FY17 BIG Idea Challenge
Questions/Responses for the Q&A Session, October 6, 2016

Judges comment on project scope.

The project is a concept study and preliminary design that should focus on modular design and robotic assembly of a tug. Some mission analysis is expected to articulate the concept of operations for your design for LEO to LRDO transits. Design analysis at a sufficient fidelity to validate your design concept is expected. Detailed designs, detailed analyses, and test approaches are not required.

<u>SEP Tug Specs</u>

1. **Does NASA offer information on how the current SEP tugs operate and where can we find it? Will we be provided any spec sheets of the SEP tug that is to be constructed?**
    a. There are no SEP-tugs currently operating – you are helping us design the future. There have been several studies on space tug needs, including orbital transfer. The student teams are encouraged to do some research in support of their proposed concept for an orbital transfer vehicle. The Big Idea challenge is looking for innovative ideas from the student teams. There is no current base line to operate from, the students have the opportunity to be the designers and creators.

2. **What size modules have been deployed into LEO before, and what rockets were employed for those launches?**
    a. ISS is one system that was assembled over 40 flights with tele-operated robotics, but ISS used the Shuttle and a SEP-Tug vehicle are expected to be smaller. Students are encouraged to look at commercial launch vehicle capabilities such as the Falcon Heavy, Atlas, or Delta rockets within this project.

3. **What is the biggest issue encountered with the current design of the SEP tug?**
    a. The biggest issue with any space system is cost, which can be directly related to payload mass or necessary launch shroud volume. NASA wants to develop durable systems with an operational life of ten years, design modularity, and operational refurbishment. All of these factors have an impact on reduced cost.

4. **What is the required lifespan of the tug? (i.e., how many years are the SEP tugs expected to stay in service and/or how many round trips to the transfer orbit)?**
    a. Some studies point to a 270-day transit time; 2 years for a round-trip coming back to LEO and rendezvousing with cargo to repeat the mission. Most of our space systems are designed to operate for 10-15 years. For the FY17 BIG Idea Challenge, target a SEP tug which could complete at least 5 round trips over a 10-year period as a design goal.

5. **Does the tug need to have life support systems and other necessities to support human life on board, or will it be completely autonomous?**
    a. NASA envisions a fully robotic system without the need for human presence so no life support system is required as part of the design.

6. **What are typical maintenance requirements for an SEP tug in orbit?**
    a. A routine maintenance expectation is refueling the electric propulsion system.

7. **Should the tug have a fail-safe for power loss or mechanical failure?**
    a. All spacecraft have a fail-safe, point toward the sun mode (navigation, etc.). Students are encouraged to address basic levels of redundancy for critical systems required for space operation.

<u>Materials</u>

1. **Is there any kind of materials limitation?**
    a. Part of the research challenge for the competition is using state-of-the-art materials for space exploration applications. Although some materials have proven space durability, weigh, cost need to be balanced against benefits. More advanced materials, including composites, have the benefit of reduced weight, but students should make the case why a specific material is chosen in the design any consideration for manufacturing cost and maturity for the intended design application.

<u>Budget</u>

1. **Are there any budget restrictions?**
    a. There are no budget restrictions for the vehicle and students are not required to do cost estimates.

1. **What types of loads will the SEP tugs encounter?**
    a. Acceleration loads - You are in benign environment, the SEP thrust level will give you max acceleration for the tug. Maneuvers will be small, but you need to account for acceleration loads from LEO to Lunar orbits
    b. Thermal loads/performance – radiators that project heat. Worry about distortion from solar arrays (hot on one side, not on the other) if these are driving cases.

2. **What kind of payload will the tug be carrying?**
    a. Crewed vehicle supplies in cis-lunar space (LDRO) – power systems; etc. Modular payloads. Think about maritime industry and containers – now we have container shipping – modular containers carrying cargo. Think about the SEP tug payload that can be packaged in one container and manipulated in the SEP tug in a similar system. Or, think about a telescope configuration – L2 orbit on other side of the moon – telescope is a likely cargo.

3. **What are the maximum dimensions and mass of the payload?**

   This is governed by the volume of the launch vehicles. You should assume commercial launch vehicles. http://spaceflight101.com/spacerockets.

4. **How does the payload need to attach to the tug? (i.e., what types of connections are needed)? Will it fit in a module, or does it need to dock externally?**
   a. Automated rendezvous and docking with some kind of docking mechanism is expected to be part of the design challenge. This could include a robotics capability where the cargo is berthed to the tug.

