A Proposed Method for CubeSat Mission Risk Analysis

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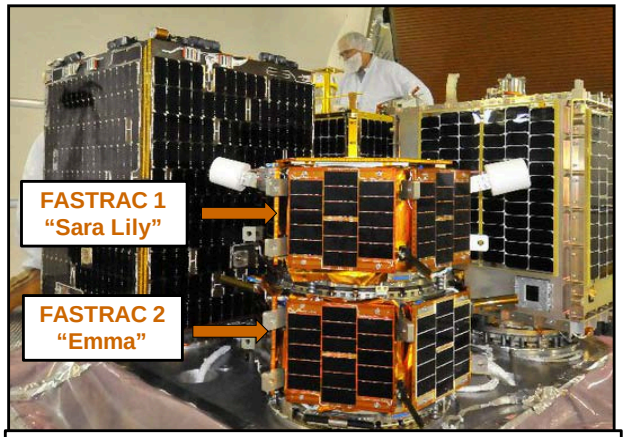
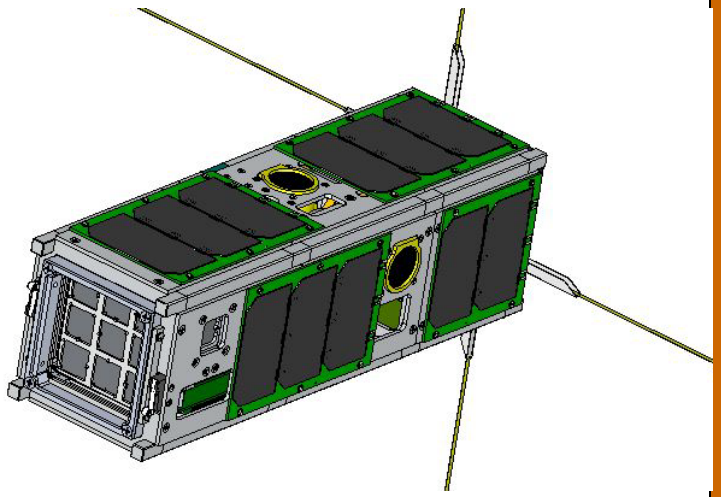
- Entirely student-led with a faculty PI (Dr. Glenn Lightsey)
- Current flight experience:
  - FASTRAC nanosatellite (25 kg each), still operational, launched in Nov. 2010
  - Bevo-1/Paradigm (1U) launched in July 2009
- On the horizon:
  - Bevo-2 (3U) w/ NASA-JSC & Texas A&M
    - Delivery to NASA in Oct. 2013
    - To be flown on CRS-4, April 2014
  - ARMADILLO (3U) w/ Baylor University
    - University Nanosatellite Program winner, Jan. 2013
    - Selected for ELaNa in Spring 2012 (to be manifested)
  - RACE (3U) w/ JPL
    - Providing spacecraft bus for radiometer mission
    - To be flown on CRS-4, April 2014
  - INSPIRE (3U) w/ JPL
    - Providing thruster; collaboration with other organizations
    - To be flown on interplanetary trajectory
- Risk Management never truly applied until ARMADILLO & Bevo-2



FASTRAC Satellites Mated on STP-S26.
Credit: U.S. Air Force photo by Lou Hernandez



Steps of a Detailed Risk Management Plan

Main Step	Sub-steps
A. Identify Risks	1. Start with the mission concept of operations 2. Identify root causes 3. Classify priority of risk 4. Name responsible party 5. Rank likelihood and consequence of root cause 6. Describe rationale for ranking 7. Compute mission risk likelihood and consequence values 8. Plot mission risks on L-C chart
B. Determine mitigation techniques	Choices consist of: 1. Avoid the risk by eliminating root cause and/or consequence 2. Control the cause or consequence 3. Transfer the risk to a different party or project 4. Assume the risk and continue in development
C. Closely monitor progress	Plot the mission risk values on an L-C chart at key design milestones to see progress.

THE ISSUE

Brumbaugh, K., Lightsey, E.G., "A Risk Management Plan for CubeSats." AIAA Space 2012, Pasadena, California. 11-13 September 2012.

