Center of robotics
Physics-Mathematics Lyceum 30

Engineering notebook for
Competition First FTC

Team PML30 –Y

Saint-Petersburg, Russia
2015

Contents

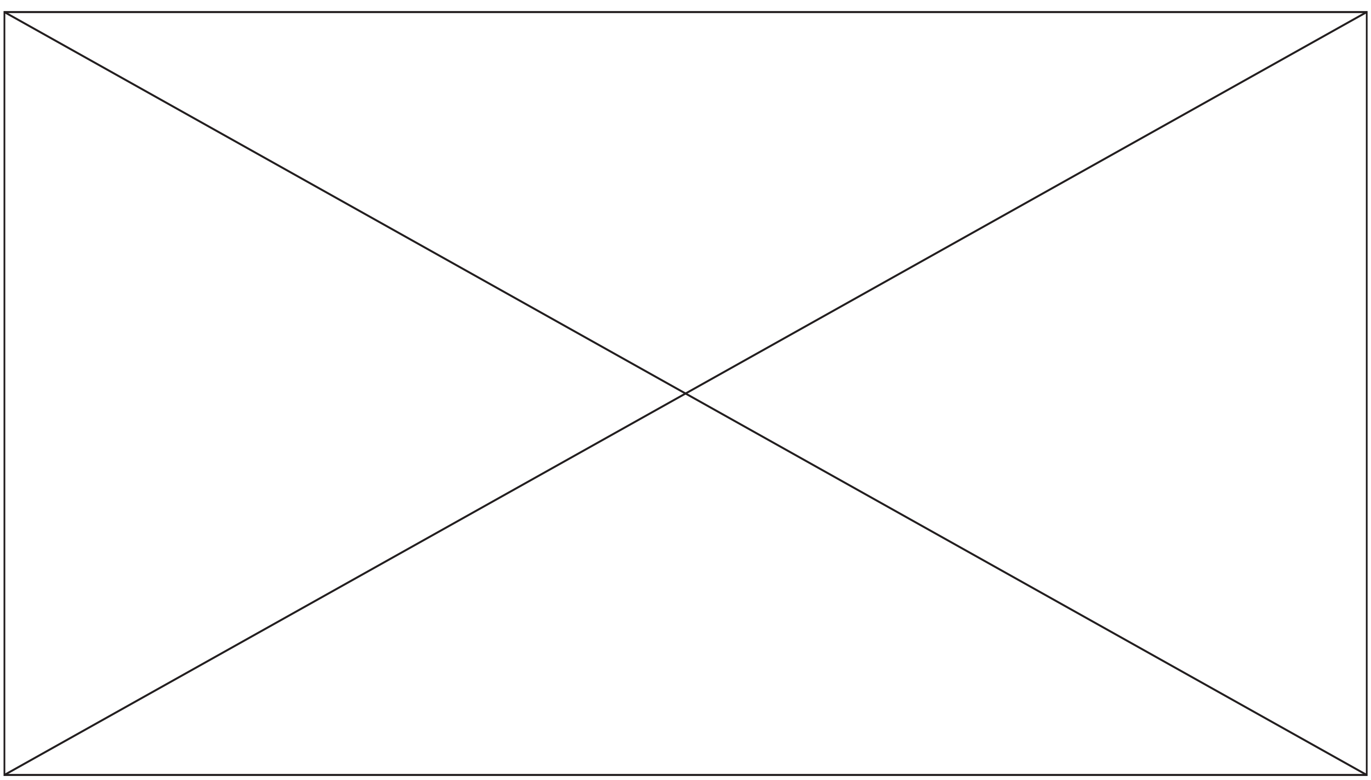
1 Introduction

1.1 How to read this book

The book consists of 4 chapters.

1. The first is an introduction. Here is represented information about our team, our instructors and sponsors.
2. The next chapter is a "Business plan". There represented information about our sponsors' support and our budget.
3. The Engineering chapter consists of two parts.
    - The consequence of meetings, which show our progress in elaborating. This part includes sections 1 to 4.
    - Documentations for each module and for tele-op and autonomous programs. These materials are available in sections 5 and 6.

    This approach allows to show the engineering process from two sides: development of the robot in general and development of each module in particular.
    The 7 section of Engineering chapter is "Key summary". It contains conclusive abilities of our robot in the game.
4. Appendix includes a number of additional materials.
    - The list of raw materials applied in robot.
    - The example of leaflet with our robot's characteristics that we intend to distribute among other teams to make them know about our abilities.
    - The information list for judges.



