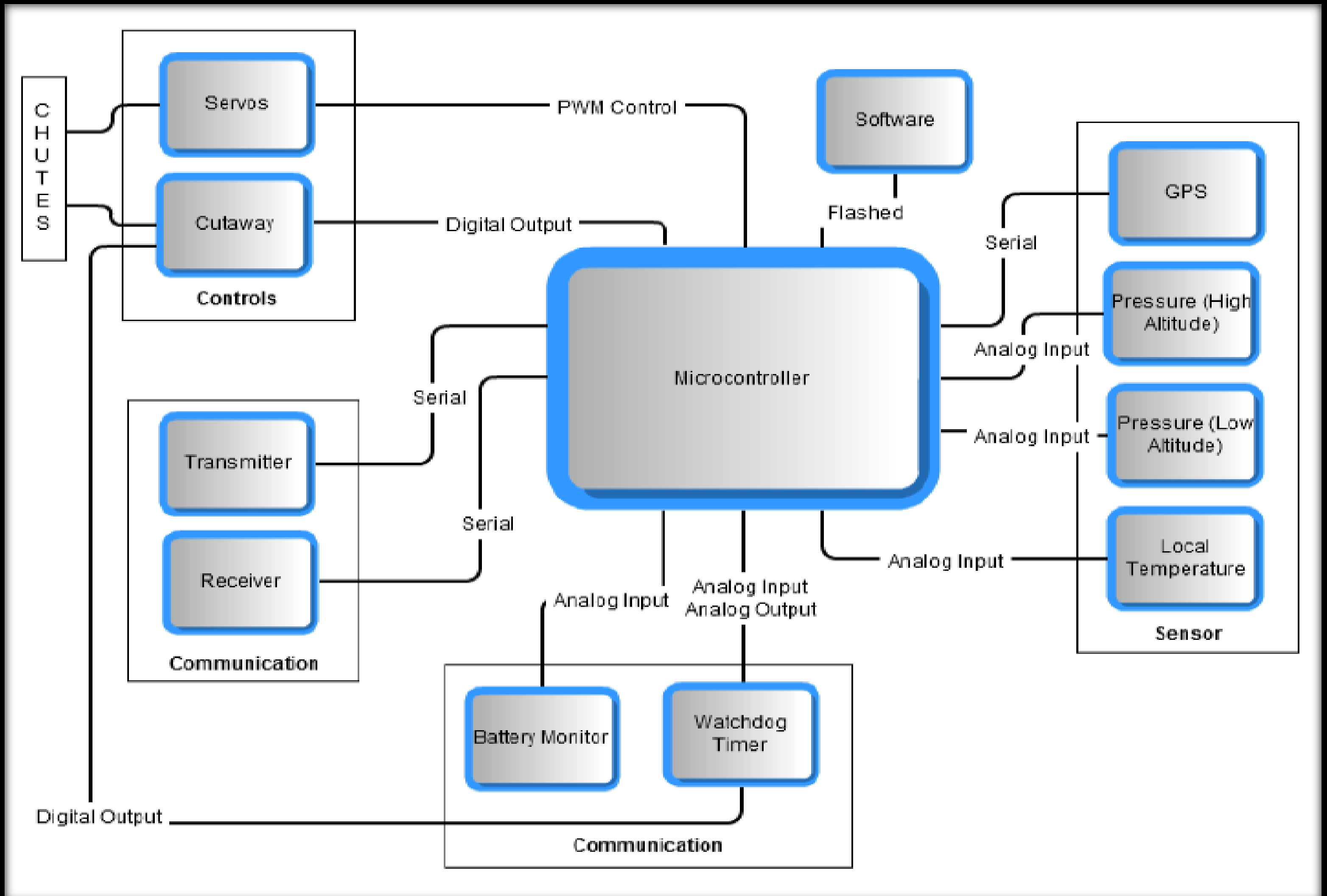
Engineering Approach – What's inside?

