Test Readiness Review

REPTAR
REcoverable ProTection After Reentry

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Customer: Steve Thilker, Collin Baukol, Cody Humbargar, Jason Latimer (Raytheon)

Advisor: Dr. Brian Argrow
Overview
REPTAR shall assist in the **recovery** of a de-orbited 1U Raytheon Payload. The mission begins once the SmallSat has re-entered the atmosphere and has reached subsonic velocity. REPTAR shall facilitate the subsonic **deceleration**, **landing**, **location determination**, and **location transmission** portions of the mission.

Recovery of payload enables:

- Lower mission costs by re-using the payload
- Obtain samples collected by payload on-board
1) Launch
REPTAR components survive launch conditions as payload attached to a bus.

2) Orbit/Standby
REPTAR Components survive on orbit conditions. Batteries charged by bus.

3) De-orbit
Receive command from bus to power REPTAR systems. Re-entry burn.

4) Re-entry
Receive command from bus to power REPTAR systems. REPTAR separation from bus. Re-entry completed by Raytheon System.

5) Deceleration
Decelerate to subsonic speeds.

6) Land and Recovery
REPTAR protects payload during ground contact and transmit location.

Legend
REPTAR Solution
Raytheon Solution
Raytheon
Raytheon
After being decelerated to subsonic speeds, REPTAR activates atmospheric deceleration systems to protect the payload.

Slows to safe landing speeds by deploying a parachute. Transmits location during descent.

Lands payload safely within launch loading requirements.

Transmits location during descent.

Recovery team receives location.

Transmits location to recovery element.
## Levels of Success

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Volume</th>
<th>Instantaneous G-Loading</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 1</strong></td>
<td>The volume of REPTAR including payload shall not exceed a maximum of 6U Standard</td>
<td>The payload shall endure a maximum instantaneous G-loading of less than 40 G’s</td>
<td>REPTAR shall beacon its location over a range of 20 miles</td>
</tr>
<tr>
<td><strong>Level 2</strong></td>
<td>The volume of REPTAR including payload shall not exceed a maximum of 4U Standard</td>
<td>--</td>
<td>REPTAR shall beacon its location over a range of 30 miles</td>
</tr>
<tr>
<td><strong>Level 3</strong></td>
<td>The volume of REPTAR including payload shall not exceed a maximum of 3U Standard</td>
<td>--</td>
<td>REPTAR shall beacon its location over a range of 45 miles</td>
</tr>
</tbody>
</table>
**Mission Timeline and FBD**

- **On-Orbit Standby**
  - Maintain battery charge

- **Descent**
  - Triggered by bus signal
  - Determine altitude
  - Attain GPS lock

- **Deceleration [3,500 m]**
  - Triggered by parachute deployment altitude being reached
  - Deploy parachute, bottom panel, and side panels.

- **Transmission**
  - Triggered by deployments
  - Transmit Location

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**Raytheon Interface**
- **Battery Charger**
- **Battery Pack**
- **Launch Inhibits**

**Avionics 3V3 Reg.**
- **Altimeter**
- **GPS**

**Black Powder 12V Reg.**
- **Black Powder Charge**

**Burn Wire 3V3 Reg.**
- **Kanthal Coil and Spring Deployer (x5)**

---

**Active Component**
- **Inactive Component**
Key Components

- Parachute Housing
- Side Panels
- Avionics Bay
- GPS Antenna
- Raytheon Payload
- Legs
- Iridium Antenna

Dimensions:
- 30 cm
- 10 cm x 10 cm x 10 cm
Assembly Animation

Landing Legs

Drop Test Measurement Equipment

Avionics Bay

Parachute Housing

Landing Side Panels
## Critical Project Elements

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>CPE</th>
<th>Explanation</th>
</tr>
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<tbody>
<tr>
<td>Descent</td>
<td>Parachute Deployment</td>
<td>If the parachute does not deploy and act properly, it will be nearly impossible to achieve any of the mission requirements.</td>
</tr>
<tr>
<td>Landing</td>
<td>Leg Deployment</td>
<td>The legs lower the maximum G loading the vehicle experiences. Without successful leg deployment, safe landing will not be satisfied.</td>
</tr>
<tr>
<td>Landing</td>
<td>Side Panel Deployment</td>
<td>The side panels assist in lowering the maximum G loading in the case of windy weather where the vehicle will have a horizontal velocity.</td>
</tr>
<tr>
<td>Avionics</td>
<td>Subsystem Interaction</td>
<td>Ensuring that the avionics integrate with the other subsystems will be crucial to success of the mission.</td>
</tr>
</tbody>
</table>
Executive Summary