Rank likelihood and consequence

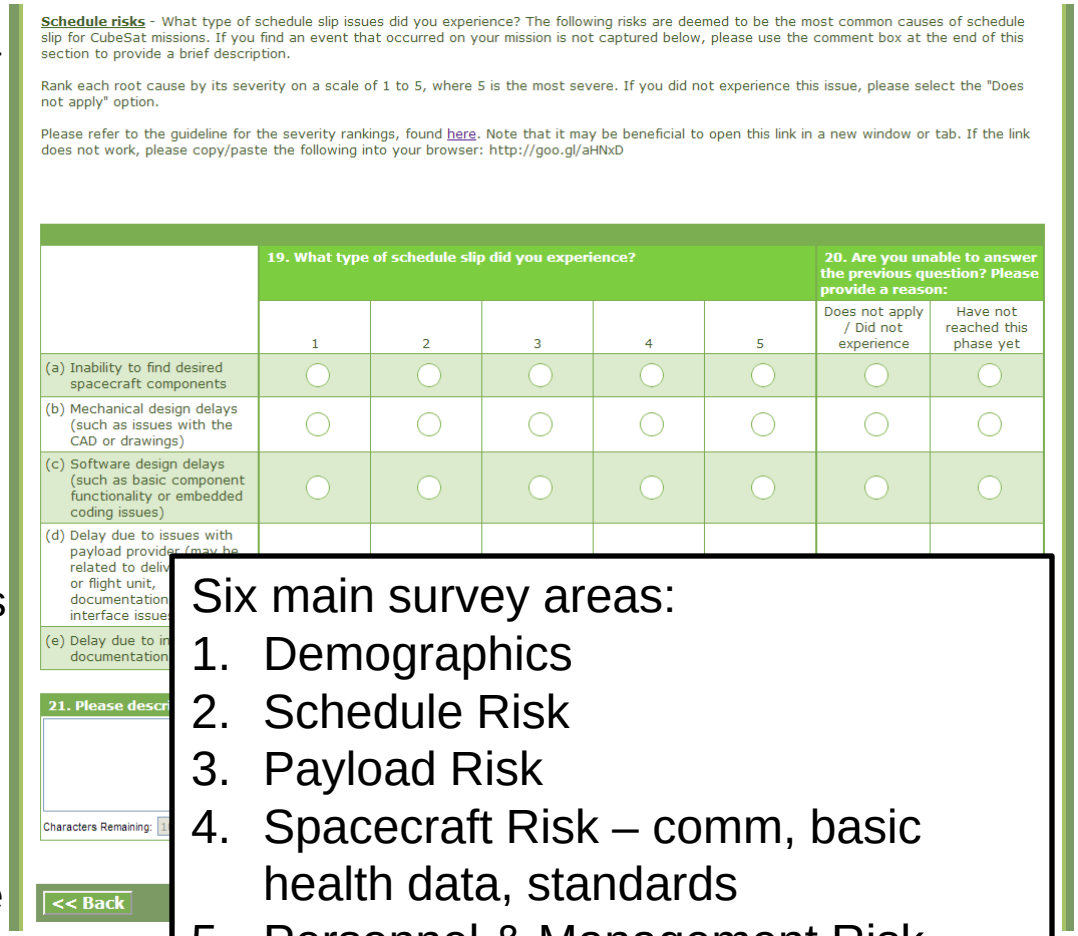
- DoD Guide to Acquisition chosen because consequence scale much more detailed
- Current methods of ranking are highly subjective to systems engineer with help of subsystem/task leads

Level	Likelihood	Probability of occurrence
5	Near Certainty	~90%
4	Highly Likely	~70%
3	Likely	~50%
2	Low Likelihood	~30%
1	Not Likely	~10%

Level	Technical	Schedule	Cost
5	Severe degradation in technical performance; cannot meet key technical/supportability threshoold; will jeopardize program success	Cannot meet key program milestones	Exceeds budget threshold (10 % of budget)
4	Significant degradation in technical performance or major shortfall in supportability; may jeopardize program success	Program critical path affected	Budget increase or unit production increase (10% budget)
3	Moderate reduction in technical performance or supportability with limited impact on program objectives	Minor schedule slip. Able to meet key milestones with no schedule float	Budget increase or unit production cost increases (5% of budget)
2	Minor reduction in technical performance or supportability, can be tolerated with little or no impact on program	Able to meet key dates	Budget increase or unit production cost increases (1% of budget)
1	Minimal or no consequence to technical performance	Minimal or no impact	Minimal or no impact

Proposed Solution – statistics-based L-C scales

- **Now:**
  - Gathering CubeSat missions & contact information
  - Developed survey to capture events & issues experienced
- **Immediate future:**
  - Develop and generate statistical models to analyze results
  - Use results to determine "Risk Estimating Relationships" similar to CER's in cost models
- **End-result:**
  - Software tool to help CubeSat developers identify, manage, and mitigate risks
  - Results published in aggregate (no published mission identification)



Schedule risks - What type of schedule slip issues did you experience? The following risks are deemed to be the most common causes of schedule slip for CubeSat missions. If you find an event that occurred on your mission is not captured below, please use the comment box at the end of this section to provide a brief description.