- Microcontroller
- Sensors
- GPS
- Radio Transceiver
- Servos
- Batteries
- Cutaway Mechanism





Electrical Engineering Approach



Cutaway

- Spring Tensioned System
- Utilizes 50lb Test Daiwa
- Parallel Nichrome Wires
- 5000 mAh NiCad Battery
- Independant
- Fail Safe

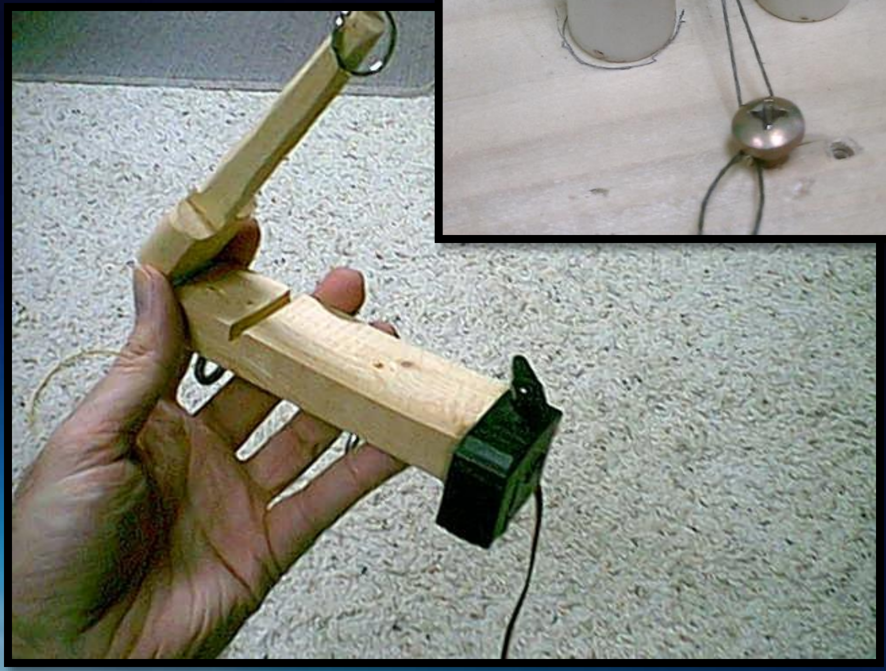


Photo courtesy UND High Altitude Balloon Project

Prediction Software

- Flight Prediction
  - Balloon Track
- Ram-Air Prediction
  - Ram Track

Photo courtesy Google Earth

Flight Control Software

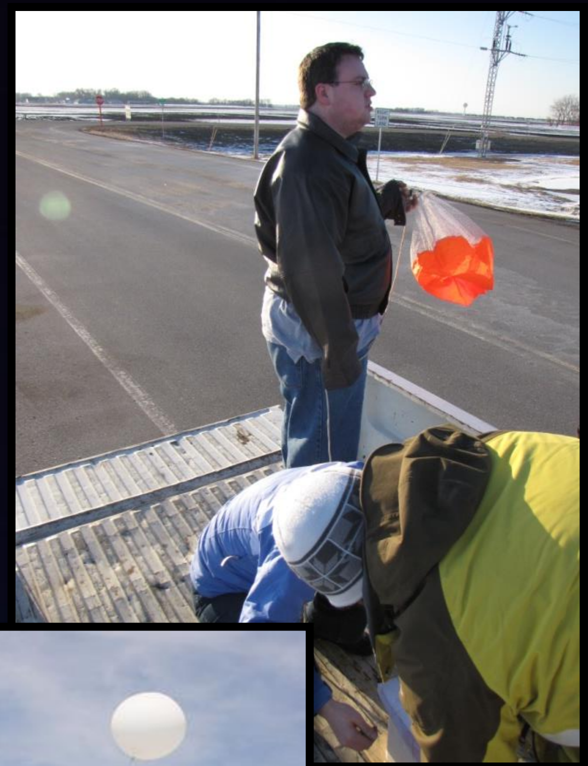
- Main Routine
  - Accent
  - Drogue Fall
  - Ram-Air Fall
- Cutaway
- Deploy
- Flight Modes and Auto Steering Flight
- Two Dimensional Tracking
- Rate of Decent and Landing
- Power Down
- Autopilot Control
- Manual Control
- Safety/Failsafe/Redundancy

Rapidly Approaching Goal: Proof of Concept

- Overall system operation
- Final system integration
- Prototype finished : March 18
- Expected flight date : April 9

Photos courtesy UND High Altitude Balloon Project

Questions?



