ITU ROVER TEAM

CRITICAL DESIGN REVIEW

Team Lead

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1. Mechanical Sub-Team

Mechanical team approaches the competition with 4 steps which consist Review, Design, Analysis and Optimization. First, examples are reviewed carefully and requirements are determined for the Rover design. In the design step, Solidworks® and CATIA® are used for 3-D model. ANSYS® is used for structural analysis, MSC Adams® and Solidworks® are used for dynamical analysis, SolidThinking® is used for obtaining topological optimization data. All simulations and designs are reviewed by advisors from university and industry.

1.1. Chassis: Double-wishbone independent suspension system was chosen to provide this mobility, it allows each wheel on the same axle to move vertically independently of each. After a few design measurements of the main chassis were determined by performing various dynamic analyzes to fulfill the tasks. For the main chassis, t-slotted aluminum profiles were selected for ease of production and light weight. With this design, the main chassis only weighs 4.5 kg.

1.1.1. Motion transfer system: In our motion transfer system low pressure beach wheels were chosen to distribute the load over a wide surface. One of the most challenge was to keep motor inside of the wheels. Original and custom-made rims and the other motion tran0sfer parts was designed to keep motors inside the wheel to provide protection against damages.

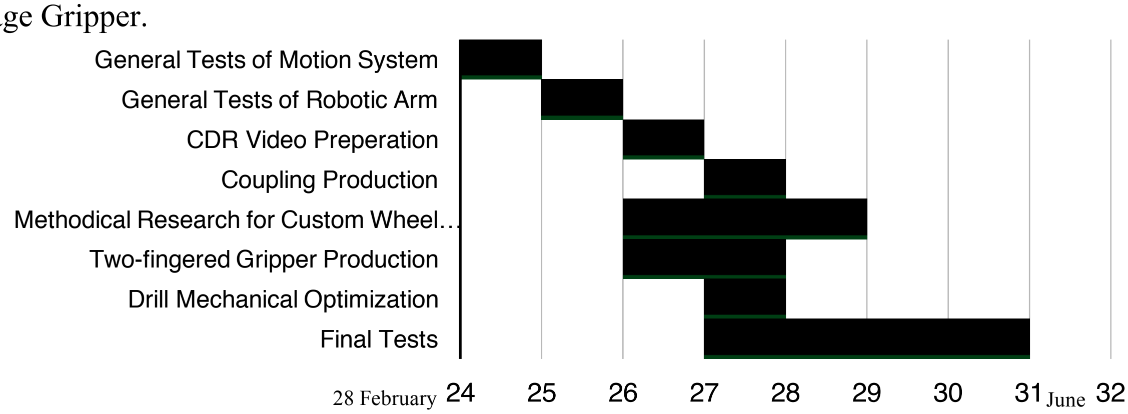
1.2. Robotic Arm: The robotic arm is focused on simplicity, mobility and weight. In any case while the number of independent axes increases, mobility and complexity of robot arm increase. Before choosing the design, tasks in the competition were analyzed then 6 independent axes found ideal for fulfilling the tasks. After selecting the general concept with linear actuator, the MATLAB GUI was used to determine the optimal robotic arm length. Aluminum plate was chosen for easy production.

1.3. Gripper: Major focused point on gripper's ability to grabbing and holding objects. As tasks required to grab objects that has nonlinear geometries, gripper fingers must be flexible to grab every type of objects. According to Das another advantage of four linkage gripper is "The pressure is applied gradually on the gripped object rather than somewhat abruptly in case of normal grippers, reducing the chances of deformation of the object."[1] Two dependent grabbing parts and springs are used, which allows to grab both spherical, cylindrical and flat objects. Gripper is the most weight sensitive part of rover because of its significantly changing center of gravity of rover and moment of inertia of the robotic arm. Gripper is connected to robotic arm with a system that allows gripper to both rotate and pitch for sensitivity required movements.

1.4. Future Plans: Even though there are so many things completed successfully, still there are a lot of works to do for a better rover such as wheel optimization, production of two-fingered gripper, and suspension optimization.

References for Mechanical Sub-Team Section:

[1] Saha, D.T., Sanfui, S., Kabiraj R., Das, S. (2014) Design and implementation of a 4-Bar linkage Gripper.



2. Electrical Sub-Team

2.1. Motion and Sensing System: Rover's main drive system includes dc motor controllers for each wheel to control direction and velocity. Custom designed circuits with high current capability are able to drive motors at their full torque. These boards are attached to a main controller and can be replaced easily without any tools in case of emergency. On the other hand an another board deals with sensors. After filtering sensor datas this board transmits valuable data to base station. Filtered data can be used for autonomous task or can be viewed at command screen to help operator at terrain traversing. Besides these onboard controllers can communicate each other or an onboard processor via Ethernet network which enables autonomous control.