Rank each root cause by its severity on a scale of 1 to 5, where 5 is the most severe. If you did not experience this issue, please select the "Does not apply" option.

Please refer to the guideline for the severity rankings, found here. Note that it may be beneficial to open this link in a new window or tab. If the link does not work, please copy/paste the following into your browser: http://goo.gl/aHNxD

	19. What type of schedule slip did you experience?					20. Are you unable to answer the previous question? Please provide a reason:	
	1	2	3	4	5	Does not apply / Did not experience	Have not reached this phase yet
(a) Inability to find desired spacecraft components	○	○	○	○	○	○	○
(b) Mechanical design delays (such as issues with the CAD or drawings)	○	○	○	○	○	○	○
(c) Software design delays (such as basic component functionality or embedded coding issues)	○	○	○	○	○	○	○
(d) Delay due to issues with payload provider (may be related to deliv or flight unit, documentation interface issue							
(e) Delay due to in documentation							

21. Please descr

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Six main survey areas:

1. Demographics
2. Schedule Risk
3. Payload Risk
4. Spacecraft Risk – comm, basic health data, standards
5. Personnel & Management Risk
6. Cost Risk

Let's walk through the survey…

- Participate with me today, and you'll get a prize!
- Survey takes approx. 15 min.
- Participate at any time, and you'll get access to the analysis and results when completed.

  NOTE: Results will be published in aggregate – no single organization will be identified by name or mission in publications.

  NOTE: Anonymous surveys will be accepted, but may be treated differently in statistical analysis

  NOTE: Separate surveys for each mission are necessary; multiple surveys per single mission okay if from different team members
- All links may be found on the ARMADILLO website in the Systems Engineering section: http://goo.gl/veM7d
- Contact Katharine with questions: katharine.m.brumbaugh@utexas.edu