References

Human Science Research Council (HSRC)
http://www.hsrc.ac.za/
UND High Altitude Balloon Project
JP Aerospace
Rocketman Parachutes
Hobbyking
Digi-Key
Human Science Research Council (HSRC)
http://www.hsrc.ac.za/

Concept Design – Round Parachute

Deployable Round Parachute

Pros

- Simple Design
- Lightweight
- Cheap and Available

Cons

- No Steering

Photos courtesy UND High Altitude Balloon Project

Concept Design - Glider

Unmanned Aircraft

Pros

- Controllable
- Known Technology

Cons

- Possibly Illegal
- Airspace Restrictions
- Potentially Expensive

Photos courtesy Art Vanden Berg

Drogue Parachute

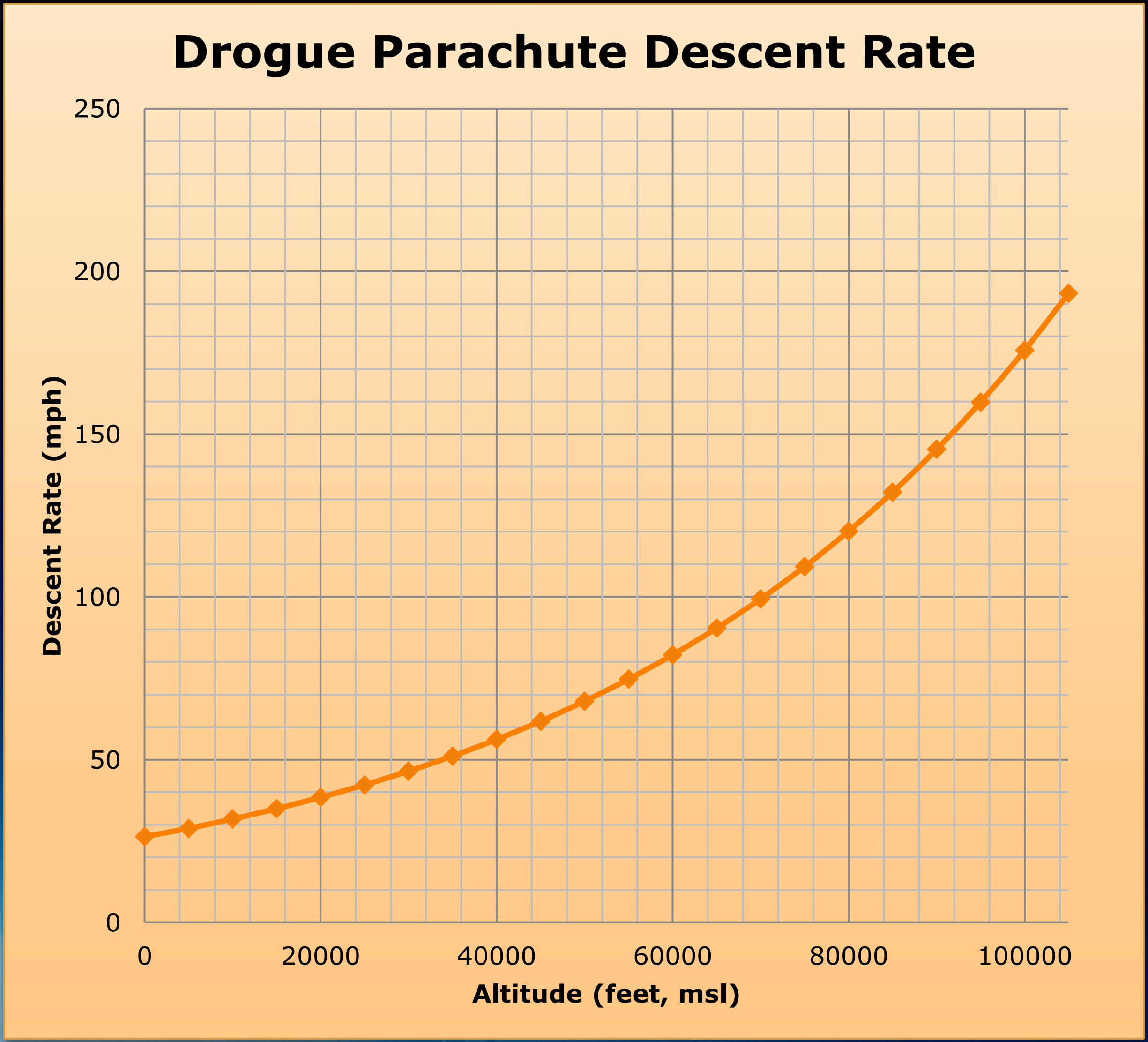
Rocketman Ballistic Parachute
Round style parachute