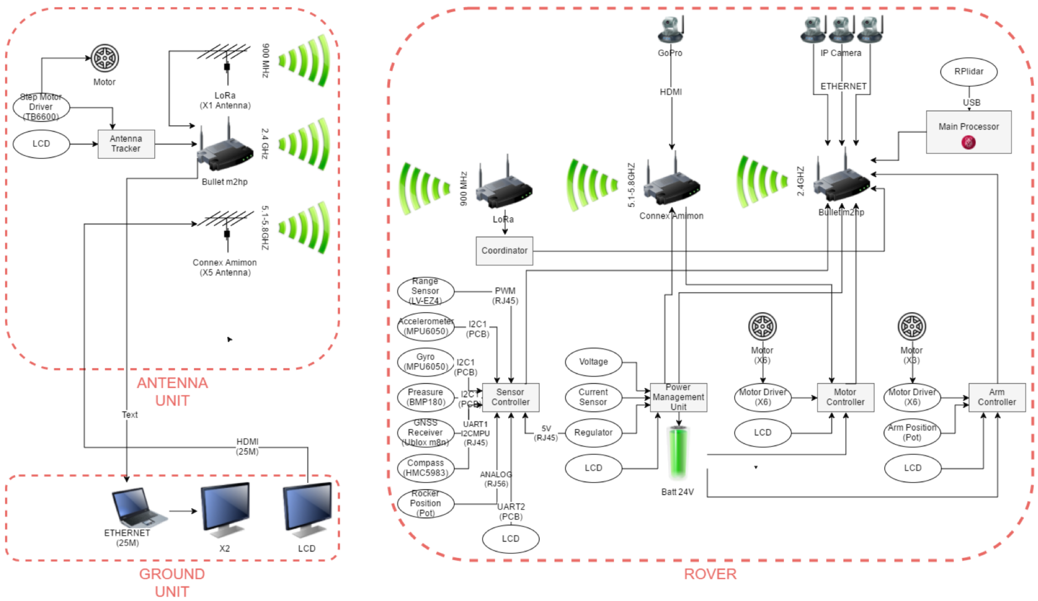


Figure I: Rover Electronics and Communication

2.2. Communication: At base station high definition video is compulsory for all tasks since pilot have to be aware of rover's surroundings. Rover's communication system includes two Bullet M2HP access point that has data rates up to 100 mbits providing data transfers for video feeds of 3 cameras each 8mbits and control signals. After first tests of wireless communication, it was observed that decreasing of signal strength causes low data rates around 20 mbits at 1km between rover and base station, thus adjustable frame rate and video quality is implanted to adapt non line of sight and long range comms. In case of a failure of data transfer at 2.4 GHz, a backup system is used consisting of RF modules with LoRa modulation operating at provided clean bandwidths of 900 MHz.

It is crucial to have steady video feed for all tasks although, especially in terrain traversing challenging terrain cause fatal vibration and useless camera angles for pilot. Onboard vibration isolator supported brushless gimbal guarantees desired camera angle with rock solid shots.

2.3. Power : To satisfy electrical system demands the first plan is battery system with li-on batteries. One of the most important reason to choose Li-on batteries is their popularity in market and their success for the demands of the proper current and voltage. The Rover system operate 6 motor which each of motors consume at rated currents for continuous operation 3.5 Ampere. For the robotic arm 3 linear actuator consume the maximum current at full load as 2.8 Ampere. To sum motoric system of a Rover current demand is approximately 30 Ampere at 24V. Because of the Rover current demand has not lots of peak values energy cells are going to use as a battery. Since 18650 li-ion battery types can be added with each other's, this feature make an opportunity to satisfy measured up current and voltage values. The optimum efficiency of the batteries is at 40 °C therefore the temperature control system will be used inside the rover.[1]

References for Electrical Sub-Team Section:

[1] Panasonic, 2012. Lithium Ion NCR 18650B Datasheet. Retrieved from https://na.industrial.panasonic.com/

3) Software Sub-Team

The general mistake that is made by the software development teams are to be unplanned and as a result the final product becomes chaotic. Knowing that from the team's previous experiences, a detailed software development plan was prepared and all of the individual team members worked on their spesific tasks. These tasks are: developing a user friendly GUI for the pilot, writing the necessary software for controlling the robotic arm and also developing a robust autonomous navigation algorithm for the Autonomous Traversal Task. Each individual were assigned one of these tasks and developed their own working software prototype independently. All the software is then uploaded to GitHub for debugging and controlling the written software as a team. All the software is written in C and C++ except the GUI, which written is C#. After the CDR, the progress will be followed up with more tests and algorithms will be developed further to assure everything goes accordingly in the competition day.