• Changes since MSR:
  • Vibration test has been removed from schedule
    • Current system structure not fully representative of the final system
      • Thermal Protection System
      • Payload
    • Aluminum cover removed from parachute housing
      • TPS is required to protect REPTAR on-orbit

• Schedule:
  • 11 days of margin incorporated before drop test

• Budget:
  • All materials in-house or ordered
  • Drop Test is only remaining major expense
  • $622.62 margin – no overall concerns
TRR to Drop Test

- Chute Deployment Testing w/ Black Powder
- Foam Impact Testing
- Day in the Life Testing
- Antennae Testing
- EGSE and Testing Device Verification

- Full System Integration
- Integrate Side Panels to Main Vehicle
- Integrate Legs and Panel Deployment
- Integrate Board to Main Vehicle
- Integrate Battery System to Main Vehicle
- Integrate Chute System into Main Vehicle
- Integrate Antennae to Main Vehicle
- Integrate EGSE and Testing Device to Main Vehicle

- Drop Test

- 03/05/2017 TRR Due
- 03/17/2017 AIAA Paper Due
- 04/07/2017 Full System Integration

- Spring Break!
Budget
Test Readiness
## Past Testing – Descent Subsystem

<table>
<thead>
<tr>
<th>Test</th>
<th>Measurement Sought</th>
<th>Requirement Validation</th>
<th>Test Takeaway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate Load</td>
<td>Deformation due to chute deployment</td>
<td>Verifies structural integrity of base plate</td>
<td>Plate is strong enough to withstand the force of chute deployment</td>
</tr>
<tr>
<td>Drag</td>
<td>$C_d$ of Parachute</td>
<td>Validate landing speed</td>
<td>$C_d$ for undamaged parachute is within threshold, $C_d$ for damaged parachute is not</td>
</tr>
<tr>
<td>BP Ignition</td>
<td>Amount of black powder needed to eject chute from housing</td>
<td>Proves chute can be deployed using black powder</td>
<td>Parachute ejected properly 10 times out of 11 in chosen configuration</td>
</tr>
<tr>
<td>Test</td>
<td>Measurement Sought</td>
<td>Requirement Validation</td>
<td>Test Takeaway</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Leg and Side Panel Deployment</td>
<td>Percentage of time that legs and side panels deploy in 6 m/s winds</td>
<td>Validates reliability of deployables</td>
<td>Little concern about proper deployment of legs and panels</td>
</tr>
<tr>
<td>Leg Locking</td>
<td>Amount of torque needed to overcome leg locking mechanism</td>
<td>Higher torque required to overcome leg locking mechanism means lower likelihood legs fold when they impact ground</td>
<td>Torque at break was ~0.165Nm causing a screw-in design to be created for a higher tolerance</td>
</tr>
<tr>
<td>Foam Impact</td>
<td>Determine crushing characteristics of aluminum foam legs</td>
<td>Verify vehicle can be slowed to a stop while staying below 40 G’s</td>
<td>Legs compressed almost exactly as anticipated</td>
</tr>
</tbody>
</table>
# Avionics Status Dashboard

## Flight Components

<table>
<thead>
<tr>
<th>Altimeter</th>
<th>Deployments</th>
<th>Drop Test Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Int. 3V3 Reg.</td>
<td>- 12V Power Stability</td>
<td>- Accelerometer</td>
</tr>
<tr>
<td>- Resolution</td>
<td>- 3V3 Power Stability</td>
<td>- Measured Accuracy</td>
</tr>
<tr>
<td>- Accuracy</td>
<td>- 12V Power Monitor</td>
<td>- COTS Integration</td>
</tr>
<tr>
<td>- Algorithm</td>
<td>- 3V3 Power Monitor</td>
<td>- Battery</td>
</tr>
<tr>
<td></td>
<td>- Algorithm</td>
<td>- Camera</td>
</tr>
<tr>
<td><strong>Location D/T</strong></td>
<td><strong>Integration Testing</strong></td>
<td><strong>Flight Integration</strong></td>
</tr>
<tr>
<td>- Iridium UART</td>
<td>- Battery Testing</td>
<td>- I2C to MSP430</td>
</tr>
<tr>
<td>- GPS UART</td>
<td>- Battery Manager</td>
<td></td>
</tr>
<tr>
<td>- Antenna Pattern</td>
<td>- Inhibits</td>
<td></td>
</tr>
<tr>
<td>- Algorithm</td>
<td>- Day-In-the-Life (DITL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>STATUS</strong></td>
<td><strong>Complete- Success</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In Progress</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>To Conduct</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In Rework</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Failure – No Recovery</strong></td>
</tr>
</tbody>
</table>
**Day-In-The-Life (DITL) – Flight Dress Rehearsal**