1.2 Team PML 30 $-Y$

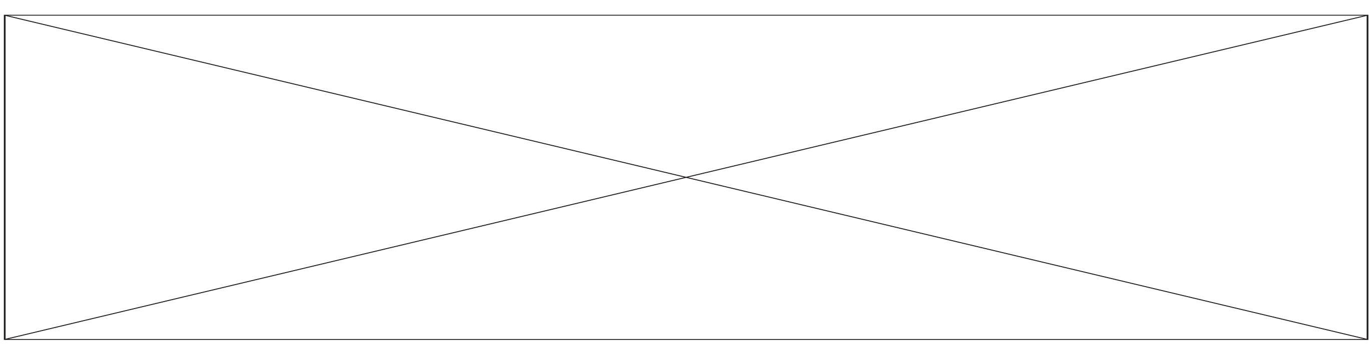
Team PML 30 – Y was assembled in October 2015 in Saint-Petersburg, Russia from 2 novices and 3 participants with experience, who took part in PML30 – φ and PML 30 – ψ teams in season 2014 - 2015. New team is based on the FTC teams that existed in our laboratory since October, 2012.

Tasks and roles of robot designing were distributed among the participants, and safety rules were established. At the first place we put spreading principles of gracious professionalism to others. All decisions were made collectively inside team with discussion to find the most optimal solutions, every idea was discussed in details to avoid missing interesting idea or making wrong decision.

During the year we took part in many events and everywhere we have tried to attract attention to our team, encourage people to take part in FTC and helped competitions organizers in the way of explaining rules and making regional qualifies as official as regional finals. Also we pursued and distributed the principles of gracious professionalism. Talking to the press, we hoped to attract more attention to our team and to the competition in general, as well as attracting sponsors. The latter was important because of the need for funds - purchasing materials and equipment costs a lot.

The team took part in the three qualifying competitions and in the regional finals. We have met number of team there and share our experience with them. Aside from meeting new teams we also kept in touch through Facebook with teams we met during previous years: Stuy Fission 310 from USA who we met in Sochi last year, a team from Romania, Auto Vortex who we met on regional finals the same season. Also, there is an active group chat with a large number of Russian teams. You can find the team page in Facebook at the address https://www.facebook.com/pages/FTC-team-PML30-PHI. To increase the efficiency of our team work we used the version control system GitHub, which allows the entire team to work simultaneously on a single projects without losing files and providing easy way to resolve problems. Also for writing technical books we had used professional typesetting system LaTeX.

For our team spreading information about FTC is very important and we try to motivate to take part in it as much people, as possible. We consider FTC very useful and interesting competitions, so we are very happy to participate in it.



1.2.1 Instructors

Dmitry Luzin
Head of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Main coach of FTC team.
Information: 25 years old, in robotics 5 years, in FTC 3 years.

Ekaterina Luzina
Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.
Information: 25 years old, in robotics 5 years, in FTC 3 years.

Anton Fedotov
Professor of Robotics Department in Phys-Math Lyceum 30, student of St-Petersburg Polytechnical University. Tutor of FTC team.
Information: 22 years old, in robotics 4 years, in FTC 3 years.

Georgii Krylov
Professor of Robotics Department in Phys-Math Lyceum 30, student of St-Petersburg Polytechnical University. Tutor of FTC team.
Information: 18 years old, in robotics 4 years, in FTC 4 years.

1.2.2 Team members

Nikita Safronov
Role in team: captain, reserve operator-2, responsible for writing the technical book, responsible for elevator and winch.
Information: 17 years old, in robotics 4 years, in FTC 2 years.
Why I chose FTC: "I have chosen FIRST because I enjoy working with mechanisms and finding unusual technical decisions for solving problems. Also working on this project helps me to get new skills in a sphere of engineering. In this case I know, that I don't spend my time in vain."

