Call For Prototypes:
Robots in Search of Extraterrestrial Life

Fall 2017 - KNW 2300 - Introduction to Engineering Design

"Is there life in our Solar System?"

1. Introduction

The NASA New Horizons spacecraft recently completed its mission of a fly-by past Pluto. The entire journey, from launch to the first images taken of Pluto, lasted 9.5 years. The mission would have taken several more years were it not for a strategic gravity assist around the planet Jupiter. By swinging around the massive planet in an extremely precise trajectory, the spacecraft significantly increased its velocity towards Pluto. During that time, the probe took pictures of Jupiter and several of its moons, giving scientists a better understanding of the surface of these celestial bodies.

There was one unexpected result. A team managing the spacecraft has identified a previously unknown Jovian moon, and the Hungarian born team leader names it "Zoltan". The probe data indicates with an unfortunately high degree of uncertainty that the surface temperature, due to internal volcanic warming, may be in the range to support liquid surface water. In addition some spectral analysis indicates an atmosphere containing oxygen and hints at the presence of organic molecules.

Because of its relative proximity to the Earth and the potential for organic life, NASA has declared that its newest high-priority mission will be to send an autonomous probe to Zoltan. The main goal is to learn about the surface of the moon: is there water? If so, what is the concentration of the water in the soil? What is the wind speed at the surface? What is the surface temperature? If these surface attributes fall within habitable ranges, additional probes can be sent in the future to better examine the organic makeup of the surface.

2. The Challenge

This probe will consist of two main components: an autonomous rover that will explore and test the surface of the moon, and a satellite that will deploy said rover and other supporting hardware to the surface. A critical piece of the supporting hardware that will be deployed to the surface along with the rover is a small lightweight bridge to allow the rover to pass over an abrupt canyon on the Zoltanian surface. NASA has agreed to build the satellite component, but has chosen to sponsor a competition to determine the best design for both a planetary rover and a lightweight bridge. NASA has chosen to fund 16 teams of multidisciplinary students from SMU who will participate in this competition[1].

To simulate the conditions on the Zoltanian surface, NASA has chosen to create a two-faceted competition field located on the SMU campus. The field has been set up to mimic the surface, including target areas of environmental investigation and terrain obstacles. While the robotics system itself is very important, NASA is also concerned with the aesthetic qualities of the robot (including weight) as well as the overall reputation of the teams participating in the challenge. NASA will indicate its view of the aesthetic qualities of the robot and team reputation through a metric known as the Coefficient of Confidence.

The goal of the competition will be to establish the best robot performance for navigation and environmental sensing.The temperature and wind speed probe for your candidate robot (see below for details) must be elevated above the Zoltanian surface by an extendible boom design in order to isolate these measurements from the surface conditions. Your rover robot must also demonstrate the capability of delivering a small, lightweight radio beacon in the vicinity of soil measured to exhibit a high water content. This beacon will mark the location of high water content of interest to future exploration missions. Since the moderate Zoltanian temperature is maintained by internal volcanic activity, and surface obstacles such as rocks may be in motion in response to planetary vibrations, your robot must also demonstrate a capability to navigate around unexpected obstacles.

In addition, the candidate bridge design must be demonstrated as capable of robustly supporting the rover robot over a representative canyon for many runs. As this bridge is intended for space flight, NASA is especially interested in your team's ability to minimize the bridge mass. An evaluation formula will be used, detailed below, that will **strongly emphasize** bridges that have been carefully designed with internal structures such as trusses that minimize material use.

The competition will take place in the inside atrium on the first floor of Caruth Hall. Each match will consist of the robots from two teams competing simultaneously.

