Potential Missions to Jovian Moons

First take a few minutes to read about the mission on the piece of paper we've handed out to you. You'll discuss this mission with the rest of your table using the questions below:

1. Which mission did your table discuss?

2. Which Jovian moon would this mission go to? What type of mission is it (orbiter/lander/other)?

3. What are the mission's main science objectives? What type of science is it best suited to address (e.g. biology vs. geology)?

4. How does the mission address the habitability of the moon the mission would study?

5. When planning a mission, NASA cares tremendously about the risk associated with it, in particular how reliable the technology aboard is. How risky is this mission?

6. Is there anything you would add or take away from this mission to make it more scientifically useful? To make it less risky?

Names:

Jigsaw Discussion

1. Each person should present about their mission, highlighting the type of mission, its main science objectives, and associated risk.

   Afterwards discuss the following questions…

2. Which of the missions addresses habitability the best and most directly? How so?

3. Which mission is the most risky? Which is the least risky?

4. Is there scientific payoff with choosing to send a riskier mission? Do you see any connection between risk and cost?

5. Pretend that you work for NASA and are in charge of choosing which mission is funded and sent to the outer solar system. Taking both scientific goals **and** risk into account, which mission would you choose to send? Why?

6. Now that you've discussed these potential missions to the Jovian moons, come up with an idea (e.g. new instrument/measurement) to add to one of these missions. How would your idea affect the scientific objectives? Would it make the mission more or less risky?

Dragonfly

<u>Destination:</u> Titan **<u>Cost:</u>** roughly $800 million - $1 billion
<u>Description:</u> *Dragonfly* is a rotorcraft (think quadcopter drone) that would be sent to Titan. Over the course of a Titan day, *Dragonfly* can fly to another region on Titan. It would then land and begin science. During Titan nights, the craft would recharge. Despite its ability to fly, most of *Dragonfly*'s science would be done on the ground. It is more a relocatable lander than an aircraft.

<u>Three main science objectives:</u>

1) Sample material on Titan's surface to determine its chemical composition. In particular search for biologically relevant compounds and traces of processes that produce organic materials. Would also use spectrometers to determine composition of the surface.
2) Use meteorology sensors to monitor atmospheric and surface conditions, and better understand the weather on Titan. It would also study Titan's methane cycle and try to detect seismic activity (to study Titan's interior structure).
3) The craft would have cameras to scout Titan's surface while flying, mapping surface geology and determining future landing sites. In-air science is not the mission's primary objective.

<u>Technical Risk:</u> While we know it would be easy to fly on Titan due to its low gravity and dense atmosphere, we have never done so before. We have, however, landed on Titan (the *Huygens* probe). A relocatable lander is new technology, but we are sure energy would not be an issue. In the event relocation of the craft cannot be done, it can still perform much meaningful science.

AVIATR: Aerial Vehicle for In situ and Airborne Titan Reconnaissance

<u>Destination:</u> Titan **<u>Cost:</u>** roughly $750 million
<u>Description:</u> AVIATR is a drone plane that would be sent to Titan. AVIATR would fly around Titan, remaining on its dayside, to image and study Titan's surface and atmosphere. Over its mission lifetime of 1 year, AVIATR would repeatedly image Titan's surface to generate high definition global maps, and study changes in Titan's wind/weather over time.

<u>Three main science objectives:</u>

1) Produce high definition global maps of Titan's surface. By imaging the same areas of Titan multiple times, stereo-imaging-created topographic maps will be generated to better understand the surface geologic structure.
2) Produce profiles of Titan's atmosphere and winds through time by climbing through the atmosphere once per Earth day. AVIATR will also have instruments to detect rain and study the atmospheric composition, albeit without direct sampling.
3) Use remote sensing to better determine surface/lake composition, and attempt to detect molecules/compounds indicative of ethane- or water-based life.

<u>Technical Risk:</u> While we know it would be easy to fly on Titan due to its low gravity and dense atmosphere, we have never done so before. This mission would be entirely dependent on our ability to fly through Titan's atmosphere. The instrument suite consists of well-used and understood technology.

TiME: Titan Mare Explorer

Destination: Titan **Cost:** roughly $450 million
Description: TiME is a sea craft that would be sent to Titan to land in one of its hydrocarbon oceans (Ligeia Mare). TiME would then float on the surface of the sea, studying both lake and shoreline properties. TiME would have no propulsion, drifting on the sea from the expected weak wind and currents. This would be the first nautical exploration of an extraterrestrial body.