Alexandr Iliasov
Role in team: operator-2, decorating robot, Power Design, responsible for the bucket.
Information: 16 years old, in robotics 3 years, in FTC 2 year.
Why I chose FTC: "I choose to partipucate in the FTC, because it requiers many skills in a lot of interesting themes: physics, engineering, programming, geometry. Also, you need to work in team, argument your choise and listen others. You need find problems and solve it. All that skills you can obtain in FTC."

Anton Ponikarovsky
Role in team: communication with other teams and community, responsible for system for scoring alpinists.
Information: 17 years old, in robotics 3 years, in FTC 2 year.
Why I chose FTC: "I decided to join FTC because I believe that this competition is one of the most challenging of those, which are familiar to me. It requires responsibility, capability of working in team, communication with other teams, working on hardware, software and even tecnical documentation. All the experience you accumulate through doing FTC, you can apply in your future profession, if it is technical oriented."

Andrew Nemow
Role in team: reserve drive-operator, responsible for the writing the program, responsible for debris collecting systems.
Information: 16 years old, in robotics 2 years, in FTC 1 years.
Why I chose FTC: "When I first I attended the event FTC saw hefty metal robots, with enthusiasm and without hesitation decided that I would like to do this."

Gordei Kravzov
Role in team: drive-operator, development strategy in the game, responsible for chassis.
Information: 16 years old, in robotics 2 years, in FTC 1 year.
Why I chose FTC:"I enjoy making huge and complicated mechanisms work, that's why I chose FIRST FTC. In my opinion it's a great way to improve your skills and broaden the mind doing something that you love by the whole heart."

1.3 Thanks and prospects

We enjoyed working on a custom and non-standard project, which, besides its technical aspect, included working with new people who shared our values of friendship and mutual understanding.

Our team is planning to continue doing robotics, setting new goals for ourselves in order to improve. This is our first year taking part in FTC and we will participate next year as well. If we don't realize ourselves this year, we'll look at all our mistakes, correct them, and preform a lot better next year.

In any case, we are ready to learn new things, improve ourselves and expand our skills.

None of us know for sure what we want to do in the future, but we are certain that our experience will be very valuable to us.

Our thanks go to the company FIRST for organizing this competition, which we are very happy to be participating in. We appreciate this wonderful opportunity to test ourselves and learn something new and wish them success and growth in their future endeavours.

Also we thank our sponsors: company PTC and it's Russian representative "Irisoft" and charitable foundation "Finist" for their support. Also we thank Physics-Mathematics Lyceum 30 and it's director Alexey Tretyakov for providing comfortable conditions for preparation to competition.

Team PML 30 φ

2 Business plan

2.1 Introduction

We take a responsible approach to finding sponsors. We also strive to spend money effectively purchasing details and equipment we need, finding ways to get maximum benefit. For instance, some of the TETRIX sets that we have were received as prizes in competitions.

2.2 Our sponsors and their support

2.2.1 Robofinist. Gold sponsor.

Robofinist Charitable Foundation organized by Temur Amindzhanov and organisation Starline. As a local organization, they offered their support to us. They help us financially providing with 2000 $every month, purchasing materials and equipment.

2.2.2 PTC and Irisoft

PTC and Irisoft representative in Russia is the one company that has helped us to begin to engage the FTC. They provided us with the first TETRIX set within the program "Score Technic" which involved our Lyceum. They provide us with CAD "Creo Parametric" that we use in engineering. They also help us with the delivery of details from the USA.

2.2.3 Physics-Mathematics Lyceum 30

Physics-Mathematics Lyceum 30 is an establishment that provides us with comfortable facilities for working.