- Diameter: 3 ft
- Descent Rate: 12 m/s

Drogue Parachute

Throw Style
Skydiving Chute
Round style
parachute

- Diameter: 28”
- Descent Rate @Sea Level: 2300 ft/min



Ram Air Parachute Specifications

Hobbyking Parafoil

- Weight: .190 kg
- Width: 2.15 m
- Depth: 0.54 m
- Fabric: Skytex
- Cells: 19
- Lines: 22

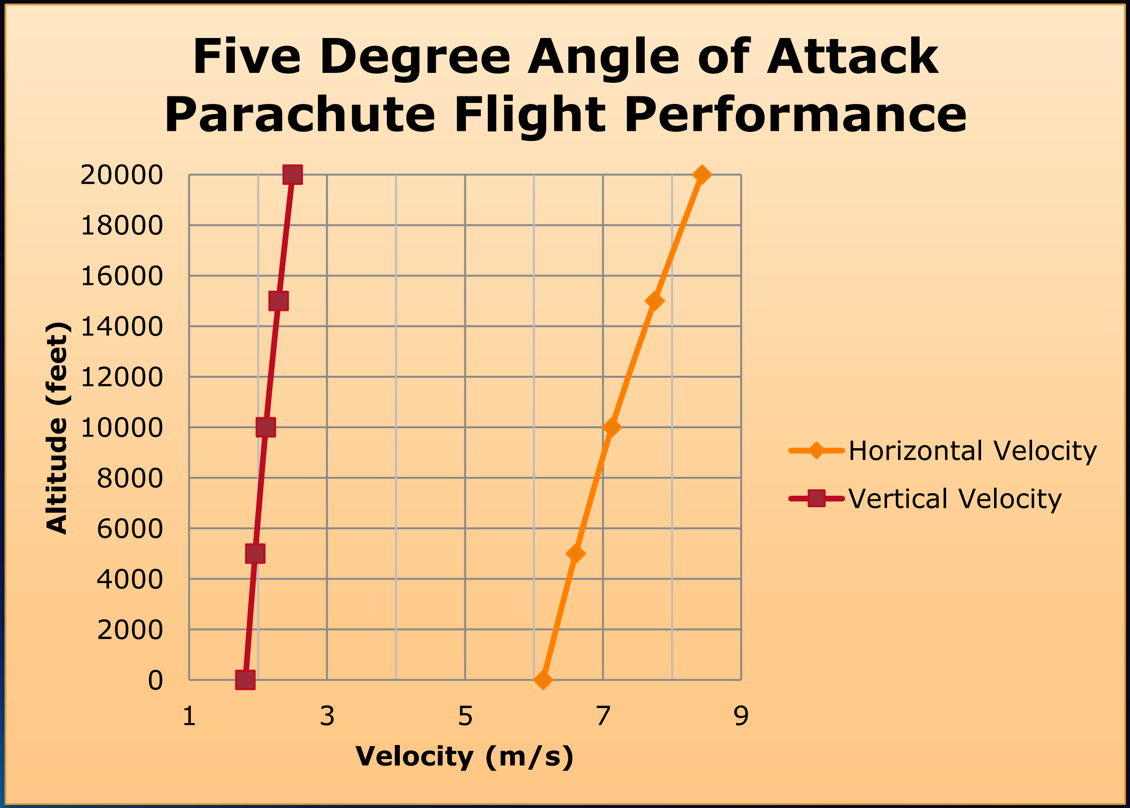
Photo courtesy Hobbyking.com

Ram Air Parachute – Flight Characteristics

- Wing Loading: 2.3 kg/m^2
  - Very low wing loading
    - Low forward velocity
    - Low sink rate
- Deployment from 20,000 ft
  - 47 minutes to touchdown
  - 13 mile range
- Deployment from 10,000 ft
  - 27 minutes to touchdown
  - 6.3 mile range

Ram Air Parachute – Flight Characteristics

Angle of Attack: 5 degrees
Coefficient of Lift: 0.88
Coefficient of Drag: 0.26
L/D Ratio: 3.8
Velocity: Altitude Dependent