The first half of the competition is a rover challenge. The goal for each match is to accrue the highest number of match points based on the point schedule in Table 1. The matches are structured such that teams that gather the most points with the highest degree of consistency will have the most success. The rover challenge will be in two main rounds, preceded by a seeding round:

- **Seed**: There will be a seeding round during lab on the week of the competition. Every team is guaranteed to compete on the day of the competition, but who you will compete

[1] Note that this is a hypothetical scenario. At no point will NASA, SMU or the Professorial staff actually provide monetary incentives for participating in this challenge or class.

against will be determined by the success of the seeding round. Each team will run individually.

- **Tournament**: Based on the seeding round, pairs of teams from KNW 2300 will compete in two five-minute matches against each other, each match starting from alternate sides of the playing field. The total number of points from both matches are totaled for each team, and this point total decides the winning team for each competition in a bracket tournament. The overall tournament winning team will be crowned the Rover Challenge Winner! The Professorial Staff will treat the winning team to a special dinner[2].

The second half of the competition is a bridge design challenge. The goal is to test the limit of the designed lightweight bridges produced by the teams. Immediately following the rover challenge, bridges will be loaded to failure. The team with the bridge that can hold the greatest load normalized to its mass by the equation: $\frac{load}{mass^2}$ will be crowned bridge champion.The Professorial Staff will treat the winning team to a special dinner[2].

3. The Field

The playing field (for graphical representation, see Figure 1 below) will have the following dimensions and attributes (note that your robot should take into account minor variances/error rates with every dimension listed below):

- Your robot will start in one of two predetermined starting boxes, clearly delineated on Figure 1. You will not know which starting box you will be placed in until right before the match.
- Certain portions of the outer perimeter of the playing field will be outlined with rigid barriers, approximately 28 cm high, as an aid to robot navigation. Navigation walls will also be present at certain boundaries interior to the field. A map of the locations and lengths of the navigation walls is provided in Figure 1.
- The field will contain two “regions of interest (ROI).” Your robot is to explore these regions and test for pre-assigned environmental attributes.
- The first ROI will be the “elevated air region”, which will rest on an elevated surface. This surface will be elevated 15cm off the ground, and be an area measuring 90cm x 90cm. To reach this surface, your robot will climb a ramp that is 45 centimeters long, having a carpet-like surface. Having climbed the ramp, your robot will elevate an anemometer and temperature sensor package on your boom to a height of at least 75cm above the base of the robot. Your robot will test for both temperature and a wind speed condition, and report the values it measured. The nominal route to this ROI is shown in blue in Figure 2.
- The last ROI will be the “surface water region”, which will be a container filled with some mixture of sand and water. The size of the container will be determined at a later date, but will be fairly large. The container will be filled with sand, which will be mixed with an

[2] This will be at the location of the winning team’s choosing. The Professorial staff have full veto power over any choice of restaurant, for any reason.

undisclosed amount of water. Your robot will test this region for surface water through the use of a conductivity probe. The nominal route to this ROI is shown in blue in Figure 2.

- For the purpose of this competition the radio beacons will be modeled with ping pong balls. Your robot must be designed with an accessible ball receptacle, which will be loaded with one “beacon” in the starting box, and is required to store the ball as it runs the competition course. You must then release the “beacon” into the sand container if the measured conductivity exceeds a given threshold.
- Another (known) obstacle in your path is a canyon. A bridge (designed and constructed by your team) will be placed before each match so that the outside edge of the bridge is colinear with the outside barrier of the demonstration field. (see Figure 1).
- Between the regions of interest your robot will encounter various obstacles, and must be capable of navigating around them. The first barricade will be found directly at the bottom of the ramp to the elevated air region, as shown in the diagram. Your robot is to detect the presence of this barricade and safely idle indefinitely until it is removed. This is indicated with a blue ✢ in Figure 2. When the barricade is removed during the competition, your robot must sense this and then proceed up the ramp and continue the course.
- The second dynamic navigation task will be in the region between the raised platform and the canyon. As shown in the figure, a path to the canyon will be available only through a gap in the wall structure on each side of the course that is 30 inches wide. Although the location of the gap relative to the static walls will remain stationary while your robot is running its course, the gap may be relocated each time your robot *leaves its starting box*. Your robot may find the gap in the wall to be anywhere from abutting the bottom wall to within 15 inches from the edge of the ramp down from the platform.