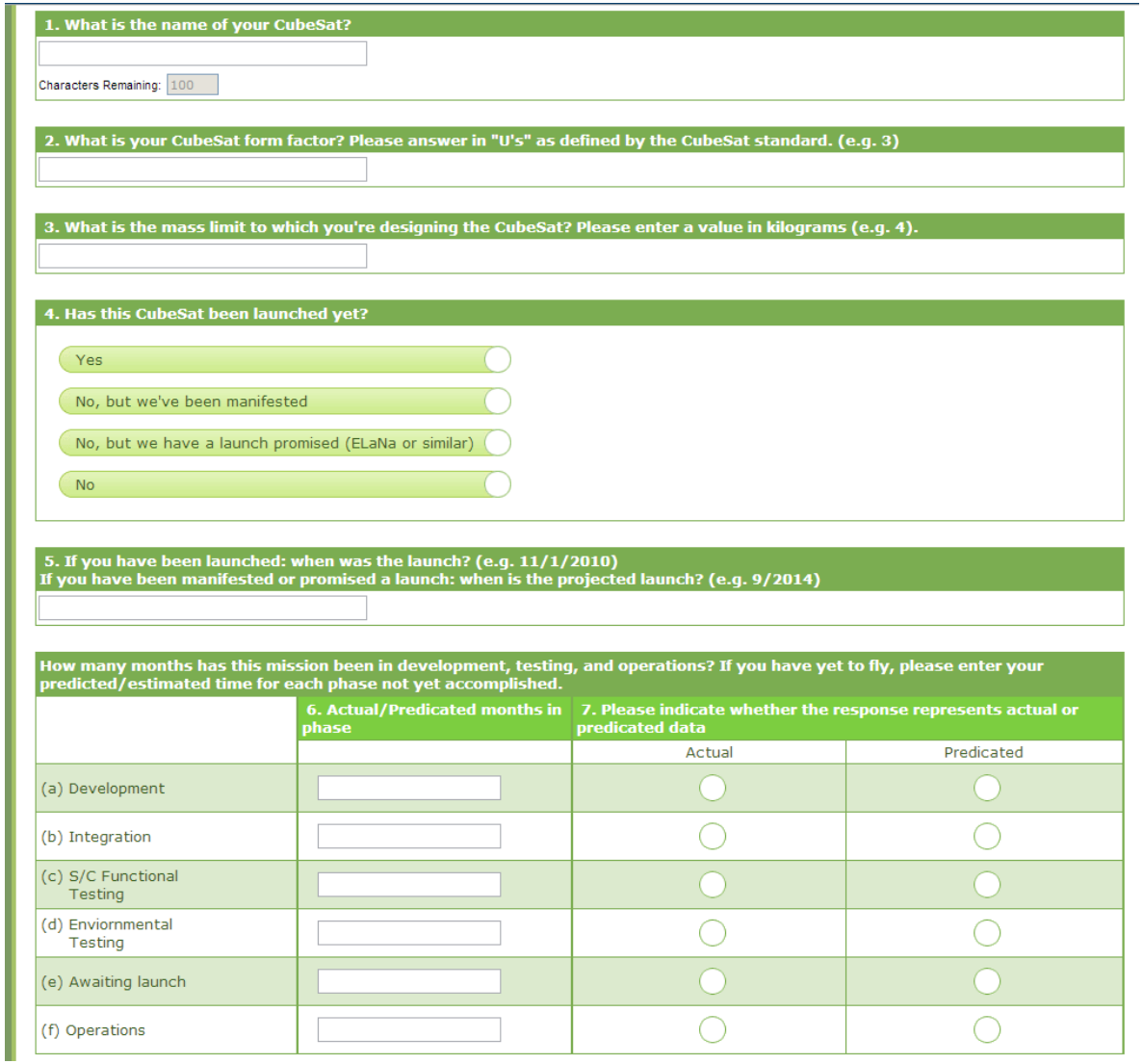
Survey (option to save and continue later)
http://goo.gl/Y8Z14

Consequence criteria (PDF)
http://goo.gl/aHNxD

Survey Companion Guide (PDF)
http://goo.gl/qKFgB

Demographics (1/4)

Basic information to categorize data



1. What is the name of your CubeSat?

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2. What is your CubeSat form factor? Please answer in "U's" as defined by the CubeSat standard. (e.g. 3)