Three main science objectives:

1) Determine the composition and structure of Titan's seas. TiME would look for signs of biology (complex organics, molecular structure) or processes involving prebiotic material (how does an environment lead to life). TiME would also study sea depth and conditions.
2) Study the atmosphere of Titan directly above the sea surface. In particular, how does the sea and atmosphere interact? TiME would improve understanding of Titan's methane cycle, and how the sea and atmosphere interactions change over the course of a Titan day.
3) Using cameras, TiME would monitor the shoreline and how it is affected by the processes in the sea. It would also study sea surface processes. This would aim to address the interactions between the sea, atmosphere, and land in regards to the methane cycle.

Technical Risk: TiME is designed around well-used and understood technology. Its descent would be similar to the *Huygens* probe, but we have never landed in an extraterrestrial sea before. The conditions of Titan's seas, however, are expected to be quite calm.

ELF: Enceladus Life Finder

Destination: Enceladus **Cost:** at least $450 million
Description: ELF is a spacecraft that would orbit Saturn and fly through Enceladus's plumes to sample the plume material. ELF is based on the *Cassini* mission, which sampled Enceladus's plume albeit with old technology. ELF's main objective is the habitability of Enceladus. The mission would potentially include a camera to image Enceladus's surface during flybys.

Three main science objectives:

1) Determine in detail the composition of Enceladus's plume, in particular to assess its evolution (through particular molecules) and habitability (e.g. pH and temperature of the ocean).
2) Look for direct evidence of present day life under the surface of Enceladus. Examples include the types of organic molecules present (pattern to the number of carbons in organics?), amino acids and their handedness, and isotope ratios.
3) Coupled with a camera, take high resolution images of Enceladus's surface during flybys to study the geologic structure/activity simultaneous with plume samples. This would help link the plume characteristics (e.g. density) with properties of the surface (heat, etc.).

Technical Risk: ELF is a direct descendant of the *Cassini* mission, and designed around well-used and understood technology. We have sampled Enceladus's plume before. Ensuring no Earth-life contamination of the instruments would be necessary.

Europa Clipper

Destination: Europa **Cost:** $1-2 billion
Description: The *Europa Clipper* is a spacecraft that would orbit Jupiter to perform almost 50 close flybys of Europa. It would not orbit Europa directly due to strong radiation from Jupiter's magnetic field. With its suite of 8 instruments, *Europa Clipper* would map Europa's surface, sample material around the moon, and confirm the presence of a subsurface ocean.

Three main science objectives:
1) Produce high resolution maps of Europa's entire surface to study its geologic features and aid in choosing a landing site for a future Europa lander. It would also use infrared observations to find and characterize areas of ongoing activity on Europa's surface.
2) Study the surface composition and chemistry of Europa using remote sensing spectroscopy. The *Europa Clipper* would also sample material in Europa's thin atmosphere to determine its composition. This composition would be connected to ocean composition and habitability.
3) The *Europa Clipper* would also confirm the presence of the subsurface ocean and determine Europa's internal structure. Using radar, the mission would be able to detect variations in the thickness of the ice crust, and find possible subsurface lakes near the top of the ice crust.

Technical Risk: We have performed similar flyby missions of Jovian moons before (including *Galileo* around Jupiter). An orbiting mission is well understood. The instrument suite consists of technology both previously used in planetary missions and state of the art (unused/untested).

ELSE: Europa Lander and Subsurface Explorer

Destination: Europa **Cost:** at least $1 billion
Description: ELSE would be sent to Europa to touch down on its surface and drill/melt into its ice crust to study the moon's subsurface. ELSE would be a relatively short mission (~20 days) due to its power source and the strong radiation on Europa's surface from Jupiter's magnetic field. It would be primarily focused on the habitability of Europa, and a true technological feat.

Three main science objectives:
1) Determine the internal structure of Europa. ELSE would include a seismometer to detect Europa-quakes and map internal layers. Determining the thickness and properties of the ice layers, and presence of a rocky core, is necessary to assess habitability.
2) Determine the composition of Europa's surface using direct samples, and search for signs of biology (such as organic molecules, building blocks of life, isotopes).
3) Deploy a probe to descend into Europa's ice shell. This probe will determine composition and structure of the thin outer ice shell, or reach subsurface water and test for active biology. This would be the most direct and likely way to detect extraterrestrial life.

Technical Risk: Without detailed maps of Europa's surface and its topographic features, landing on its surface would be risky. While we are fairly sure of the presence of subsurface water, we do not know Europa's internal structure precisely. Thus, we can not be certain a drill would reach any subsurface water. Ensuring no contamination of the lander would be of utmost importance.