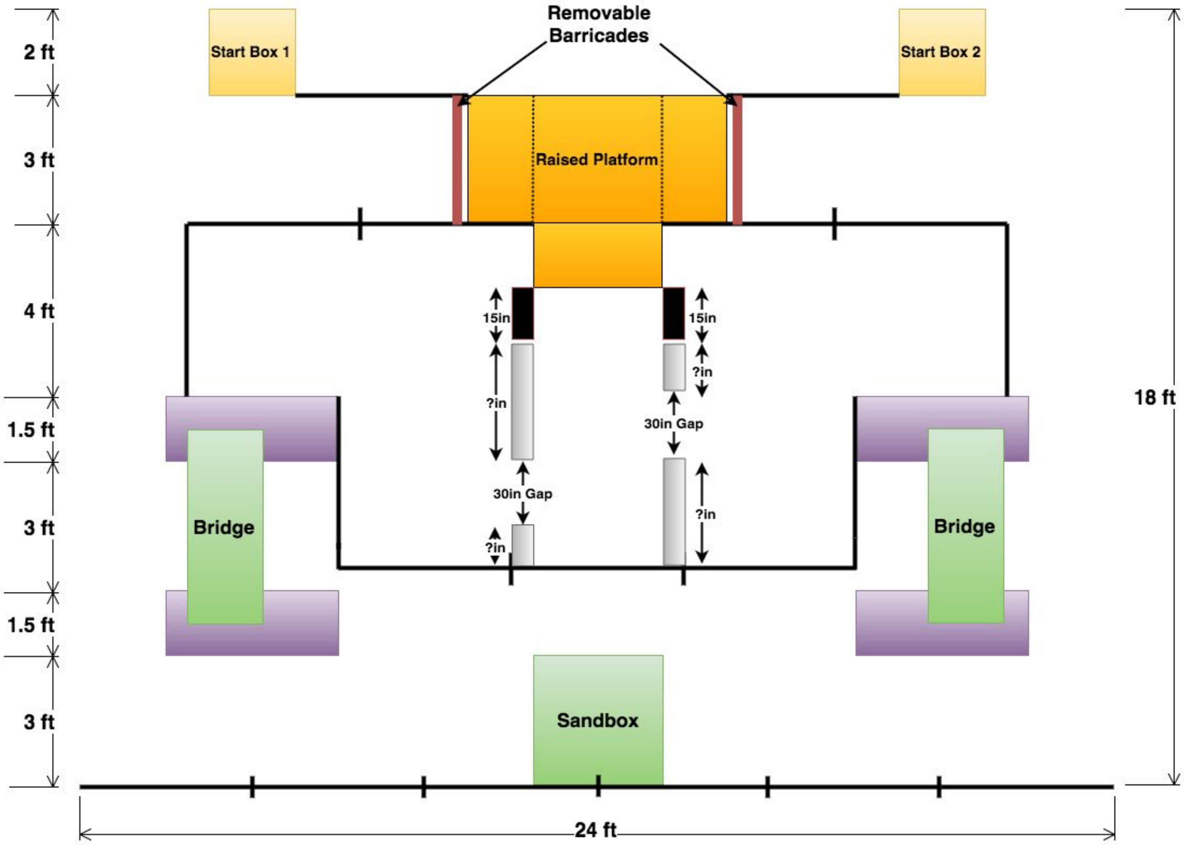

Figure 1: Schematic plan view off the playing field

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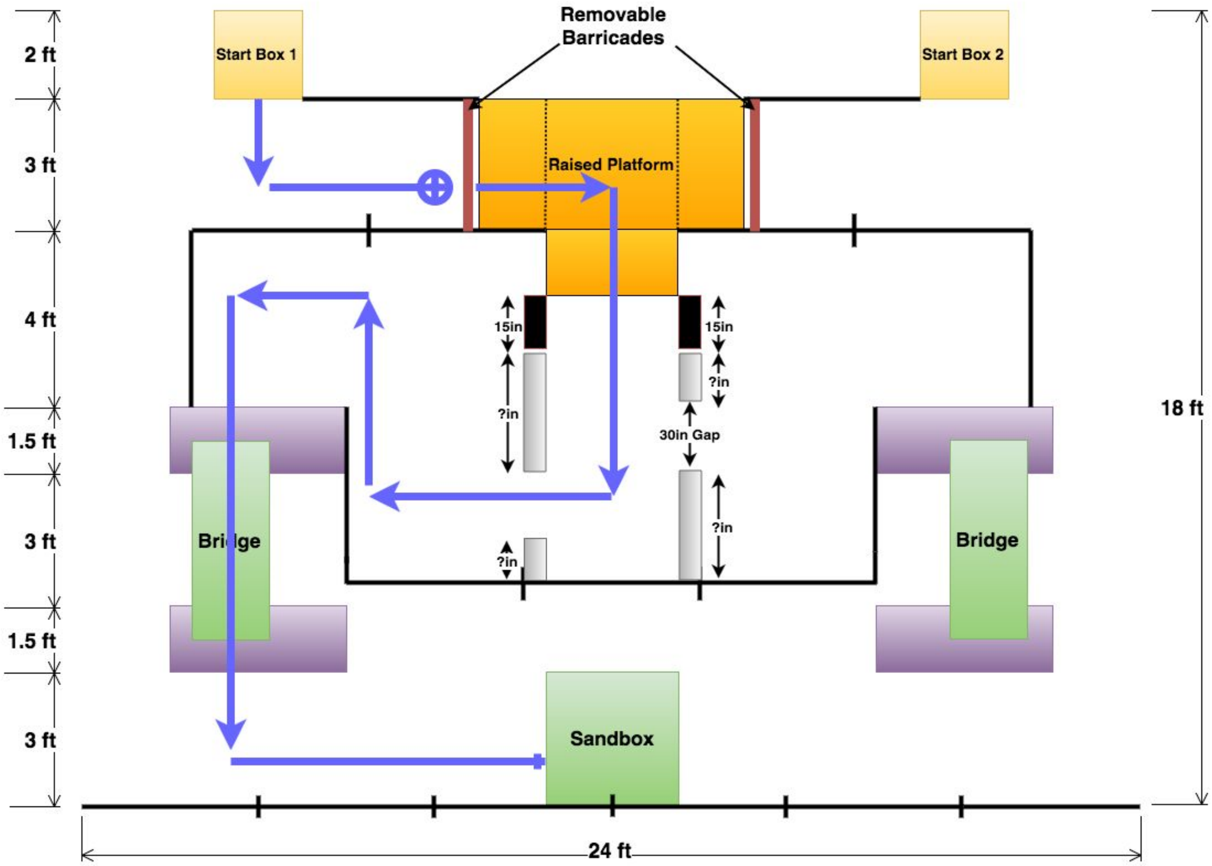

Figure 2: Schematic plan view of the playing field with a nominal robot roving path.

4. Rules of the Competition

1. **The Match**
    a. The duration of each match will be 5 minutes. The total of points over two matches, with teams starting from alternate starting positions on the playing field, will decide the winner of each competition in the bracket tournament.
    b. During a match, at most two members of each team are allowed within the boundaries of the playing field.
    c. During a match, the two competing robots will accumulate as many match points as possible based on the point schedule in Table 1. Not all tasks must be attempted.

d. Before the competition, the judges will provide each team with a “bucket” of points based upon that team’s Coefficient of Confidence. Before each pair of matches, a team will be able to apply any number of points remaining in the “bucket” to their score for a particular match pair. (The possible range will be communicated at a later date)..