3. What is the mass limit to which you're designing the CubeSat? Please enter a value in kilograms (e.g. 4).

4. Has this CubeSat been launched yet?

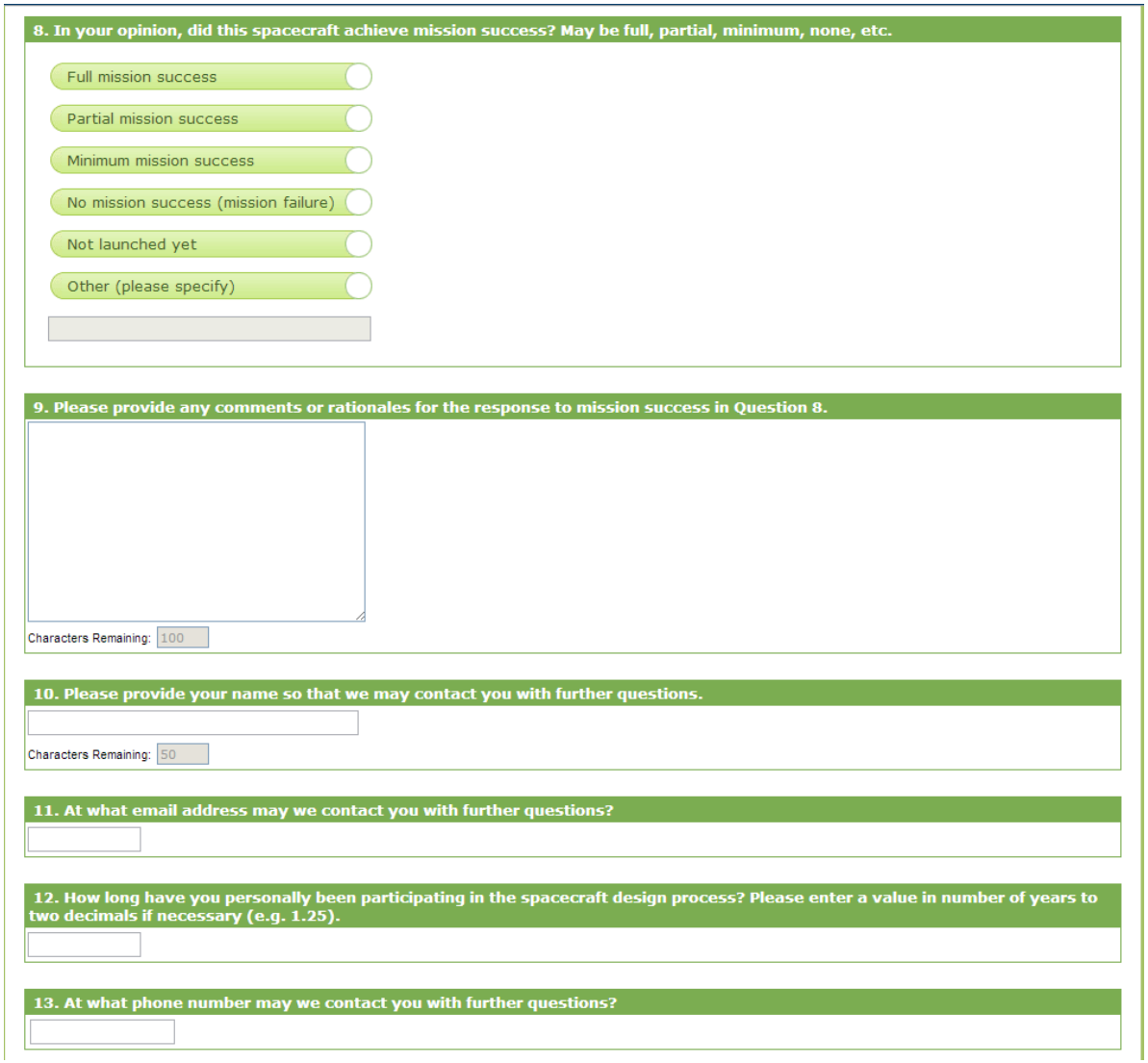
- Yes
- No, but we've been manifested
- No, but we have a launch promised (ELaNa or similar)
- No

5. If you have been launched: when was the launch? (e.g. 11/1/2010)
If you have been manifested or promised a launch: when is the projected launch? (e.g. 9/2014)

How many months has this mission been in development, testing, and operations? If you have yet to fly, please enter your predicted/estimated time for each phase not yet accomplished.

	6. Actual/Predicated months in phase	7. Please indicate whether the response represents actual or predicated data	
		Actual	Predicated
(a) Development			
(b) Integration			
(c) S/C Functional Testing			
(d) Enviornmental Testing			
(e) Awaiting launch			
(f) Operations			

Demographics (2/4)



8. In your opinion, did this spacecraft achieve mission success? May be full, partial, minimum, none, etc.

- Full mission success
- Partial mission success
- Minimum mission success
- No mission success (mission failure)
- Not launched yet
- Other (please specify)

9. Please provide any comments or rationales for the response to mission success in Question 8.

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10. Please provide your name so that we may contact you with further questions.

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11. At what email address may we contact you with further questions?

12. How long have you personally been participating in the spacecraft design process? Please enter a value in number of years to two decimals if necessary (e.g. 1.25).

13. At what phone number may we contact you with further questions?

Demographics (3/4)

Information to categorize experience of respondent

Demographics (4/4)

Information to categorize lab/organization

17. Please indicate the approximate percentage of the team representing each of the following demographics: (e.g. Professionals - 1; Undergraduates - 74; Graduate - 25; Other - 0)

Note: Total should equal 100%. If it does not, the values will be normalized.

Professionals

Undergraduate students

Graduate students

Other

Total

18. What is the funding level of this spacecraft?

If a question does not apply to your mission, please enter "N/A".

(a) Is this spacecraft a funded activity? (Yes/No)

(b) What organization is providing funding?

(c) What is the nature of the funding? (e.g. competitive award, non-competitive award, internal funds)

(d) What is the total funding level of this mission? (please provide units)

(e) For how many years is the funding provided?

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Clear answers on page

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17%

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Schedule Risks

- Need to use Consequence Criteria
- Offers “N/A” options

Schedule risks - What type of schedule slip issues did you experience? The following risks are deemed to be the most common causes of schedule slip for CubeSat missions. If you find an event that occurred on your mission is not captured below, please use the comment box at the end of this section to provide a brief description.

