RocketSat-10
Integrated Subsystems Test Review (ISTR)

University of Colorado-Boulder
04 June 2014
Purpose of ISTR:

PLEASE READ:

This review assumes
- all individual subsystems have been tested
- all hardware is in house
- all mechanical items are machined
- all individual subsystems are ready to be tested together
- a version of software is being used for the testing

After successfully completing this review, your team will be ready for the Full Mission Simulation Review (FMSR)
Presentation Outline

• Section 1: Mission Concept and Interfaces
• Section 2: Design Overview
• Section 3: Subsystem Testing Status
• Section 4: Integrated Subsystem Testing Status
• Section 5: Plan for FMSR
• Section 6: Project Schedule
• Section 7: June Operations
• Section 8: Conclusion
1.0 Mission Concept and Interfaces
Mission Overview: Mission Statement

The objective of this mission is to generate a sample of an immiscible alloy composed of Aluminum and Indium in nominal ratios to investigate the effect of solidification in microgravity on the microstructure.
Mission Overview: Success Criteria

• Minimum Success Criteria
  – Retrieval of Aluminum-Indium sample formed in microgravity
  – Verification of successful process via telemetry data
  – Generation of ground sample for comparison

• Comprehensive Success Criteria:
  – Retrieval of Aluminum-Indium sample formed in microgravity
  – Verification of successful process via telemetry data
  – Generation of ground sample for comparison
Mission Overview: Success Criteria

• Verification of Successful Process
  – Temperature verification of heating
  – Temperature verification of cooling (if needed)
  – Pressure data for environment integrity verification
  – Acceleration data for microgravity environment verification
Payload Location

- **Chance CUB will switch positions with NNU**
Activation Sequence:

<table>
<thead>
<tr>
<th>Event</th>
<th>Time On</th>
<th>Dwell</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE 1</td>
<td>T-180 sec</td>
<td>512 sec</td>
<td>NNU: Main power to payload; Power to Raspberry Pi</td>
</tr>
<tr>
<td>GSE 2</td>
<td>T-180 sec</td>
<td>512 sec</td>
<td>Main power to payload; Power to Arduino and sensor array</td>
</tr>
<tr>
<td></td>
<td>T+000 sec</td>
<td></td>
<td>Launch</td>
</tr>
<tr>
<td>TE-2</td>
<td>T+077 sec</td>
<td>250 sec</td>
<td>NNU: Power to GoPro motor carriage; Extraction and retraction of camera</td>
</tr>
<tr>
<td>TE-1</td>
<td>T+085 sec</td>
<td>45 sec</td>
<td>NNU: Rotate revolver; Power airfoil deployment system</td>
</tr>
<tr>
<td>TE-R</td>
<td>T+128 sec</td>
<td>60 sec</td>
<td>Turn on induction heater and begin heating of sample</td>
</tr>
<tr>
<td>TE-3</td>
<td>T+188 sec</td>
<td>120 sec</td>
<td>Open solenoid valve and release air</td>
</tr>
</tbody>
</table>
Pin Assignments: Power

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GSE 1</td>
<td>NNU</td>
</tr>
<tr>
<td>2</td>
<td>TE – RA</td>
<td>Activate Induction Heater</td>
</tr>
<tr>
<td>3</td>
<td>TE – RB</td>
<td>Activate Induction Heater</td>
</tr>
<tr>
<td>4</td>
<td>TE – 1</td>
<td>NNU</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>NNU</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td>NNU</td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
<td>NNU</td>
</tr>
<tr>
<td>8</td>
<td>GND</td>
<td>NNU</td>
</tr>
<tr>
<td>9</td>
<td>GSE 2</td>
<td>Power to Payload (Arduino, sensors)</td>
</tr>
<tr>
<td>10</td>
<td>TE – 2</td>
<td>NNU</td>
</tr>
<tr>
<td>11</td>
<td>TE – 3</td>
<td>Cooling activation</td>
</tr>
<tr>
<td>12</td>
<td>GND</td>
<td>Payload Ground</td>
</tr>
<tr>
<td>13</td>
<td>GND</td>
<td>Payload Ground</td>
</tr>
<tr>
<td>14</td>
<td>GND</td>
<td>Resonator Ground</td>
</tr>
<tr>
<td>15</td>
<td>GND</td>
<td>NNU</td>
</tr>
</tbody>
</table>
## Pin Assignments: Telemetry

