## The Team

<table>
<thead>
<tr>
<th>Name</th>
<th>Class</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eric Qu</td>
<td>2018</td>
<td>Tuna Can</td>
</tr>
<tr>
<td>Noah Kang</td>
<td>2018</td>
<td>Tuna Can</td>
</tr>
<tr>
<td>Ethan Tsai</td>
<td>Grad Student</td>
<td>Stacer</td>
</tr>
</tbody>
</table>
1. Subsystem Requirements
2. Tuna Can
   1. Overview
   2. Major Subsystem Changes
3. Stacer
   1. Overview
   2. Major Subsystem Changes
Deployables

- Requirements
- Overview
## Requirements

<table>
<thead>
<tr>
<th>REQ ID</th>
<th>Requirement</th>
<th>Rationale</th>
<th>Parent(s)</th>
<th>Verification Method</th>
<th>Completion</th>
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<tbody>
<tr>
<td>MECH-10</td>
<td>All antennas shall be capable of deploying while ELFIN is tumbling.</td>
<td>Flow-Down</td>
<td>MSN-08</td>
<td>T/A: Thorough testing of all deployable antennas.</td>
<td>Complete</td>
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<tr>
<td>MECH-13</td>
<td>The Mechanisms subsystem shall be capable of deploying the stacer.</td>
<td>Flow-Down</td>
<td>MSN-02</td>
<td>T: Deployment tests</td>
<td>Complete</td>
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<tr>
<td>MECH-14</td>
<td>The Mechanisms subsystem shall be capable of constraining the deployables while the spacecraft is stowed, transported, and launched.</td>
<td>Flow-Down</td>
<td>MSN-02</td>
<td>I: Inspection of Development, Engineering, and Flight Model</td>
<td>Complete</td>
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<tr>
<td>MECH-20</td>
<td>The P-POD rails and walls shall not to be used to constrain deployables.</td>
<td>Flow-Down</td>
<td>MSN-11</td>
<td>I: Inspection of Development, Engineering, and Flight Model</td>
<td>Complete</td>
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<tr>
<td>MECH-24</td>
<td>The length of the stacer shall be known to at least 0.25 cm accuracy.</td>
<td>Accurate data collection from FGM</td>
<td>MSN-08</td>
<td></td>
<td>Waived</td>
</tr>
<tr>
<td>MECH-25</td>
<td>The rotation of the stacer shall be known to at least 45 degrees.</td>
<td>Accurate data collection from FGM</td>
<td>MSN-08</td>
<td></td>
<td>Complete</td>
</tr>
<tr>
<td>MECH-26</td>
<td>The bending of the stacer shall be known to at least 5 degrees.</td>
<td>Accurate data collection from FGM</td>
<td>MSN-08</td>
<td></td>
<td>Complete</td>
</tr>
<tr>
<td>MECH-27</td>
<td>The Mechanism subsystem shall be designed for a 6 month lifetime.</td>
<td>Flow-Down</td>
<td>SYS-37</td>
<td>T: Long term stowage test</td>
<td>Complete</td>
</tr>
<tr>
<td>MECH-28</td>
<td>The Mechanism subsystem shall be designed to operate at a dose of 5 krad/yr or greater.</td>
<td>Flow-Down</td>
<td>SYS-38</td>
<td></td>
<td>Complete</td>
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<tr>
<td>MECH-29</td>
<td>The Mechanism subsystem shall be SEU tolerant.</td>
<td>Flow-Down</td>
<td>SYS-39</td>
<td></td>
<td>Complete</td>
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</tbody>
</table>
Deployables Overview
Tuna Can Overview

Stowed Configuration

Deployed Configuration
Tuna Can Overview

Expanded View Assembly

LoadPath Antenna + the Rattail
Spectraline Routing
Tuna Can Overview

Spectraline Routing

Burn resistor (VU1)

Burn resistor (VU2)
• Deployment attempt 3x per orbit, beginning 3 hours after PPOD ejection
  • VU2 for first 3 orbits, then VU1 for next 3 orbits
Basic design analysis and verification