2. **Robot Operation**
    a. No team member may interact with the robot during a match.
    b. In between matches, you can modify your robot or control software in any way you see fit. However, matches will start at their scheduled time.
    c. If your robot gets stuck somewhere on the playing field during a match, your team will have to make a quick decision if you want to “reset” your robot. If your team chooses a match “reset”, the robot goes back to its starting square and you forfeit any points earned in the match up to the point of reset. The clock does not stop ticking during a reset. Note that this only resets the points for one of the two matches between each pair of teams in the tournament.
    d. If your control program encounters an unrecoverable error during a match, your team has the option to reset (as indicated in the previous bullet point) or restart your control program *without moving your robot*. If you choose to restart your program, no modifications to the code will be allowed but no points will be deducted for the match.
3. **Robot Size and Materials**
    a. Your robot may not exceed 50cm x 50cm x 50cm in size, before the boom is extended.
    b. You must construct your robot from the materials provided by the KNW 2300 staff.
    c. The use of adhesive tape, of any type, and “zip ties” is allowed on your robot, but only for limited purposes. Tape or ties may be used to secure wiring to the frame, attaching decoration, or other non-structural purposes. However, your design must strictly adhere to the “Cohen[3] Rule”: *Adhesive tape or zip ties must not be used as any mechanical structural element*.
    d. The use of glue to directly attach components to the MicroRAX frame is prohibited.
    e. If you desire additional components, you must send an email to Professor Quicksall with a direct link that can be used to order the component and a brief justification for why you need it. The strict deadline for requesting purchases is Friday, October 13th.
    f. Any additional components purchased by KNW 2300 for your team or any additional components your team purchases may not exceed a total of $30.00. Any components that you already own still count towards this limit (including materials from the Innovation Gym).

[3] Professor Adam Cohen, Mechanical Engineering Department, Southern Methodist University

g. Your team will be given a balance of 500 “KNW Bucks”. This currency is used to “purchase” materials owned by the KNW 2300 staff. This includes components like motors, servos, certain sensors, Arduino processors, and other building materials (each team will be given some of each at the start of the project). These can be purchased through the vending machine located in the Innovation Gym. **Retaining unused “KNW Bucks” at the end of the project will result in a significant improvement on your team’s final course grade.**
h. Any additional requests for materials will be handled on a case-by-case basis by the course staff. All decisions are final.

4. **Sensor Boom Construction**
    a. All booms must be of a length to elevate the sensor package to a total height of at least 75cm, measured from the base of the robot, upon extension. If a fully extended boom does not reach this height, no points will be awarded related to the boom.
    b. If a team exceeds 125cm of total height above base of the robot, a bonus will be awarded (see table 1).
    c. The size limit of 50cm x 50cm x 50cm for the overall robot applies for the unextended state of the boom.
5. **Bridge Construction**
    a. You will use only three materials: tongue depressors, floral wire, and hot glue
    b. Hot glue must be used for attachment purposes only, and not for any surface area
    c. Floral wire is to be used for connections only
    d. Your team will be issued one box of 500 tongue depressors, and you are limited to using a maximum of this number of depressors for all development, prototyping and final construction of your bridge unless your team purchases more via KNW bucks. In order to minimize the $mass^2$ denominator in your bridge figure of merit, it is hoped that your design uses significantly less than 500.
    e. Tongue depressors may be cut into smaller lengths
    f. The span is set at 3 feet +- 0.5 inches
    g. The maximum width is set at 30 inches
    h. Some part of your bridge structure will extend over pier supports attached to the ramps at the ends of the canyon that are 12 cm above the bottom of the canyon
    i. No portion of the bridge may touch the bottom of the canyon