**Purpose:**
To verify the integrated performance of the Avionics Hardware and Software.

**Deviations from Test Flight:**
- Black Powder Trigger will be representative load
- Altimeter Readings from EGSE
Parachute Deployment

• Setup Details:
  • Very similar to flight article

• Repeatability:
  • Follow Checklist Procedure

• Risk Reduction:
  • Increases confidence that chute will deploy

• Expected Results:
  • 0.4 g of Black Powder to Eject Chute

• Actual Results:
  • Successful Ejection: 10/11 = 90.9%
  • Successful Canisters: 34/36 = 94.4%
  • Overall Confidence of Deployment: 85.8%
Full System Drop Test
Full System Drop Test

<table>
<thead>
<tr>
<th>Scope</th>
<th>Drop REPTAR from airplane in controlled environment</th>
<th>• Requires aircraft, large drop zone</th>
</tr>
</thead>
</table>
| Rationale              | Full system drop test is the culminating test that provides proof of concept and full integration testing | • Testing high speed parachute deployment  
• Location determination during descent  
• G loading profile |
| Risk Reduction         | Reduces risk by validating in-flight performance before real flight with expensive payload | |

CU AES Senior Projects 2016-2017 : REPTAR TRR
Drop Test Logistics

• April 4th (primary date) and April 11th (backup date)

• No-go days: Surface wind of more than 30 knots (34.5 mph) or cloud clearance of less than 1000 ft from the desired drop altitude

Graph:
- Actual Flight
- Ideal Drop
- Proposed Drop 12500 ft
- Min Alt Drop 11500 ft

FR.3 - Keep safe during descent and landing
FR.4 - locatable after landing

FAA Rules and Regulations: Skydive Colorado
Drop Test Measurement Unit

- **Where?**
  - Housed where Raytheon Payload would be stored in actual mission

- **How?**
  - Accelerometer (ADXL377, +/- 200G with an error of 1G)
  - Raspberry Pi Camera

- **Quantities from the main avionics:**
  - Altitude (Altimeter)
  - Location (GPS)

- **Mass and Volume**
  - Mass: 177 g of instruments + 1157 g of ballast
  - Volume: 1U

- **Additional Measurements will be taken from the plane**
Expected G-Model

G Loading During Descent

Chute Deployment

G Loading during Landing

Percent Leg Deformation
Drift Zone and Recovery

Monte Carlo Parameters
- Initial Velocity = 32.0 [m/s]
- Initial Velocity Variance = 5.0 [m/s]
- Min Alt = 12500 [ft], Alt Variance = 200 [ft]
- Heading Range = 20 [deg]
- Pos. Variance (x) = 500 [m]
- Pos. Variance (y) = 500 [m]
- Pos. Shift (x) = -250 [m]
- Pos. Shift (y) = -250 [m]
- Wind Vel. min = 5 [kts]
- Wind Vel. Variance = 5 [kts]
- Wind Dir. min = 230 [deg]
- Wind Dir. Variance = 40 [deg]
- Chute Open Alt Min = 1900 [m]
- Chute Open Variance = 200 [m]
- Standard Deviation = 213.5 [m]
- Known Winds: 2520 2530 2540 2545
Entire drop zone is accessible for recovery

1.5km radius Reference Circle
<table>
<thead>
<tr>
<th>Quantities</th>
<th>All golden!</th>
<th>Location Transmission Fails</th>
<th>Landing Fails</th>
<th>Parachute Fails</th>
<th>All fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>G's experienced</td>
<td>37</td>
<td>37</td>
<td>52</td>
<td>840</td>
<td>840</td>
</tr>
<tr>
<td>Location Determined?</td>
<td>Yes</td>
<td>No</td>
<td>Likely</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Time to Land (s)</td>
<td>~86 s</td>
<td>~86 s</td>
<td>~86 s</td>
<td>~32 s</td>
<td>~32 s</td>
</tr>
<tr>
<td>Data survived</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Likely</td>
<td>Likely</td>
</tr>
</tbody>
</table>
Post Flight Analysis