<table>
<thead>
<tr>
<th>Telemetry Connector--Customer Side</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pin</strong></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
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</tr>
<tr>
<td>13</td>
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</tr>
<tr>
<td>15</td>
</tr>
<tr>
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</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>19</td>
</tr>
</tbody>
</table>
# Updated Power Budget

## RocketSat 10 - Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Component</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Watts</th>
<th>Time On (min)</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>Arduino</td>
<td>3.0</td>
<td>0.04</td>
<td>0.12</td>
<td>10</td>
<td>0.006667</td>
</tr>
<tr>
<td>Sensors</td>
<td>Accelerometer</td>
<td>3.3</td>
<td>0.0004</td>
<td>0.00</td>
<td>10</td>
<td>6.67E-05</td>
</tr>
<tr>
<td></td>
<td>Thermocouples &amp; Drivers</td>
<td>5.0</td>
<td>0.0003</td>
<td>0.00</td>
<td>10</td>
<td>0.000005</td>
</tr>
<tr>
<td></td>
<td>Pressure Sensor</td>
<td>5.0</td>
<td>0.002</td>
<td>0.01</td>
<td>10</td>
<td>0.000333</td>
</tr>
<tr>
<td></td>
<td>Photoresistor</td>
<td>5.0</td>
<td>0.02</td>
<td>0.10</td>
<td>10</td>
<td>0.003333</td>
</tr>
<tr>
<td></td>
<td>SD Breakout Board</td>
<td>5.0</td>
<td>0.150</td>
<td>0.75</td>
<td>10</td>
<td>0.025</td>
</tr>
<tr>
<td><strong>External Power</strong></td>
<td><strong>Battery Bank</strong></td>
<td>22.2</td>
<td>17.00</td>
<td>377.40</td>
<td>2</td>
<td>0.566667</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Over/Under</strong></td>
<td><strong>17.21</strong></td>
<td></td>
<td><strong>378.38</strong></td>
<td></td>
<td><strong>0.602117</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>0.397883</strong></td>
</tr>
</tbody>
</table>
## User Guide Compliance

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1” plane of plate?</td>
<td>YES</td>
</tr>
<tr>
<td>Weight 15.0 +/- 0.5 lbs?</td>
<td>YES</td>
</tr>
<tr>
<td>Max Height &lt; 5.35”</td>
<td>YES: &lt; 5”</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>YES</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
<td>YES</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>YES: Using 9 A/D Lines</td>
</tr>
<tr>
<td>Using/Understand Parallel Lines</td>
<td>N/A</td>
</tr>
<tr>
<td>Using/Understanding Asynchronous Line</td>
<td>N/A</td>
</tr>
<tr>
<td>Using GSE Line</td>
<td>YES, GSE 2</td>
</tr>
<tr>
<td>Using Non-Redundant PWR Lines</td>
<td>YES, TE-3</td>
</tr>
<tr>
<td>Using Redundant Power Lines</td>
<td>YES, TE-RA</td>
</tr>
<tr>
<td>Using &lt; 0.5 Ah</td>
<td>YES</td>
</tr>
<tr>
<td>Using &lt;= 28 V (High Voltage)</td>
<td>YES</td>
</tr>
<tr>
<td>Using RF</td>
<td>NO</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>NO</td>
</tr>
<tr>
<td>Whole team consists of US Persons</td>
<td>YES</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
<td>NO</td>
</tr>
</tbody>
</table>
2.0 Design Overview
Structural Changes Since STR

- No longer including resonator braces
  - Instead, re-soldering pieces into a horizontal configuration and securing directly to the mounting plate.
- Smaller steel insert volume
  - Previous volume was shown incapable of melting, so smaller volume was selected.
  - Space between new steel insert and ceramic filled with aerogel insulation.
Electrical/Software Changes Since STR

• Inhibit to be added to code/hardware
  – GSE line will set Arduino out to high
  – Output routed to input pin
  – Induction heater will NOT run if input high
• Switch from electrical relay to MOSFET
  – No more mechanical switching component
• Addition of more voltage regulators
Electrical/Software Changes Since STR
Top View No Shell

- Electronics
- Resonator
- Coolant tank
- Gasket
- Induction coil
- Coil support
- Batteries (in box)
- Cooling valve
- Crucible and sample
Isometric View with Shell
Isometric View without Shell
More Isometric View without Shell
Side View with Shell
Side View No Shell
Mass Specifications

- Current mass 14.1 lbs
- Cable mass will bring up to 15 ± 0.5 lbs
- If cooling system is removed (likely), mounting holes will be used to secure ballast.