Parachute Testing

- Reason for Test
  - See if control of parachute is feasible
- Procedure
  - Drop from aircraft and obtain flight profile
    - Readjust control line to change angle of attack

Adhesives Testing

Reason for Test

- Slipping knots on parachute lines

Glue Types

- "Zap A Gap" (cyanoacrylate)
- E-6000
- Quick Grip

Outcome

- E-6000 withstood the highest force, 281 N

Deployment Testing

- Reason for Test
  - Ensure parachute opens without tangling
- Testing Procedure
  - 30 MPH (Minimum Falling Speed)
    - Prove deployment with minimal force by drogue
  - 60 MPH (Maximum Falling Speed)
    - Prove parachute lines could withstand impact force
- Outcome
  - No lines broke and parachute was able to deploy at minimum speed

Cut Away Analysis

Ohmic Heat

$$W = WI\Delta t$$

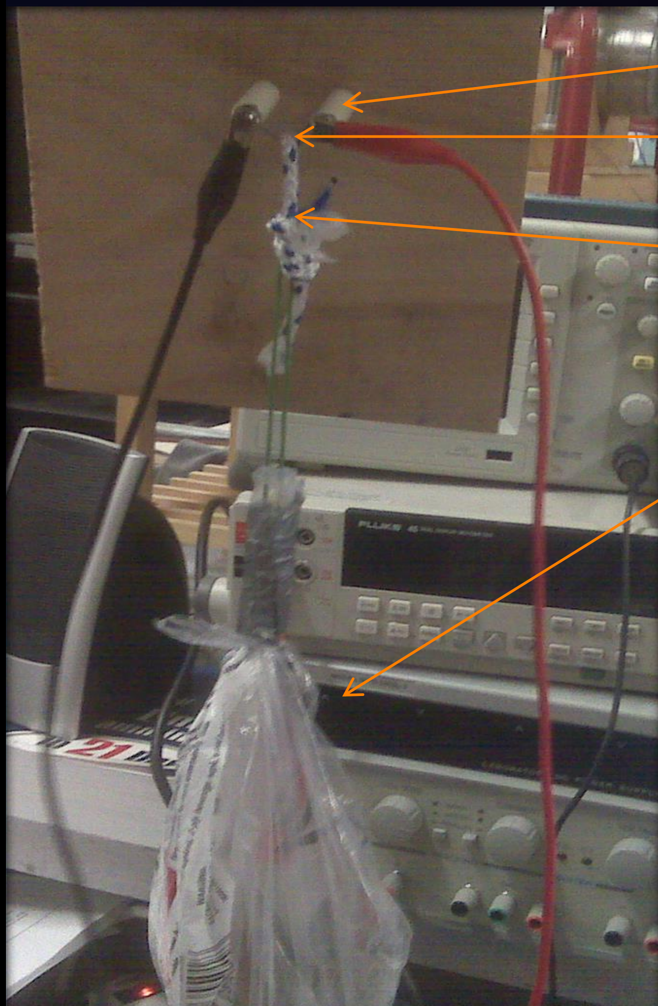
$$Q = VI\Delta t = I^2 R\Delta t$$

$$\Delta Q = mC_p\Delta T$$

Temperature Coefficient of Resistance

$$R = R_{ref}\left[1 + \alpha\left(T - T_{ref}\right)\right]$$

Cut Away Test



Rope	Time to Break (sec)
Nylon	16.4
Nylon	65.0
Nylon	44.1
Polypropylene	5.6
Polypropylene	4.5
Polypropylene	2.3