Compare:

- G-loading experienced during flight
- Expected drift vs actual drift
- Expected time to land vs actual time to land

Review:

- Leg deployment footage
Summary of Confidence for Drop Test

• Descent System:
  • 85% confidence of parachute deployment

• Landing System:
  • High confidence that legs and side panels will properly deploy
  • 95% confidence towards aluminum foam landing characteristics
  • Concerns towards uncontrollable landing environment

• Avionics System:
  • High confidence in avionics system as designed
  • Flight environment can introduce issues in communication

• Overall:
  • Current: 81% confidence that full system will perform successfully in drop test
  • Further testing to reduce variance
Questions?
Parachute Drag Test

• Objective:
  • Determine the coefficient of drag of good and bad parachute

• Measurement Sought:
  • Force (lbs) and Wind (MPH)

• Expected Value:
  • Based on provided info from manufacturer –
    • Good parachute ~ 2.2
    • Bad parachute < 2.2

• How it Reduces Risk:
  • Higher coefficient, lower landing velocity, stay under 40 G’s during landing
  • Too high of coefficient, go over 40 G’s during deployment
Parachute Drag Test Cont.

• Results:
  • Good parachute $n = 23$, $Avg = 2.42$, $Std = 0.529$
  • Bad parachute $n = 32$, $Avg = 2.09$, $Std = 0.553$

• What This Means:
  • If parachute $Cd$ is $< 2.05$, landing is over 40 G’s
  • Bad parachute, less than 66% confident will be more than 2.05
  • Good parachute, slightly less than 66% confident will be more than 2.05
Parachute Drag Test

- Parachute shock chord will be attached to rope which will be attached to a digital scale with hook
- The digital scale will be attached to the rod of a headrest in a car
- The rope will be approximately 4 meters in length
- Team member will begin to accelerate car to 13 mph
- Team member in back seat will slowly release line of rope as parachute gets taut
- Car will stay at 13 mph, team member in back will record different values of force from scale
- Third team member will hold anemometer out window and record wind data as backseat member records force
- Comparing the velocity and force will allow calculation of the coefficient of drag of parachute
- Important because if coefficient is off, landing team must prepare for different landing speed

![Graph showing predicted drag force vs velocity]
Black Powder Tests, No Parachute

- PVC Housing created to hold ejection canister
- Pressure gauge attached to bottom of PVC Housing
- High speed camera placed on gauge
- Canister connected to 12V, 5A power supply
- Top of PVC sealed down to prevent leaks
- From Model to create 20 psi equilibrium, 0.128 g of powder needed
- Results:
  - High speed camera showed equilibrium pressure of 24 psi
  - ~17% difference in experiment and model

![Graph](image-url)
Air Compressor Test

- Pressure gauge removed
- U-bolt attached to bottom of housing
- Shock chord of parachute fed through housing and attached to U-bolt
- Parachute folded inside PVC housing
- Air compressor attached to hole where ejection canister would be
- Aluminum foil taped over top
- Some parts of experiment had small perforation in middle of foil

Results:
- 40 psi – slight emergence of parachute through middle
- 50 psi – slight emergence of parachute through side of foil
- 50 psi w/ perforation – good emergence of parachute through middle
- 80 psi – very good emergence through middle
- 80 psi w/ perforation – fully deployed through middle
Black Powder Tests With PVC Housing

• Objective:
  • Determine if parachute will deploy from PVC housing
  • Determine amount of black powder needed to deploy
  • Determine if velocity of parachute is too high

• Measurement Sought:
  • Amount of black powder needed in grams to 2 decimals
  • Velocity of parachute does not put REPTAR over 40 G’s

• Expected Value:
  • Amount of powder to be > 0.10 grams which is approximately 75 psi
    • 80 psi is what expelled parachute during compressor test
    • With 4kg REPTAR, velocity of parachute must be 80 m/s to go over 40 G’s

• How it Reduces Risk:
  • Need parachute to deploy in order to be under 40 G’s
  • Ensures REPTAR stays under 40 G’s during deployment
Black Powder Tests With PVC Housing

• Results:
  • .1 grams powder predicted to be ~75 psi instantaneous pressure
    • Did not hear ignition go off and no movement of parachute
  • .4 grams powder predicted to be ~248 psi instantaneous pressure
    • Parachute left housing, video recorded, burnt parachute
    • From video, velocity calculated to be 3.29 – 4.83 m/s