- Current center of mass: Y = 0.04”  X = 0.12”
Hazardous Electrical Items:

• High Voltage/Current
  • 22.2VDC Lithium Ion Batteries
  • Batteries to resonator ≈17A
  • Resonator to induction coil 12VAC, ≈17A

• Induction Coil
  • Will increase in temperature as it operates

• Resonator
  • Will increase in temperature as it operates
  • Heat sink to payload deck to compensate
Payload Partnerships

• Air Force Research Laboratories (AFRL)
  – Jeff Ganley
  – Arup Maji
  – Provide support and technical assistance
  – Provide information on needed results and nature of expected results
3.0 Subsystem Testing Status
System Overview: Functional Block Diagram

- **Heating System**
  - Batteries
  - Switch
  - Voltage/Current Sensor
  - Power Resonator
  - Induction Coil

- **Power Control Board**
  - Voltage Regulators (28V to 12V) (28V to 5V)
  - Thermocouple Driver
  - Thermocouple Driver
  - Micro-Controller
  - SD Card
  - Physical Inhibit

- **Housing**
  - Accelerometer (X,Y,Z)
  - Pressure Sensor
  - Thermocouple

- **Pressure Vessel System**
  - Pressure Vessel (Air Tank)
  - Valve

**Color Codes**
- 28 V: Blue
- 22.2 V: Purple
- 12 V: Brown
- 5 V: Yellow
- 3.3 V: Orange
- <3.3V: Green
- Induction Energy: Red
- Coolant Line: Gray
- Analog Data Lines: Black

**Locations**
- **Wallop Power & Telemetry**
  - GSE 2 (28V)
  - TE-3 (28V)
  - TE-R (28V)

- **Arduino Mega**
- **Crucible/Sample**
- **Temp Paint**
- **Photodiode**

**Systems**
- Heating System
- Pressure Vessel System
- Power Control Board
- Housing

**Additional Elements**
- Induction Coil
- Photodiode
- SD Card
- Physical Inhibit
- Temperature Paint
- Thermocouple
- Accelerometer
- Pressure Sensor
- Voltage Regulators
- Induction Energy
- Coolant Line
- Analog Data Lines
Subsystem Testing Status:

Structures Subsystem

- Gasket has been tested.
- Both size and hole alignment have been confirmed
- Induction coil brace has been tested and fit has been confirmed
- Crucible has been made and fit confirmed
- Pyrex lid has been made and fit confirmed
- Battery box has been made and fit confirmed

- No testing has resulted in a failure at this point

- Shell fit has yet to be tested
- It will be tested upon the completion of manufacturing
- Tests will involve fit checks and hole alignment.
- Payload seal will also be tested and confirmed

- Tests will be completed after the shell is finished being CnC’d
Gasket Fit Check
Subsystem Testing Status:

Electrical Subsystem

- All components and sensors except the comparator circuit have been successfully tested.

- Multiple linear regulators will be used to power the board to improve voltage accuracy as shown by our testing.

- Full integration with inductor circuit will be tested within the next week to prove controls viability.

- New PCB ordered by June 5th at latest and will be tested when it arrives.
Subsystem Testing Status:
Subsystem Testing Status:

Software Subsystem

- All sensors have been tested independently and together.
- Currently populating first revision of PCB.
- Comparator has been tested but failed due to the invasion of fire ants.
- Inductor and inhibits have not been tested but will be by next week at latest.
- Have not tested corner cases in the software and will not be complete until everything is fully integrated.
4.0 Integrated Subsystem Testing Status
Integrated Subsystem Testing Status:

Electrical and Computer Science

- All sensors breadboarded with Arduino and code
- Arduino through PCB by 28V line
- Full population of the PCB and testing with Arduino will be finished by the end of the week
Integrated Subsystem Testing Status:

Structural and Electrical

- Some mounts checked for fit (induction coil and batteries)
- All components and hole alignments check out so far
- Mounts need to be finished and fit checked
- Holes for all mounts/components need to tapped and fit checked
- Complete housing and put full system together in housing
- Completion of housing during week of 6/9
- Test full system with housing in vacuum chamber/vibration
5.0 Plan for Full Mission Simulation Review (FMSR)
Mechanical Testing

- Fit check components
  - Hole alignment for plate and housing
  - Fit check of all mounts
- Test housing seal in vacuum chamber
- Vibe testing of payload at Wallops
- Tests to be performed once housing is completed (Week of 6/9)
- No mechanical inhibits needed
Electrical Testing

• Full testing of Rev 2 PCB when it arrives (will be ordered by the end of the week)
• Complete integration with Rev 2 PCB along with the induction circuit
• Physical inhibit to connect Digital Out to Digital In on Arduino
Software Testing

• Full testing of the next PCB revision.
• Integrating that with the inductor.
• Minor changes to code including unique filenames for every power cycle as well as error handling for the SD card.

• **Will be adding an inhibit for the inductor in the code.**
System Level Testing

• Final subsystem checkouts
  • Fit check of all components/mounts/housing
  • PCB and sensor checkout
  • Ardiuno and code checkout
  • Induction system battery power checkout
System Level Testing

- Integrated system checkout
  - Full electronics checkout
  - Mount all electronics to plate and check fit
  - Check for shorts across the payload/plate
  - Fit entire payload together with enclosure
- Run full mission simulation with payload
  - Check for potential across plate/housing
  - Check temperature conditions
  - Check pressure conditions
Plan for FMSR

- Structures
  - Bolt pattern implemented on flight deck and enclosure plate
  - Enclosure machined
  - Remaining mounts completed
- Electrical/Software
  - All electronics must be prepared for testing
  - Induction system run on batteries
  - All inhibits in place and functioning
- Major Hurdles
  - Enclosure manufacturing
  - PCB manufacturing
  - Managing thermal issues
6.0 Project Schedule
Burn Down Schedule

• May
  – Construction and testing of subsystems

• June
  – Weekly teleconferences: 6/3, 6/10
  – Visit from AFRL: 6/9
  – Integration of subsystems into payload
  – Testing of full payload (preliminary DITL)
  – Integration testing at Wallops (6/23 – 6/29)
    • Have payload structure built
    • Have electronic system built
    • Have command and data handling built
Burn Down Schedule

• July
  – Full Mission Simulation Review: 7/9
  – Payload testing and refinement
  – Launch Readiness Review: 7/22
• August
  – Re-vibe testing if needed (8/5)
  – Launch of payload (8/12)
7.0 June Operations
June Operations:

- RS – X GSE
  - Initial check-in will be conducting without inhibits
  - Be ready to follow procedure provided by Chris
- Sequence testing with Wallops GSE
  - Inhibit will be used to prevent activation of the induction system
  - Telemetry data will still be taken
- Vibration testing
  - Look for structural weaknesses
- Post-vibe sequence testing with Wallops GSE
  - Inhibit will be used to prevent activation of the induction system
  - Telemetry data will still be taken
June Operations:

• Induction coil and resonator will not be tested while on the rocket due to orientation and safety concerns
8.0 Conclusions
Conclusions

• Why does this mission deserve to fly?
  – High feasibility of creating an alloy in a microgravity environment
  – Looking into relatively unexplored field of immiscible alloy crystal structure formation in a microgravity environment
Design and Payload Concerns

• Magnetic Field
  – Induction coil induces current in sample for heating
  – Predicted magnetic field of \( \approx 19000 \) A/mm inside of coil
  – Magnetic field at distance of 40mm from center 0.3 A/m

• Coolants
  – Venting of gas into space surround rocket
  – Under pressure in tank (\( \approx 75 \) psi)

• Temperature
  – Expected sample temperature to reach 660\(^\circ\)C
  – Induction coil itself may experience heating from current

• Power
  – Payload runs on high voltage (12-28 V) and current (\( \approx 17 \) A)