Assembly

1. **Are we responsible for the casing of the components?**
   a. You've got to be able to disassemble the stowed modular SEP tug from the launch vehicle and then reassemble it into the operational configuration based on your design.

2. **Are external assembly devices allowed, or does it have to self-assemble?**
   a. Autonomous capabilities are the requirement - it's up to you to choose what makes sense; fixed-base robotics, spider robot(s), free-flying robots, etc.

3. **What existing un-manned assembly capabilities will we be able to utilize?**
   a. ISS is expected to cease operations around 2024 and we need the SEP tugs to last beyond that, so don't rely on ISS. There are no other in space robotics platforms that will be available, so any required platform will need to be launched either with the SEP tug vehicle or separately. This needs to be included in the trade space as the number launches required will effect total cost.

4. **How "futuristic" can the concept of operations for robotic assembly be? The requirements specify that the components should be launched on currently available launch systems, but how far should we look forward in terms of currently developing assembly concepts?**
   a. We're looking for new ideas and approaches. Be futuristic, while using concepts that could exist in the mid 2020's time frame that do not add considerable risk. Consider commercial services – that's the emphasis.

5. **Can the robotic assembly utilize resources already in orbit (ISS, other satellites), or should it be a completely independent system?**
   a. It should be independent of existing assets.

6. **By what means can we account for ground testability of the assembly process?**
    a. Ground testing details and testability is outside of the scope of this competition. It's certainly worth including some analysis, but not at the cost of your systems design.

<u>Packaging and Launch</u>

1. **Is there a specific shape preferred for packaging? Specific launch vehicle? Specific fuel?**
    a) Use the commercially available launch systems. Fuel is dependent on your choice of electric propulsion – it is best to focus on the available launch systems and payload capacities. Figure out how it connects with the commercial launch system. Volume and mass of current vehicles is on the web. (<u>http://spaceflight101.com/spacerockets)</u>

<u>Power</u>

1. **What specific types of solar panels are used and how much power is generated per square meter? What is the weight per square meter of solar panel? Is there a target value for the volume that could be transported by the completed system?**
    a. We encourage you to use the latest and greatest and incorporate that into your designs creatively – don't spend a ton of time devising your own. You are encouraged to research 2 state-of-the-art solar arrays:
        i. Orbital space systems "ROSA" – 25 kw levels is baseline
        ii. Ultra SLUX (built by ATK) – Used in Government Applications, 25 kw rays (module for a larger array); you may need more of them for a 200 kw SEP tug.

2. **Is 200KW the amount of power that the tug needs to produce from solar power in total, or is it the maximum amount of power that is required by the thrusters?**
    a. 200 KW should be available to drive the Hall thrusters. You'll probably need an additional 10-15 KW to power onboard avionics. Take note of beginning of life vs. end of life power; after 10 years it should still have close to 200 KW available for thrusters.

3. **Are we able to store power for use to provide the required Delta Vs, when they are required? This would mean having a small solar array capable of producing 20kW for example, but having the full 200kW available after charging.**
    a. Yes, you always need to have some storage capabilities for avionics for onboard operations. Storage capability is good.

4. **Can we use existing solar array technologies such as Deployable Space Systems' roll out solar arrays (ROSA) or should we develop our own?**
    b. Yes, use of existing technologies is encouraged. A fact sheet on SEP can be found here: https://www.nasa.gov/mission_pages/tdm/sep/index.html

5. **Specifications of ion thruster (size, power usage, heat generated)**
    a. You'll have to do the research on that (Hall thrusters) – See documented work at the Glenn Research Center

6. **Are you looking for innovation in the ion engines, or is it ok to use normal ion engines?**
    a. The focus of the challenge isn't to redesign ion engines; it's to focus on modularity. Please use existing, state-of-the-art SEP designs.

7. **Does the tug need to be 100% solar powered, or can it have a propellant based reaction control system (e.g.: hydrazine)**
    a. It's fine to have some attitude control system with hydrazine if you need to. Note that commercial satellites are moving to all solar-powered attitude control systems.

8. **Will the space tug utilize Hall Thruster technology?**
    a. That's the baseline. However, if you have a compelling argument, we're open to options.