Rank each root cause by its severity on a scale of 1 to 5, where 5 is the most severe. If you did not experience this issue, please select the "Does not apply" option.

Please refer to the guideline for the severity rankings, found here. Note that it may be beneficial to open this link in a new window or tab. If the link does not work, please copy/paste the following into your browser: http://goo.gl/aHNxD

	19. What type of schedule slip did you experience?					20. Are you unable to answer the previous question? Please provide a reason:	
	1	2	3	4	5	Does not apply / Did not experience	Have not reached this phase yet
(a) Inability to find desired spacecraft components	○	○	○	○	○	○	○
(b) Mechanical design delays (such as issues with the CAD or drawings)	○	○	○	○	○	○	○
(c) Software design delays (such as basic component functionality or embedded coding issues)	○	○	○	○	○	○	○
(d) Delay due to issues with payload provider (may be related to delivery of EDU or flight unit, documentation, or interface issues)	○	○	○	○	○	○	○
(e) Delay due to inadequate documentation	○	○	○	○	○	○	○

21. Please describe any additional schedule issues which were not listed above.

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Payload Risks

Payload risks - What type of payload issues did you experience? The following events are deemed to be the most common causes of issues with the CubeSat mission payloads. If you find an event that occurred on your mission is not captured below, please use the comment box at the end of this section to provide a brief description.

Rank each root cause by its severity on a scale of 1 to 5, where 5 is the most severe. If you did not experience this issue, please select the "Does not apply" option.

Please refer to the guideline for the severity rankings, found here. Note that it may be beneficial to open this link in a new window or tab. If the link does not work, please copy/paste the following into your browser: http://goo.gl/aHNxD

	22. What type of issues did your spacecraft experience with the payload during mission operations?					23. Are you unable to answer the previous question? Please provide a reason:	
	1	2	3	4	5	Does not apply / Did not experience	Have not reached this phase yet
(a) Software interface issues between payload and spacecraft bus	○	○	○	○	○	○	○
(b) Hardware/electrical interface issues between payload and spacecraft bus	○	○	○	○	○	○	○
(c) Payload malfunction due to mechanical issues	○	○	○	○	○	○	○
(d) Payload malfunction due to software issues	○	○	○	○	○	○	○

24. Please describe any additional payload issues which were not listed above.

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Spacecraft Risks (1/2)

Spacecraft risks - What type of spacecraft bus issues did you experience? The following risks are deemed to be the most common causes of issues with the CubeSat spacecraft bus (i.e. no payload). If you find an event that occurred on your mission is not captured below, please use the comment box at the end of this section to provide a brief description.

Rank each root cause by its severity on a scale of 1 to 5, where 5 is the most severe. If you had the component on the spacecraft, but did not experience this issue, please select the zero (0) option. If you did not have the component on the spacecraft, select the N/A option.

Please refer to the guideline for the severity rankings, found here. Note that it may be beneficial to open this link in a new window or tab. If the link does not work, please copy/paste the following into your browser: http://goo.gl/aHNxD

	25. Inability to communicate with spacecraft: What issues caused your ground station to be unable to communicate with the spacecraft once in orbit?					26. Are you unable to answer the previous question? Please provide a reason:		
	1	2	3	4	5	Have not reached this phase yet	Did not include in s/c design	Included in s/c design, but event did not occur
(a) No frequency on which to communicate with spacecraft due to delay in receiving frequency allocation.	○	○	○	○	○	○	○	○
(b) Failure of spacecraft radios (due to either hardware or software issues)	○	○	○	○	○	○	○	○
(c) Failure of spacecraft antennas due to improper deployment or activation.	○	○	○	○	○	○	○	○
(d) Failure of ground station radios (due to either hardware or software issues)	○	○	○	○	○	○	○	○
(e) Failure of ground station antennas (due to either hardware or software issues)	○	○	○	○	○	○	○	○

	27. Inability to gather health data from spacecraft: What issues caused the spacecraft to be unresponsive or the data to be unhelpful?					28. Are you unable to answer the previous question? Please provide a reason:		
	1	2	3	4	5	Have not reached this phase yet	Did not include in s/c design	Included in s/c design, but event did not occur
(a) Failure of flight computer (due to either hardware or software issues)	○	○	○	○	○	○	○	○
(b) Failure of sensors gathering health data (due to either hardware or software issues)	○	○	○	○	○	○	○	○
(c) Failure of actuators causing unstable spacecraft motion (due to either hardware or	○	○	○	○	○	○	○	○