Room Temperature Deployments
(August 2016 – November 2016)
22 Deployments

Ambient Hot (+60°C) & Cold (-40°C) Case Deployments
(May 2017)
11 Deployments

TVAC Hot (+60°C) & Cold (-40°C) Case Deployments
(June 2017)
5 PSU Deployments, 2 Avionics Deployments

Post-EM1 Vibe/Shock (Delta II Qual) Deployment
(July 2017)
1 Deployment

6-Month Stowage Deployment
(February 2018)
1 Deployment

FM Room Deployments
(March 2018 – April 2018)
6 Deployments

Gathering deployment power requirements and testing avionics, electronics, and power supply

Vibe survival verification

Performing characteristic deployment leading to late design upgrade

Final check and ensuring confidence

Basic design analysis and verification
Tuna Can Deployment In Action!

- Thermal Ambient
- TVAC
- Long Term Stowage
- FM Deploy
Resistor power selection

- Two resistor sets
  - VU1: 9 V boost + 14.3 Ω resistors, 11.3 W burn
  - VU2: 5 V ringbus + 3.6 Ω resistors, 13.9 W burn

Major Changes Since CDR

- Ambient burn
- Ambient fail
- TVAC burn
- TVAC fail
- Burn power
Major Changes Since CDR

- Tuna Can structure and stowage
  - Rolls stowed tighter together
  - Antenna stowage caps and assembly jig
  - Pads + silver epoxy changed to spring fingers
Major Changes Since CDR

- Tuna Can structure
  - Element width issue
  - Tapered walls and PTFE tape
  - Deployment kick springs
Stacer
Stacer Overview

• Custom design by Kaleva Design Inc.
• 75 cm overlapping tapered helical structure
• Boom held by TiNi P10 SMA pinpuller
• 3 kick springs initiate motion
• Motion constrained by lanyard and flywheel
• Restow performed by Kaleva personnel
Operational Overview

• Nominally, only deploys on ground command
• In noncommunicative timeline, 2 week automated hail mary, attempts both channels
• Two channels on pinpuller
  • 9 V, 6 Ω, 1.5 A, 13.5 W, 26 ms pulse
  • 5 V, 6 Ω, .83 A, 4.16 W, 95 ms pulse
Stacer Failure Modes

• Jammed stacer
  • Fails mission
  • Occurs when load on P10 > 10 lbs
  • 100% occurred due to lanyard fit
  • Near certain this will not happen
    • Due to redesign

• Broken lanyard
  • Does not fail mission
  • High confidence this will not happen
    • Due to redesign

• Inadvertent deploy
  • Fails mission
  • Near certain this will not happen
    • Mechanically robust via v/s test
    • Due to software mitigations
Stacer Deployment In Action!

Good Deploy, Realtime  
Bad Deploy, Realtime  
Bad Deploy, Slow Motion  
Good Deploy, -35 C
Test Overview and late redesign

Stacer Unit 1
- Room Temp Deploy
- Sensor, harness, blanket mate
- -35 C Cold Deploy
- 6 Thermal Cycles
- Room Temp Deploys
- 3 good deploys
- Vibe/Shock
- 4 Thermal Cycles

Aug 2017

Stacer Unit 2
- Delivery in Jan 2018
- Room Temp Deploys
- Sensor, harness, blanket mate
- 3 good deploys
- 1 Thermal cycle
- Vibe/Shock
- 4 Thermal Cycles

Mar 2018

- 1 deployment attempted, failure: broken lanyard
- 3 deployments (all short, due to extra forces)
- Mate sensor/harness/blanket
- Several deploy attempts, all failure: pinpuller fails to retract
- Another deployment attempt, failure: broken lanyard. Realized design flaw.
- Redesign (both FM1 and FM2) and thicker dacron to match FM1 (only FM2)
- 3 more successful deployments on both before stowage for flight

*RED INDICATES NOT ACCORDING TO PLAN
*Purple indicates part of other test campaign
Redesign
Inherent Mission Risk

• A mechanically identical unit was tested after vibe tests for the ELFIN-Lomo campaign and deployed successfully, although their vibe profile was more benign than ours.