<u>Miscellaneous</u>

1. **"Fundamental Flexible body vibration mode should be 0.05 Hz or higher" - what does that frequency mean? What part does the frequency pertain to? Does the "fundamental flexible body vibration mode" refer to the fundamental frequency of the structure?**
    a. Do analysis of your design to determine the lowest frequency natural vibration mode of the SEP tug
    b. 0.05 HZ frequency is the lowest we can have to not interfere with attitude control system.

2. **Is there a time constraint on the maximum amount of time that the tug takes to transfer from LEO to LDRO? What is the maximum time allowed?**
    a. No maximum but a 1 year or less is a reasonable target.

<u>Proposal</u>

1. **How far along the design process is appropriate for the proposal?**
    a. As much as you're able to contribute at the time that it's due will increase your chances of advancing. The judges are looking for original analysis and engineering and unique and novel, unprecedented designs. Remember that more innovation may require more risk analysis of why you chose that option.

2. **What level of detail should our CAD drawings include?**
    a. Don't go into manufacturing level of detail, but you need sufficient detail to validate your design concept and communicate your design. For example, electrical systems are more at a system block diagram than a schematic level,

but mechanical design needs to be at a fidelity for you to do first order FEM analysis.

3. **Is it recommended to propose or include concepts or technology that haven't been fully developed and/or tested?**
   a. Try to use existing technologies, but be innovative. If your design / concept needs a new technology, that's fine but explain why. You really need to understand the risk/value proposition of the new technology and be convinced that the payoff is worth the risk.

4. **What kind of testing should be conducted by teams to prove that the design meets performance requirements?**
   a. Computer models and simulations for key aspects that have a lot of uncertainty can be a good means of reducing design uncertainty. If a physical model is designed and tested this could add credibility to your design concept, but this is not required.

5. **Can we assume the following topics are accounted for?**
   a) Flux from the Sun: This will decrease as the Tug gets farther from Earth and the power constraint should account for this change.
   b) There are standard chemical rockets that could be used for launch: You should assume commercial launch vehicles. http://spaceflight101.com/spacerockets
   c) The material of the hull and electrics for safe passage through the Van-Allen Belt: Yes, your design should be durable for 10-years of operation in the space environment from LEO to LDRO.

<u>During Call</u>

1. **It was mentioned in the announcement that it should be scalable to 500 Kw for future deep space missions. Do we see any scaling in acceleration or vibrations, or should we assume the same modes?**
   a. You can use the same acceleration levels and fundamental frequency.

2. **Would you prefer black box designs "This will be the component of the SEP tug, but we'll focus on the assembly?"**
   a. If you can say the black box has been flown and these are the kinds of things that are in this black box, it is OK to use it. Don't develop the detailed avionics systems. The challenge is focused around modular design and in-space assembly.

3. **More specifics on LDRO orbit and what range that is with respect to the moon?**
   a. It changes every few years, but if you target a 60,000 km orbit around the moon, you'll be good.

4. **A general idea of the scope / depth for orbital mechanics for space tug and transfer orbits. What's in scope vs. out of scope?**
    a. If you have the tools, optimization of size and orbit parameters would be useful. It would be good to know the number of round trips your tug could do in a 10 year life (this parameter could be useful in trading off different designs). It is certainly within scope, but not the primary piece we are evaluating.

2. **Can we use smaller ion propulsion thrusters working synchronically?**
    a. Depends on your design. That may work well for your modular design

5. **What is meant by TRL?**
    a. That's a common scale used by NASA and the Department of Defense to measure a technology's maturity level. It stands for "Technical Readiness Level." TRL is described in the NASA Systems Engineering Handbook (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080008301.pdf) in Appendix G.

6. **Specifications on assembly orbit? Can we assume a generic LEO assembly orbit from Cape Canaveral, FL?**
    a. Yes – you can choose the one that works best for you. Probably standard, but different commercial launch vehicles may have different orbits.

7. **Do we need to prepare a contingency for replacing module mid-transit from LEO to LDRO?**
    a. No, not in transit. One advantage of modularity is still being useable in transit after a module failure. It may take longer, but still works. Explore the possibility of replacing it at either end (LEO or LRDO).

8. **There are a lot of state-of-the-art solar panels that are not yet flight-tested. Should we use ones that are already rated, or can we assume they would be space flight ready in 5-10 years?**
    a. If you want to propose an alternative solar array that's fine – but it does insert risk in your design. The risk/value proposition should be compelling.