• What This Means:
  • Parachute will not cause REPTAR to go over 40 G’s
  • Need to conduct black powder test with fiberglass housing
  • 0.40 grams should be sufficient to expel parachute from housing
  • 99% confidence parachute will not cause REPTAR to go over 40 G’s
Black Powder Tests With PVC Housing

- PVC Housing with ejection canister inside
- Parachute shock chord attached to U-bolt
- Parachute folded inside of housing with recovery wadding between it and ejection canister
- Aluminum foil with small perforation in middle and taped down
- Canister attached to power supply with 12V and 5A

Results:
- .1 grams powder predicted to be ~75 psi instantaneous pressure
  - Did not hear ignition go off and no movement of parachute
- .4 grams powder predicted to be ~248 psi instantaneous pressure
  - Parachute left housing, video recorded, burnt parachute
- Could lower grams and probably still deploy
Black Powder Test Checklist

1. Fill canister with 0.4g black powder and place recovery wadding inside
2. Wipe down inside with wet rag
3. Dry inside with dry towel
4. Light sanding of inside with 600 grit
5. Lube inside with Aerokroil
6. Place ejection canister
7. Feed parachute through bottom and connect to u-bolt
8. Screw housing to wood and place in vise facing 180 degrees
9. Tape holes on back of housing with electrical tape
10. 2.5 sheets of recovery wadding placed over ejection canister
11. Lube up sides of parachute
12. Twisting parachute fold and fit inside housing, push down to make sure parachute is flush with housing surface
13. Connect power lines to canister lines and check resistance on other side
14. Connect other side to power supply and turn on power for ignition
Drop Test

- Lines placed across ECOT to give measurements of distance
- High speed camera set up with two other team members filming
- Caution tape placed to cut off courtyard from bystanders
- Parachute was as inflated as possible before drop
- Dropped from 8th story window instead of 3rd due to difficulties
- Anemometer on ground gave maximum reading of 2.2 mph
- Drift model stated 2.2 mph would provide 4 meter maximum drift
- Trouble communicating and ensuring safety of bystanders
- Once dropped, accelerated to wind speed and moved away from tower
- Minimal good data was acquired
Aluminum Plate Load Test Explanation

• Model:
  • MATLAB simulation to determine G-loading
  • Solidworks to compare deformation

• Purpose:
  • Show aluminum plate withstands impulse from parachute inflation
  • Verify model and simulations
Aluminum Plate Load Test

- Aluminum plate will be attached to railings of CubeSat
- U-bolt will be placed in center and screwed into plate
- Shock chord of parachute will be attached to U-bolt
- When parachute deploys and becomes taut it will cause approximately 40 G’s or 353 lbs of force on the aluminum plate
- Test is to ensure plate will not fracture/buckle
- Plate with railings will be suspended upside down
- A chain will be attached to U-bolt and other end will hold a ten pound plate
- Chain will be 1 meter in length
- Ten pound plate will be held against aluminum plate and dropped vertically
- If aluminum plate breaks it will need to be reinforced. If not test is a success
Load Test: Measurements

• What and how well?
  • Deformation: mm to two decimal places
  • Drop Height: in to nearest 1/16th
  • Mass of weight: kg to nearest g

• How?
  • Distance between straight edge going across plate to top of deformation with caliper
  • Tape measure in projects work shop
  • Scale from composites lab
Aluminum Plate Load Test SolidWorks

48 G’s Impulse
2” thick plate - 2.84 mm Displacement

48 G’s Impulse
4” thick plate - 2.15 mm Displacement

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10/3/17
Aluminum Plate Load Test

• Objective:
  • Determine deformation of aluminum plate due to instantaneous force from parachute becoming taut

• Measurement Sought:
  • Deformation in mm to two decimal places

• Expected Value:
  • From SolidWorks simulations, deformation is 2.80mm

• How it Reduces Risk:
  • Ensures aluminum plate and/or U-bolt does not fracture
  • Minimizes deformation that could affect antennas
Aluminum Plate Load Test

Results:
- Measured deformation to be 2.43mm
- Error could exist in method of measuring due to human error
- Error from caliper used

What This Means:
- Increased thickness to minimize deformation
- Antennas have chance of being slightly angled
- Aluminum plate will not fracture and parachute lost
- 99% confidence aluminum plate and/or U-bolt will fracture
Landing Backup
Foam Leg Drop Test