Thermal Analysis

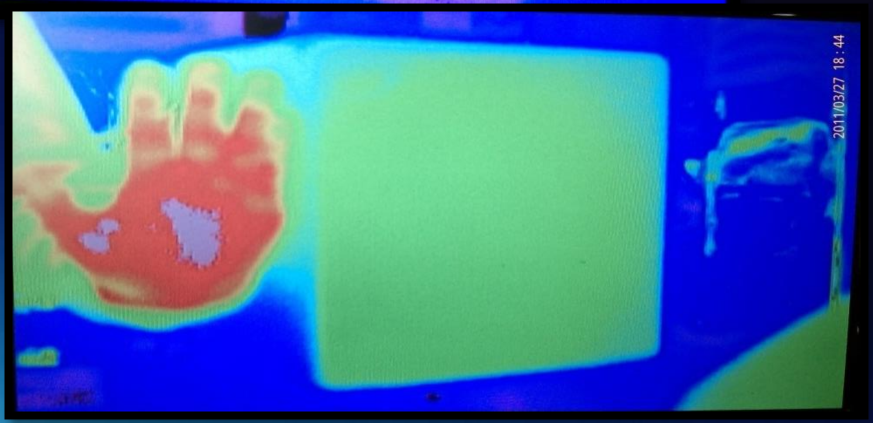
Radiation Absorption

Heat loss

- Around 8 Watts per components

Thermal Testing

- Reason for Test
  - Verify Components stay within operating range
- Component Analysis
  - Battery
    - +0.98 Watts
  - Micro Controller
    - +2.12 Watts
  - Servos
    - 0.15 Watts
- Solution
  - Mylar Covering



EE: Hardware Testing

- Testing involved
  - Breadboarding components
  - Testing individual components
  - Testing components' interactions
  - Populating a PCB
  - Sensors
    - Temperature, magnetometer, pressure
  - Autopilot/GPS
  - Flash memory
  - UART
  - APRS radio/modem

- Future Testing Plan
  - First thermal, vacuum test
    - Repairs if needed
  - Second thermal, vacuum test

Component Power Requirements

Component	Voltage (V)	Current Max (A)	Current Idle (A)	Current Average (A)	Power (Watts)
CPU	5		0.25	0.25	1.25
GPS	5		0.075	0.075	0.375
Press/Temp1	5		0.003	0.003	0.015
Press/Temp2	5		0.003	0.003	0.015
Compass	5		0.003	0.003	0.015
Radio	5	0.33	0.025	0.1165	0.5825
Servo1	5	0.4	0.03	0.215	1.075
Servo2	5	0.4	0.03	0.215	1.075
RC Receiver	5		0.02		0.1

Power Analysis

	Ascent	Drogue Fall	Main Fall		Retrieval
Projected Times (min.)	100	30	40		Unknown
Active Components:	Radio	Radio	Radio		Radio
	CPU	CPU	CPU		GPS
	GPS	GPS	GPS		CPU
	Press/Temp 1	Press/Temp1	Press/Temp 1		Beacon
	Press/Temp 2	Press/Temp2	Press/Temp 2		
	Compass	Compass	Compass		
			Servo1		
			Servo2		
			RC Receiver		
Payload mAh Required	844.59459	253.378378 4	828.828829		Unknown
Total Known mAh	1926.8018				
Selected Battery	7.4 V	5000 mAh			

EE: Software Testing

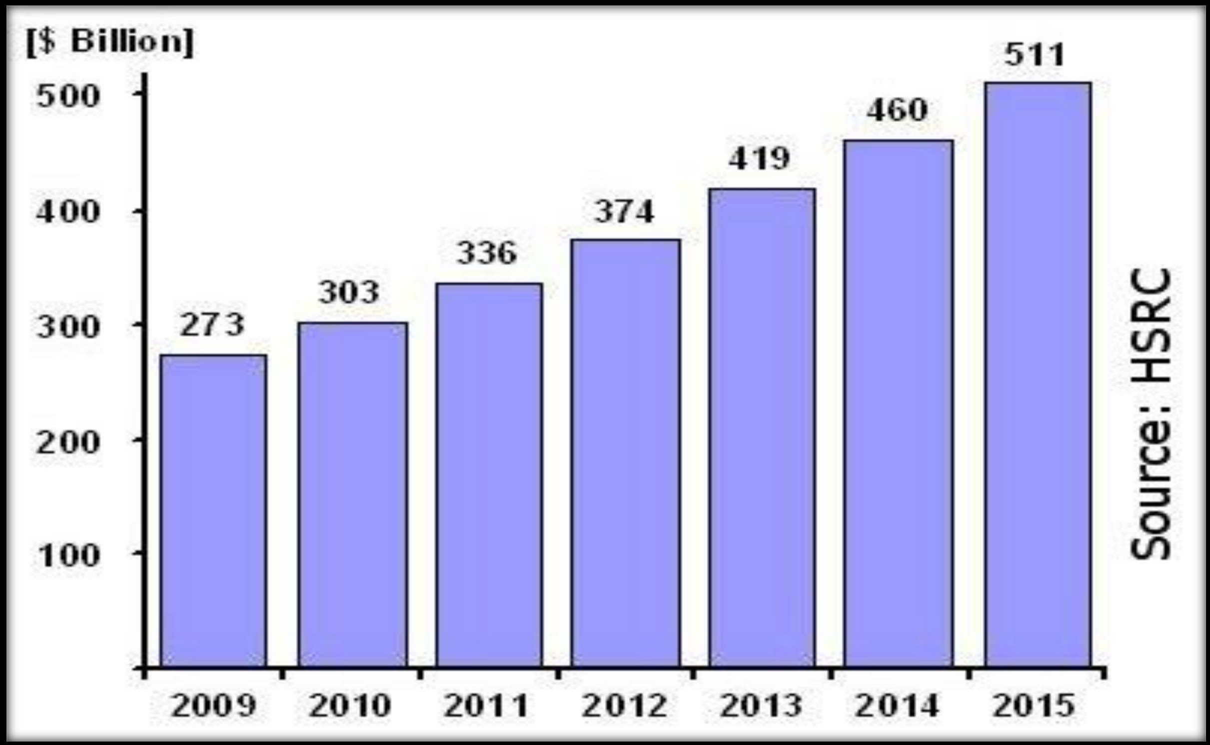
- Testing Involved
  - PIC code
  - Matlab code
  - Ground station
  - Payload
  - Integration
- Future Testing
  - Several Subprograms
  - Flow chart for interaction
  - Final integration