3.1. Robotic Arm: To provide a user friendly control of the robotic arm a 3DOF control algorithm is developed. The algorithm is first simulated in MATLAB then integrated in C++. This custom developed control algorithm uses inverse kinematics and iterative forward kinematics to achieve a smooth robotic arm control. Also, a joystick is used to control the robotic arm and the algorithms developed were implemented to GUI to accomplish an all-in-one ground station, which helps the pilot to see and manage all the data and the control mechanisms at once.

3.2. Autonomous Navigation: To satisfy the Autonomous Traversal Task's requirements with our internal navigation system, a custom iterative path finding algorithm is developed using Robotic Operating System Working with ROS for developing this algorithm is benefitial for better visualizing and debugging the problems. The algorithm is also compatible with the GUI as backup, which ensures the rover to reach its target autonomously.

3.3. GUI: In the competition, it is so crucial that operators to master their driving skills. So, an idea of training a driver has came up. A custom Windows Forms application UI in Visual Studio was developed to satisfy all the needs. Although, it was looking feasible only until it became obvious that there will not be enough time left for teaching a complicated UI to operators. For overcoming this problem, we decided to create a graphical user interface which is so simple, user friendly and skillful that any team member can ride just like playing a video game. For fulfilling this task the team started to develop a GUI on Unity Game Engine platform. On the first version, the GUI had a panel which shows the real time orientation of the arm joints and bodies in a 3D scene which gives the operator a better perspective. This system has been evolved to a simulation that was developed for testing the inverse kinematics and robotic arm dynamics. This additional simulation is still being developed as a training platform to operators. A Joystick situation monitor, two mjpeg video feeds, a satellite based map and a data panel with a plotter were implemented to GUI. The system is working precisely and for further development the system is still being perfected as a potential solution to the blind drive mode. As Tanenbaum says, UDP is especially appropriate for client-server systems since either client and server does not effected by lost massages during the traffic. [1] UDP protocol is chosen for communication between GUI and rover due to its' high speed and video stream performance for the camera feeds. A 3DOF gimbal is used for the main camera to achieve a stable vision. The team is also developing a system that allows some mobile co-stations which shows more detailed data retrieved from the sensors.

References for Software Sub-Team:

[1] Tanenbaum(2003), Computer Networks(4th edition), 526,Pearson Education, Inc.

4) Public Relations & Finance Sub-Team

After several months of research, design and analysis, budget of the project has started to shape in the mid-September. A detailed budget plan was prepared. In order to meet our plan, we attended many fairs and social activities such as workshops, seminars, expos etc. In addition to that we have contacted with many governmental and private institutions for fund raising. These negotiations resulted in financial support as well as production and material sponsorships.

We introduced our project by taking part in the national televisions and radio channels and also in the printed press to take attention to our project. With the help of our social media accounts and website, we are reaching more and more people. We have provided to take part in social responsibility projects by organizing workshops on robotics as much as possible.

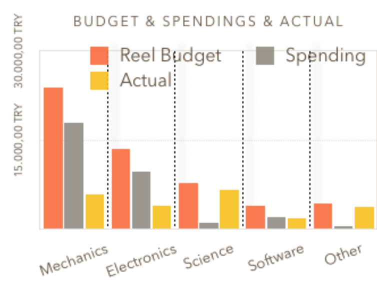
In our project budget plan, transportation, accommodation and other needs during the competition has a great proportion. To meet this need, we found a sponsorship, SSI Company provided our 10 team members who has U.S. visa, plane tickets from Istanbul to Los Angeles.

We will continue to seek financial support in order to be able to participate in the competition with more team members. Furthermore, we will continue our efforts to promote our team and make people aware of space researches.