- **Objective**
  - To achieve landing velocities to determine crushing characteristics of a one leg setup as well as G-loading in a one leg scenario at a 5.7 m/s landing velocity
  - Requirement DR 3.2 The payload shall not experience instantaneous loading exceeding 40 G's

- **Measurement Sought**
  - Deformation of foam leg in the compressive direction as well as G-Load upon impact

- **Expected value**
  - Expected to deform for validation of ERG Aerospace’s projected value of 70%+ compression
  - G-Loading of 11.8 G's

- **How it reduces risk**
  - Provides verification of design to reduce G-loading below the 40 G limit requirement
Foam Leg Drop Test

• Results
  • Dropped at 1.66 m ± 0.05 m
  • Initial Leg Length: 8.00 ± 0.05 cm
  • Initial Leg Width: 1.80 ± 0.05 cm
  • Final Leg Length: 2.35 ± 0.05 cm
  • Final Leg Width: 3.60 ± 0.05 cm
  • G-Loading experienced: 29.2 G's

• What this means for our project
  • This shows that the assumption of a 65% deformation during calculations for areas and lengths required for the leg design can be upped to 70% deformation following the validation of ERG Aerospace’s claim
  • 98% due to the performance meeting expectations of foam, and increasing area would lower G-Loading experienced
Foam Leg Drop Test

• Using kinematics the proper height to drop was found
  • \( V = V_0 + at = 0 + 9.81t \)
  • \( X = X_0 + V_0t + \frac{1}{2}at^2 \)
  • \( V = 5.7 \text{ m/s} \)
  • Solving for \( X \) the leg must drop 1.66 m to achieve the proper impact velocity
Leg Locking Testing

- **Objective**
  - To determine the point of breakage for the leg locking mechanism
  - Requirement DR 3.2 The payload shall not experience instantaneous loading exceeding 40 G's

- **Measurement Sought**
  - Amount of torque held by locking mechanism housing walls

- **How it reduces risk**
  - By verifying the load required to break, the design can be altered to not allow rotation upon landing following the locking of the mechanism
Leg Locking Testing

• Results
  • The setup broke following a 0.6 kg load applied at the end of a 16.5 cm vice grip equating to a 0.165 N load

• What this means for our project
  • This caused a redesign to involve a thicker housing wall and a screw-in setup for the housing walls
  • By changing the design it upped the confidence to 99%
Leg Deployment Testing

- Objective
  - To achieve reliability numbers for deployment of the aluminum foam legs
  - Requirement DR 3.2 The payload shall not experience instantaneous loading exceeding 40 G's

- Measurement Sought
  - Number of successful deployments in both no-wind and 6 m/s wind scenarios

- Expected value
  - 95% deployment success rate

- How it reduces risk
  - Indicates the reliability of these deployments following extensive testing for their on mission deployment probability
Leg Deployment Testing

• Results
  • The setup was tested 40 times in both the no-wind and 6 m/s wind scenarios and successfully deployed in all cases

• What this means for our project
  • This verified the design of utilizing torsion springs and epoxy for deployment purposes while the legs are attached to a slotted pin
  • This result provided a confidence level of 99%
Side Panel Deployment Testing

• Objective
  • To achieve reliability numbers for deployment of the machined aluminum side panels
  • Requirement DR 3.2 The payload shall not experience instantaneous loading exceeding 40 G's

• Measurement Sought
  • Number of successful deployments in both no-wind and 6 m/s wind scenarios

• Expected value
  • 95% deployment success rate

• How it reduces risk
  • Indicates the reliability of these deployments following extensive testing for their on mission deployment probability
Side Panel Deployment Testing

• Results
  • The setup was tested 40 times in both the no-wind and 6 m/s wind scenarios and successfully deployed in all cases

• What this means for our project
  • This verified the design of utilizing torsion springs and epoxy for deployment purposes while the side panels are attached with steel pins
  • This result provided a confidence level of 99%
Avionics Backup
Altitude Determination Algorithm

EGSE Testing Components:
- Altimeter Breakout Board
- Raspberry Pi 3 EGSE

Flight Testing Components:
- MainBoard
- Raspberry Pi 3 EGSE (if MSP430FR drivers fail)
EGSE Testing Components:
- N/A

Flight Testing Components:
- MainBoard
- EGSE (if MSP430FR drivers fail)
Location Determination/Transmission Algorithm