Spacecraft Risks (2/2)

(d) Failure of power regulation/battery system (due to either hardware or software issues)	○	○	○	○	○	○	○	○
(e) Failure of solar panels to generate power (due to either hardware or software issues)	○	○	○	○	○	○	○	○
(f) Unexpected thermal environment caused system issues	○	○	○	○	○	○	○	○
(g) Unexpected vibration environment caused system issues	○	○	○	○	○	○	○	○

	29. Inability to meet spacecraft standards: Many international standards exist for spacecraft design, development, launch, and operations. Please identify any issues related to these tasks which your mission experienced.					**30. Are you unable to answer the previous question? Please provide a reason:**		
	1	2	3	4	5	Have not reached this phase yet	Did not include in s/c design	Included in s/c design, but event did not occur
(a) Spacecraft will not de-orbit within 25 years after end-of-life	○	○	○	○	○	○	○	○
(b) Spacecraft bus does not meet in-house requirements (i.e. dimension, mass limits, structural/thermal analyses)	○	○	○	○	○	○	○	○
(c) Spacecraft does not meet on-orbit launch and release mechanism provider requirements (i.e. waiting to beacon and deploy antenna)	○	○	○	○	○	○	○	○
(d) Mission does not supply required documentation as requested by launch and release mechanism providers	○	○	○	○	○	○	○	○

31. Please describe any additional spacecraft bus issues which were not listed in the previous three questions.

Personnel and Management Risks

Personnel and Management risks - What type of personnel and management issues did you experience? The following risks are deemed to be the most common personnel and management issues with the CubeSat missions. If you find an event that occurred on your mission is not captured below, please use the comment box at the end of this section to provide a brief description.

Rank each root cause by its severity on a scale of 1 to 5, where 5 is the most severe. If you did not experience this issue, please select the "Does not apply" option.

Please refer to the guideline for the severity rankings, found here. Note that it may be beneficial to open this link in a new window or tab. If the link does not work, please copy/paste the following into your browser: http://goo.gl/aHNxD

	32. What issues did the mission experience from a personnel and management perspective?					33. Are you unable to answer the previous question? Please provide a reason:	
	1	2	3	4	5	Does not apply / Did not experience	Have not reached this phase yet
(a) Loss of information (due to configuration management issues or computer malfunction)	○	○	○	○	○	○	○
(b) Loss of hardware (perhaps due to uncontrolled access to lab environment and hardware)	○	○	○	○	○	○	○
(c) Lack of sufficient training for team members completing flight qualification necessary tasks.	○	○	○	○	○	○	○
(d) Attrition or turnover of team members	○	○	○	○	○	○	○
(e) Sudden loss of crucial team members (due to either personal or work/school reasons)	○	○	○	○	○	○	○

34. What requirements does your team place on its team members in order to work on the project? In other words, for student teams: does your lab enforce a GPA requirement? For industry teams: does your company enforce a certain amount of required experience?

Characters Remaining: 100

Captures organization's selection method

35. Please describe any additional personnel and management issues which were not listed above.

Characters Remaining: 100

Cost Risks

Cost risks - What type of cost issues did you experience? The following risks are deemed to be the most common cost issues with the CubeSat missions. If you find an event that occurred on your mission is not captured below, please use the comment box at the end of this section to provide a brief description.

Rank each root cause by its severity on a scale of 1 to 5, where 5 is the most severe. If you did not experience this issue, please select the "Does not apply" option.

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	36. Building a spacecraft is expensive. Please identify which cost risks your mission experienced.					**37. Are you unable to answer the previous question? Please provide a reason:**	
	1	2	3	4	5	Does not apply / Did not experience	Have not reached this phase yet
(a) Incomplete understanding of the projected total mission cost	○	○	○	○	○	○	○
(b) COTS component prices increase	○	○	○	○	○	○	○
(c) Inability to obtain new research grants or funding.	○	○	○	○	○	○	○
(d) Delay of receiving promised funding	○	○	○	○	○	○	○