SUMMARY

1 USD = 3.92504 TRY 15.000$ = 58.8756 TRY

Category	Estimated Budget	Reel Budget	Spending	Actual
Mechanics	22.500,00 TRY	23.762,93 TRY	17.849,00 TRY	5.913,93 TRY
Electronics	15.000,00 TRY	13.508,62 TRY	9.623,00 TRY	3.885,62 TRY
Science	10.000,00 TRY	7.672,41 TRY	1.000,00 TRY	6.672,41 TRY
Software	5.000,00 TRY	3.836,21 TRY	2.000,00 TRY	1.836,21 TRY
Other	5.500,00 TRY	4.219,83 TRY	412,00 TRY	3.807,83 TRY
Total	58.000,00 TRY	53.000,00 TRY	30.884,00 TRY	22.116,00 TRY

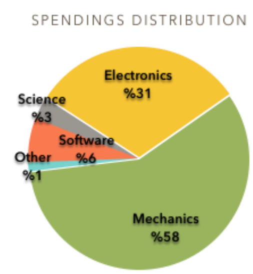


OTHER SUPPORTS

Company	Category	Description	Amount
ODAK PCB	Electronics	printed circuit board	2.000,00 TRY
IKO	Mechanics	bearing	1.000,00 TRY
OO-Kuma	Mechanics	3D printing	500,00 TRY
Normsay	Mechanics	Prototyping	2.000,00 TRY
YILDIZ CNC TORNA	Mechanics	Prototyping	3.000,00 TRY
Total			8.500,00 TRY

CASH FROM SPONSORSHIPS

Company Name	Amount
ENKA VAKFI	5.000,00 TRY
İSTANBUL YAŞ MEYVE SEBZE İHRACATÇILAR BİRLİĞİ	1.500,00 TRY
TURKSAT	3.000,00 TRY
USKUDAR BELEDIYESI	15.000,00 TRY
ORUCOGLU HOLDING	10.000,00 TRY
TEKFEN HOLDING	10.000,00 TRY
Total	44.500,00 TRY



TOTAL PROJECT BUDGET

Category	Estimated Budget	Reel Budget	Spending	Actual
Rover	58.000,00 TRY	48.780,17 TRY	30.884,00 TRY	17.896,17 TRY
Transportation	50.000,00 TRY	30.000,00 TRY	30.000,00 TRY	0,00 TRY
Spending in USA	31.500,00 TRY			
Other	5.500,00 TRY	4.219,83 TRY	412,00 TRY	3.807,83 TRY
Total	145.000,00 TRY	83.000,00 TRY	61.296,00 TRY	21.704,00 TRY

5) Science Plan

In the science cache task, the operators will seek out for geological structure to determine potential sample collection sites. When the sample is returned by the rover, further analysis will be conducted in the lab.

5.1. Onboard Instruments

5.1.1. Atmosphere Pressure and Atmosphere Temperature Sensors: Atmospheric pressure and temperature sensors will provide data for figuring out whether liquid water present at the surface. Phase diagram of water will be consulted for this decision.

5.1.2. Subsurface Temperature and Soil Humidity Sensors: Surface condition of the Mars is not suitable for liquid water but the sub-surface conditions are more sustainable for microbial life due to higher temperature and pressure values. [1] In the competition site the humidity level and the temperature of the soil is important for the sample collection decision.

5.2. Laboratory Tests & Measurements

5.2.1. HCl Test :HCl will be used to determine the presence of $CaCO_3$. If the sample contains $CaCO_3$, bubbling will be observed since the CO_2 gas forms when the acid is dropped. This will prove presence of carbon and it past presence of water in the soil sample. HCl will be purchased by the team from Los Angeles and brought to the competition area. The product will be COTS, so the product will be included in the GHS Classification and will be transported and stored in accordance with GHS hazard and precautionary statements.

5.2.2. pH and Electrical Conductivity (EC) Measurement: The pH and EC meter help in determining conditions of the sample. Electrical conductivity and pH are indicators of available nutrients in the soil. Also, microorganisms live in this pH range will be investigated via microscope.

5.2.3. Microscope: The presence of organisms in soil sample will be proven via microscope photography. Microorganisms, bacterial species and archea in Utah desert soil are being investigated.

5.2.4. Luminometer and ATP Water Test: Luminometer gives information about the amount of ATP which is produced by living cells. Presence of living microorganisms will be investigated via this measurement.

5.2.5. Reflectance Spectrometer: Sample soil type will be determined by reflectance spectra which will be evaluated by ALTA II Reflectance Spectrometer. Measured spectral curve will be compared with the database created from similar soil based on its components.

5.2.6. Drill System: The robotic arm with drill on its end, will be moved to dig the site orthogonally to the ground. The robotic arm will be removed and the hole will be used for the scientific test. The readings from the probe sensor will inform us about the hospility of the potential sample. If the results are promising, the robotic arm will pass the second drilling phase and the last sample is collected in the target sealed container.

References for Science Plan:

[1]Mars, Water and Life. (n.d.). Retrieved from https://mars.jpl.nasa.gov/msp98/why.html

[2] Hanlon, E. A., & Bartos, J. M. (1993). Soil pH and electrical conductivity: a county extension soil laboratory manual. Gainesville, FL: University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service