Budget

Item	Vendor	Quantity	Price
Microprocessor - ArdupilotMega	Sparkfun	1	59.95
GPS Receiver - GS407	Sparkfun	1	89.95
Magnetometer HMC5843	Sparkfun	1	49.95
Transceiver - UHX1	Radio Metrix	2	0.00
Servo (control)	Hobby-Lobby	2	120.00
DC-DC Converter (+5v)	Digi-Key	1	58.00
DC-DC Converter (+3.3v)	Digi-Key	1	100.00
Pressure Sensor (broad range)	Digi-Key	1	30.00
Pressure Sensor (low pressure)	Digi-Key	1	32.00
Ram Air Parachute	Hobbyking	1	25.00
Round Parachute	Rocketman	1	25.00
Foam Structure	Lowes	1	20.00
Aluminum Structure	States Mfg.	1	50.00
Batteries	Thunderpower	3	250.00
Misc Gear	-	1	100.00
		Total	$1,009.85

Target Market

Target Customers are people who seek easy-to-assemble payload recovery system at a reasonable cost and people who are environmentally friendly and look for eco-friendly or "green" products.



Spring Semester - Timeline

	Lead	Jan		Feb		March		April	
Software Design	PT/CK	In Progress							
Deployment Bag Design	WS	Complete							
Parachute Testing	WS			In Progress					
Restring Parachute Lines	CK	Complete							
Circuit Board Design	EA	Complete							
Payload Design	CA	Complete							
Energy Requirements Analysis	EA	Complete							
Servo Selection	CA	Complete							
Thermal Shield Construction	CK							Complete	
Thermal Analysis	CA	Complete							
Assembly/Integration	WS			Complete					
Deployment Testing	CK				Complete				
Parachute Rigging Testing	CA			Complete					
Payload Testing	WS					In Progress			
Servo Testing	CA/WS				Complete				
Circuit Board Testing	EA				In Progress				
Software Testing	PT/CK	In Progress							
Energy Requirements Testing	EA				In Progress				
Thermotron Testing	CK				Complete				
Testing Report	CK								25-Apr
Engineering Expo	TEAM								26-Apr
Flight Readiness Review	TEAM								28-Apr
High-Altitude Balloon Flight	TEAM								1-May

Fall Semester

	Lead	Aug		Sept		Oct		Nov		Dec	
Team Completely Formed	CK										
Research Design Possibilities	WS										
Conceptual Design Review	CA					1-Oct					
Preliminary Design Review	CK							1-Nov			
Cut Away Design	CK										
Parachute Design	WS										
Critical Design Review	CA									1-Dec	
Cut Away Testing	CK										
Software Design	PT/CK										
Preliminary Report	CK										7-Dec