5. Task Point Values

Table 1: Task Point Values

Task	**Points**
Leave the starting box	5
Idle and resume after an arbitrary time at the dynamic barrier	10
Climb onto the platform of the “elevated air region”	10
Raise the probe to a height of >75cm & <125cm above the platform height	10
Raise the anemometer/temperature probe >125cm above the platform	20
Measure the temperature of the “elevated air region”[6]	10 maximum
Measure wind speed condition of the “elevated air region”[6]	10 maximum
Navigate through the relocatable gap	10
Navigate onto the bridge	10
Successfully cross the bridge	10
Navigate to the “surface water region”[4]	10
Deploy conductivity sensor into the “surface water region” container[5]	10
Measure conductivity of the “surface water region” container[6]	15 maximum
Successfully deliver a radio beacon in a high water content container	10
Team member or robot **intentionally** interrupts operation of another robot	**Disqualification**

[4] This region will be larger than the container of sand/water. Your robot successfully navigating within a reasonable deployment range, to the judgement of NASA, of the sand/water container is sufficient to gain these points

[5] The robot inserting the probe into the sand/water will signify that the sensor has been deployed

[6] The number of points actually awarded for this depends on the difference between the reported measurement value and the actual expected value.

6. Use of the Classroom/Innovation Gym Space and Materials

Being a member of this course affords you certain privileges not available to every undergraduate engineering student at SMU. With these privileges comes responsibilities. The points below are not suggestions; **they are requirements**.

- You are given 24/7 access to Junkins Hall, Junkins 202, and the Deason Innovation Gym. These spaces belong to everyone. It is extremely important that you respect these spaces, and it is your responsibility to clean up after yourselves.
- Professionalism in the engineering quad is **extremely important**. Families, prospective students, and guests of SMU enter and exit the building regularly. Using that space brings with it the potential to show off the amazing things your team is building as young engineers. Poor behavior could lead to catastrophic consequences for the entire course, not just your team. **Use common sense.**
- You are given a toolkit containing a number of tools, listed below. Your team is responsible for these tools for the semester, and your team will be required to return ALL items during the final exam period. Every team is assigned a numbered kit, and the tools in those kits have been marked with a matching number. Each kit contains the following set of tools:

  - Tape Measure
  - Large Wire Strippers
  - Medium Wire Strippers
  - Wire Cutters
  - Jeweler’s Screwdriver kit (with 6 screwdrivers)
  - Slip Joint Pliers
  - Long Nose Pliers
  - Scissors
  - Level
  - Short Screwdriver (¼” x 1½” Flathead)
  - Short Screwdriver (PH2 x 1½” Phillips head)
  - Medium Screwdriver (3/16” x 3” Flathead)
  - Medium Screwdriver (PH1 x 3” Phillips head)
  - Large Screwdriver (¼” x 4” Flathead)
  - Medium Screwdriver (PH2 x 4” Phillips head)
  - 2x 2mm Allen wrenches

If a tool breaks during normal use, notify a KNW2300 staff member, and your tool will be replaced. In the event that you lose a tool, one of several things may occur:

- If your team is aware that a tool is lost during the semester (before the final competition), notify a Professor. We will re-supply the tool, at the expense of your team’s $30 budget

    - If your budget has been exhausted, then at least two members of your team will be required to help in the Innovation Gym (i.e. cleaning) for one hour per tool lost. We will re-supply your tool(s).
- If your team returns an incomplete toolkit during the final exam time, then you will be docked 1 point from your semester average per tool lost or incomplete (in the case of the Jeweler's screwdriver kit for example). Each bullet point above constitutes a single tool.

Under no circumstances should you take possession of any tools that belong to the Innovation Gym. You are free to use those tools that you have access to while in the Gym, but you may NOT remove them from that space.

During the semester, your locker may be checked for *unnecessary collection* of class materials. The definition of "unnecessary collection" is up to the discretion of the KNW2300 staff. Remember, you are sharing the lab with 15 other teams. Storing an unreasonable number of parts and supplies hinders the effectiveness of the other teams. The is a practice we do not tolerate, and if it happens more frequently than we like, it may be considered academic sabotage of the other teams, which is a violation of the SMU Honor Code.