38. Please describe any additional cost issues which were not listed above.

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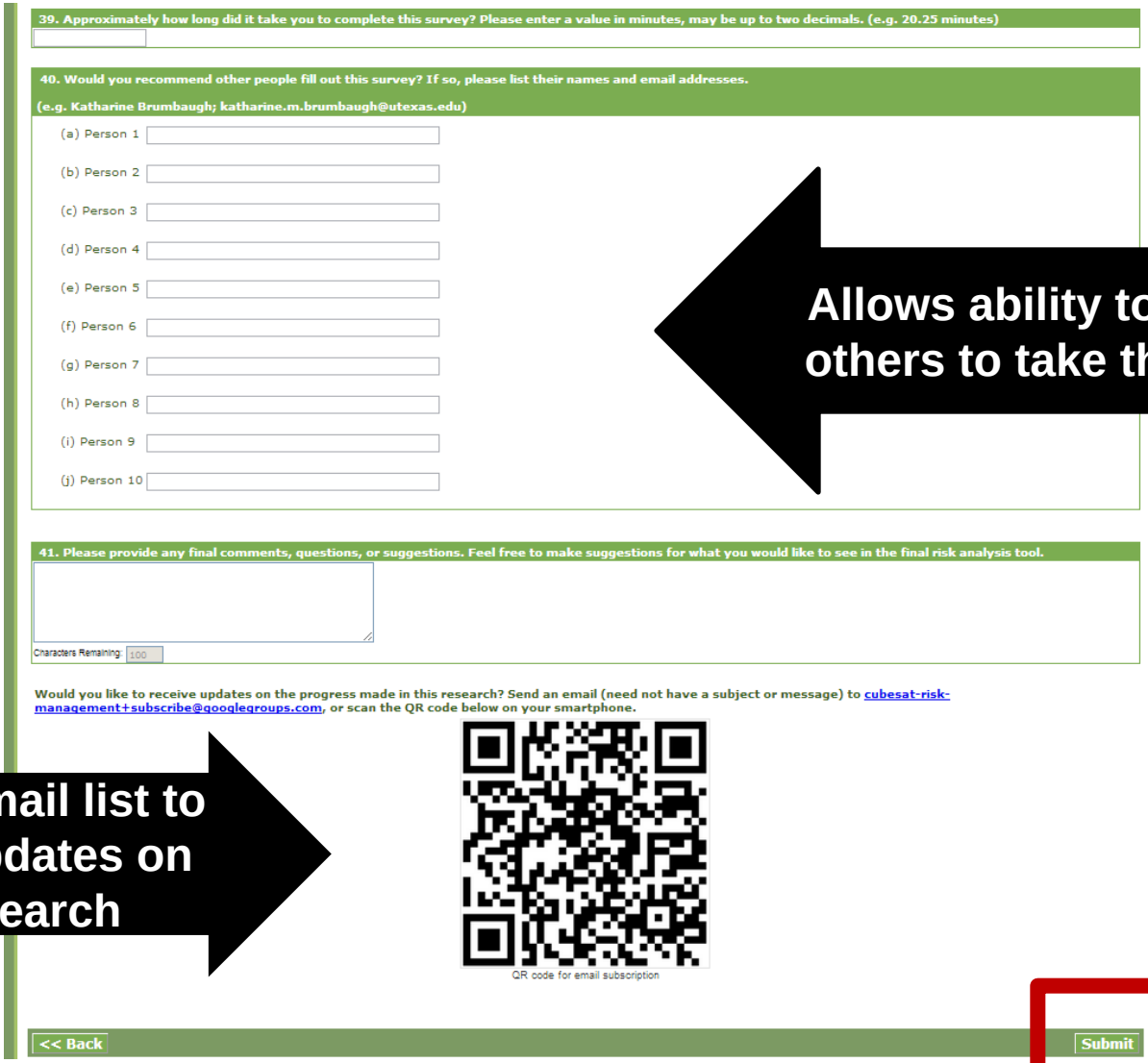
Finish & Submit!



Allows ability to suggest others to take the survey

Join the email list to receive updates on the research

Thank You!

- Participate with me today, and you'll get a prize!
- Participate at any time, and you'll get access to the analysis and results when completed.

  NOTE: results will be published in aggregate – no single school will be identified by name or mission in publications.
- All links may be found on the ARMADILLO website in the Systems Engineering section: http://goo.gl/veM7d
- Contact Katharine with questions: katharine.m.brumbaugh@utexas.edu

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