EGSE Testing Components:
- Iridium RockBlock
- Venus GPS
- Raspberry Pi 3 EGSE

Flight Testing Components:
- MainBoard
- Raspberry Pi 3 EGSE (if MSP430FR drivers fail)
3V3 Internal Regulator

Responsible For:
- Providing power to GPS, Iridium, and MSP430FR

Hardware Tests:
- Verify Absolute Voltage Accuracy (+-5%)
- Verify Voltage Ripple (<300mV)
- Verify Current Draw (2A Max)

Software Tests:
- N/A

Off-ramps:
- Hardware: COTS Dev. Board
Altimeter

Responsible For:
- Altitude Determination with MSP430FR

Hardware Tests:
- Altimeter Correctly Mounted
- Verify Altimeter Accuracy via comparison to known standard barometer

Software Tests:
- Verify I2C Interface
- Verify Altitude Calculation (MSP430FR)
- Flight Test

Off-ramps:
- Hardware: COTS Dev. Board
- Software: Raspberry Pi 2 EGSE

10/3/17
GPS-Iridium Interface

Responsible For:
- Determining and Transmitting Location

Hardware Tests:
- Correct Electrical Connections
- Internal 3V3 Regulator Testing

Software Tests:
- Verify UART Communication to each
- Verify Parsing Code
- Flight Test

Off-ramps:
- Hardware/Software: Raspberry Pi 2 EGSE
Black Powder Trigger

Responsible For:
- Parachute Deployment

Hardware Tests:
- Power Sensor Verification via known Standard
- Trigger Logic Verification
- 12V Regulator Power Verification

Software Tests:
- Trigger logic Verification

Off-ramps:
- Raspberry Pi 3 EGSE
Kanthal Coil Triggers

Responsible For:
- Side and Bottom Panel Deployment

Critical Hardware Tests:
- Power Sensor Verification via known Standard
- Trigger Logic Verification
- 3V3 Regulator Power Verification

Critical Software Tests:
- Trigger logic Verification

Off-ramps:
- Raspberry Pi 3 EGSE
Avionics Design Changes

• Trimmed down complexity of Main Board Revision A
Avionics Development Approach

- Separate Hardware and Software Testing
- Make all testable components independently testable
- Provide as many proven offramps as reasonably possible
- EGSE can interface the Raspberry Pi 2 to all Components
- Raspberry Pi 3 is first step for software testing always
- Extensive Design work on Mainboard to separate testable elements
Manufacturing Summary

Work Completed:
• Revision A designed and (ordered/received/not ordered)

Future Work:
• (Solder any additional components?)
• Validate Revision A and decide if a Revision B is necessary
• Continue down Test Paths for subsystem validation
• Integrate Main Board in REPTAR structure
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<th>Price</th>
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<th>Price</th>
<th>Key Items Bought</th>
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<td>$293</td>
<td>Rev A</td>
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<td>Under/Over</td>
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In-plane measurements

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<th>Quantity</th>
<th>How</th>
<th>Why</th>
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<tr>
<td>Coordinates and time of the point REPTAR is dropped</td>
<td>Drop a pin using a map app</td>
<td>To calculate final drift, assist recovery</td>
</tr>
<tr>
<td>Indicated airspeed</td>
<td>Plane instruments</td>
<td>To validate wind aloft model and predict drift</td>
</tr>
<tr>
<td>Outside Air Temperature</td>
<td>OAT Gauge</td>
<td>To calculate True Airspeed</td>
</tr>
<tr>
<td>Pressure Altitude</td>
<td>Plane altimeter</td>
<td>To calculate True Airspeed</td>
</tr>
<tr>
<td>Ground speed</td>
<td>GPS</td>
<td>Compare with True Airspeed for Winds Vector Calculation</td>
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<tr>
<td>Ground track vs heading</td>
<td>Magnetic compass</td>
<td>To validate wind aloft model and predict drift</td>
</tr>
</tbody>
</table>
Expected Drift Model

Drop Height 12500 ft

Drift Distance [m]

- TOF = 86.83 s
- TOF = 31.59 s

Winds [kts]
Drift Zone and Recovery

**Full Variance 14000ft Chute Opens**

- $1\sigma$
- $2\sigma$
- $3\sigma$
- 1.5 km radius

**Full Variance 14000ft No Chute**

- $1\sigma$
- $2\sigma$
- $3\sigma$
- 1.5 km radius