• Decided at a management level that it was impossible to do stacer tests after vibe/shock for ELFIN's mission due to:
  • Cost, could not afford an extra test unit, otherwise we would have in EM1
  • As cubesat, never had real requirements or test flow from LSP/integrator until we were late in our test flow campaign. This meant we could not restow after vibe/shock as originally planned, so we didn't have the time/money to mitigate this risk earlier on.

• For vacuum, we simply cannot, as deployment requires a counterweight pulley system (stacer cannot support it's own weight in gravity), that was not feasible in the tank.

• Vac is not really a concern compared to cold temperatures; this is why we tested at -35 C on one unit.
Mech-24: The length of the stacer shall be known to at least 0.25 cm

- Cannot verify
- 3 final deployments all had some variation
- Lanyard sized so stacer is 75±.5 cm
  - Thermal variations can only help
  - If lanyard broke, then we’d be beyond 75 cm
- Infer distance using onboard coils
- No risk to mission success
- Status: waived

<table>
<thead>
<tr>
<th>FM1</th>
<th>FM2</th>
</tr>
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<tbody>
<tr>
<td>75 cm</td>
<td>75 cm</td>
</tr>
<tr>
<td>74.75 cm</td>
<td>66 cm</td>
</tr>
<tr>
<td>74 cm</td>
<td>71.5 cm</td>
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*Heights for the final 3 deployments*
Questions?
Backup slides
• All antennas capable of deploying while ELFIN is tumbling
  • Burn resistors for Tuna Can antenna can deploy regardless of orientation; problem 1U CubeSats with bad CG giving high tip-off rate
    • Not really an issue for 3U CubeSats, especially since we meet the CG requirements (STRC-15 and STRC-16)

• Mechanisms subsystem shall be capable of deploying the stacer
  • Stacer deployment testing on both flight units

• Mechanisms subsystem capable of constraining deployables while stowed, transported, and launched
  • RBF inhibit screw, stacer RBF pin, antenna spectraline
• P-POD walls and rails not used to constrain deployables
  • All deployables independently constrained
• Mechanisms subsystem shall not actuate any deployables for 15 minutes after launch vehicle separation
  • Will be discussed further in C&DH presentation
• Length of the stacer shall be known to 0.25cm
• Rotation of the stacer shall be known to 45 degrees
• Bending of the stacer shall be known to 5 degrees
  • Refer to ADCS presentation for Stacer requirements
Post-Vibe Deploys

DM1 Vibe (August 2015)
DM2 Vibe (October 2015)
DM3 Vibe (March 2016)
EM1 Vibe/Shock (July 2017)
<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Status</th>
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<tbody>
<tr>
<td>232</td>
<td>Close ‘Tuna Can’ trade study; account for UV degradation</td>
<td>Resolved</td>
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<tr>
<td>233</td>
<td>Detail a more rigorous test plan for antenna deployment</td>
<td>Resolved</td>
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Close ‘Tuna Can’ trade study; account for UV degradation

• **Windform LX 2.0**
  - Passed NASA outgassing tests, good thermal properties
  - Passed VUV testing
    - Exposed to continuous VUV light for 36 hours; equivalent to 8 suns at LEO
    - No measurable erosion
• **Flight heritage**
  - KySat-2
  - TuPOD (Windform XT 2.0)
Detail a more rigorous test plan for antenna deployment

• Test objectives to determine burn time, burn temperature, resistance change from burn, and effective resistance during burn

• Tested deployment in relevant environments
  1. Initial room deployment
  2. Ambient thermal testing at -40 °C and +60 °C
  3. TVAC testing at -40 °C and +60 °C
  4. Prolonged stowage deploy
  5. FM room deploys
RFA 233 - Resolved

Thermal Ambient Deploys
RFA 233 - Resolved

TVAC Deploys
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