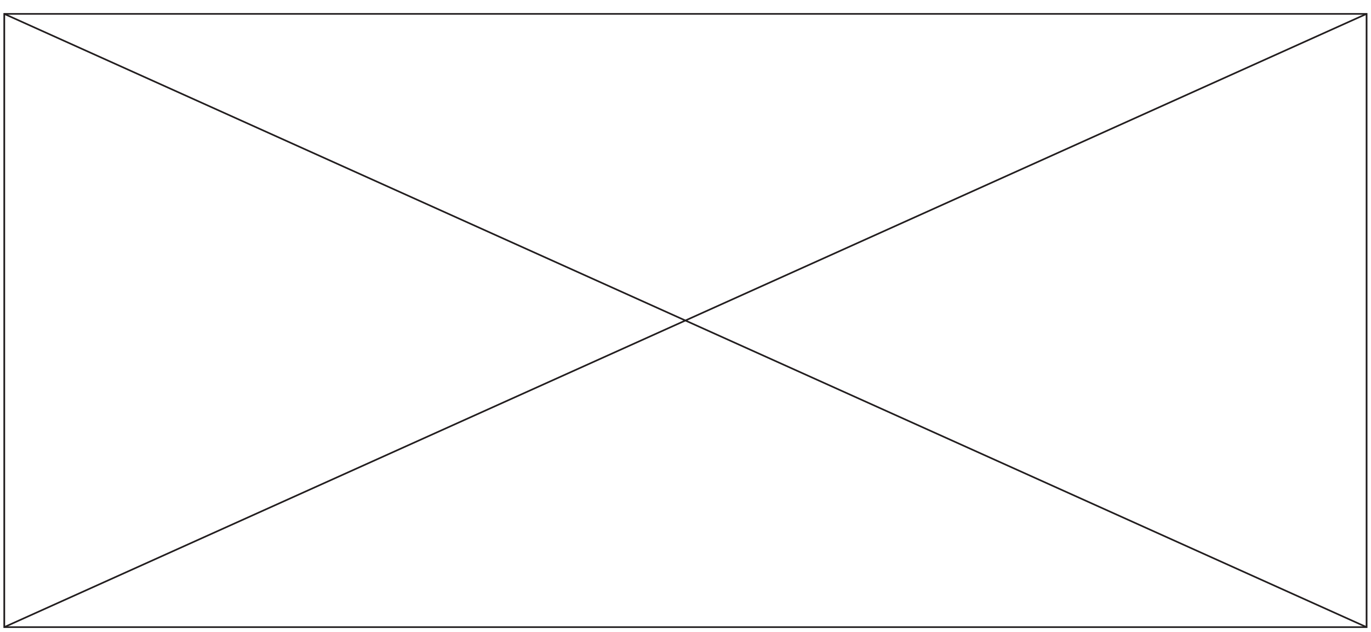
2.3 Our resource and financial situation

Table 1: Resources that we had at the beginning of season 2015-2016.

Name	Amount
Basic TETRIX Max kits	4 sets
Resource TETRIX Max kits.	4 sets
Andy Mark NeveRest DC motors.	12 motors
Extra TETRIX DC motors (beyond kits).	10 motors
TETRIX Max chains and gears for them.	4 sets and extra gears
TETRIX Max 4 inch omni-wheels.	8 wheels
Servo MG 995.	25 servos
Extra TETRIX Max Battery packs (beyond kits).	4 parts
Tetrix Max caterpillars.	2 sets
Box for transporting robot.	1 piece
Matrix resource kit.	1 set
Joysticks Logitech F310.	2 joysticks
Lego Light, Touch and RGB Sensors.	Over 10 each
Hi-Technic Compass, Gyro and Colour sensors.	1 each

Table 2: Our expenses in season 2015-2016.

Name	Price (roubles)
New components that were purchased during this season	
FTC RESQ playing field.	106 000
New Android system (3 Modern Robotics Electronic Modules&Sensors Kit + 2 phones Motorola Moto G).	178 000
Another box for transporting robot and elements.	4 500
2 Servo S4315R.	4 000
1 Servo F5519M.	3 000
Wires 1.5mm.	720
Consumable materials (tape, cable screeds).	500
TETRIX components.	70 000
Rubber hose.	500
USB hub.	700
Aluminium construction profiles.	4 200
Blocks.	800
Rope.	180
Furniture slats 45 cm.	300
Workbench and vise.	23 500
Joysticks Logitech F310.	6 000
Purchasing total	*402 900*
Competitions that we took part in during this season	
Trip to "Robofest-South" in Krasnodar.	38 500
Trip to "Robofest-Ryazan".	16 100
Trip to FTC "Scrimage" in Nizhny Novgorod.	10 500
Trip to "FTC RUSSIA Open 2016" in Sochi.	100 000
Trips total	*165 100*
Total expenses	***568 000***



3 Engineering

3.1 Brainstorming (21.09.2015)

Time frame: 21.09.2015 17:00-21:00
Preview: Since this year FTC rules were published, every member of our team had carefully read them. Today we gathered together to discuss all the aspects of this year gameplay and think of how to get on with the most significant features of the game.
General aspects:

Features	Solutions	Label
Moving to the ramp is essential to achieve high score.	Robot's wheel base should be good at moving on the ramp.	chassis
Space between each two bars in 3-rd zone is wider than the standard TETRIX wheel diameter.	Using tracks or 3-4 wheels from each side of the robot will prevent robot from getting stuck.	chassis
It will take a lot of time to climb to the 3-rd zone of the ramp.	It is possible to deliver debris to the highest goal with elevator standing on the 2-nd zone instead of climbing to the 3-rd.	elevator
Goals for debris have a very little capacity.	It is more preferable to collect cubes than balls. That's why we need mechanism to prevent balls from collecting.	gripper
Pulling up costs 80 points. It's not difficult to realise then.	At least 1 DC motor should be reserved for pulling up. It is possible to grasp the pull-up bar with hook and lift to it by reeling the cable.	pull up
Moving over the inclined plane and pulling up require high moment on motors. However, the number of motors is limited.	Robot should be light enough to decrease the moment required for moving and, as a result, increase speed of moving.	weight
All the zones of red alliance are the mirror reflection of blue alliance's zones.	Robot should be symmetrical and capable of playing on both sides of field.	concept
Robot can grip 5 debris at once, when the maximal capacity of one bucket is 24 cubes. So, to fill one bucket robot has to repeat collecting and taking cubes to the goal 5 times per 1,5 minutes	Gripper for debris should be at the front side of the robot and extractor for scoring elements - from the back side. It will allow robot to go to the ramp backwards, so it won't need to turn around on the ramp before going down to collect debris. It will save some time.	concept
It's quite inconvenient to exchange ramps with your ally during the game.	We will negotiate with our ally about spheres of influence before each game. Additionally, there should be two autonomous programs for climbing onto both ramps.	strategy
The only main difficulty of this year autonomous period is that both robots in alliance have to fulfil the same tasks at the same place. So, there is a high risk of collisions between them.	A number of different programs for autonomous period are needed for easier adjustment to the ally's strategy.	strategy
It's not restricted to collect debris in autonomous period.	It will be useful to realise automatic collection of 5 cubes in autonomous period. At the conclusion of autonomous period the robot will remain on the ramp with 5 cubes and we will put them to the goal immediately	strategy

Detailed explaination:

1. As we know from our previous FTC seasons experience, there are strict constraints for wheel bases can be used for climbing mountains. Firstly, omni and mechanium wheels are completely not suitable, because mechanium wheels can ride only on plain surface (when 2-nd and 3-rd zones have cross hurdles) and omni wheels have ability of undependable movement on small rollers so they behave very unstable on mountain. Various combinations of standard and omni wheels can't be used too, as in the 2-nd zone there are obstacles which can cause some wheels lose contact with ground and if the rest of wheels will behave differently, the whole robot would be unstable. In conclusion, we can use only standard wheels or tracks.

   Additionally, wheel base should be symmetrical against central axis for stable climbing to the mountain.

   If we decided to climb 3-rd zone with standard wheels, we will have to put 3-4 wheels at the each side to avoid getting stuck on hurdles (the space between two hurdles is for about 14 cm, when the diameter of big TETRIX wheels is only 10 cm).

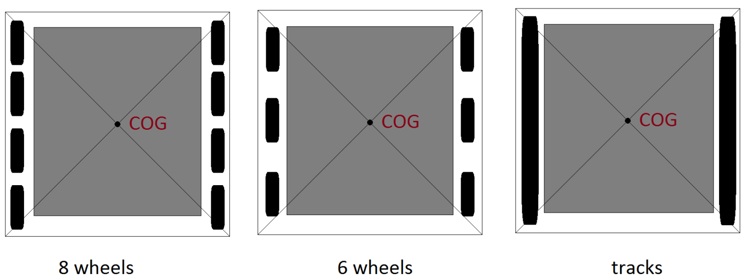


Figure 1: possible wheel bases

2. To score in high zone goal from 2-nd zone robot should have a mechanism for delivering debris to the distance of 40 cm or more. Shooting debris is entirely unsuitable approach, because it's impossible to realise enough accuracy for stable scoring cubes and especially balls. Another way is elevator. There are three types of lifts which familiar to us: they're crank lift, scissor lift and retractable rails.

   Scissor lift is not suitable for this year competition, because despite it's main advantage - the ability of extracting the longest distances of all - it's too difficult in development.

   Crank lift allows to vary the angle of turning of each segment. However, it requires at least one DC motor of strong servo for every joint.

   Retractable rails can only move along one axis. However, they require the least space and can be equipped by one DC motor (as all the motors are connected to the only reel, which winds the cable).

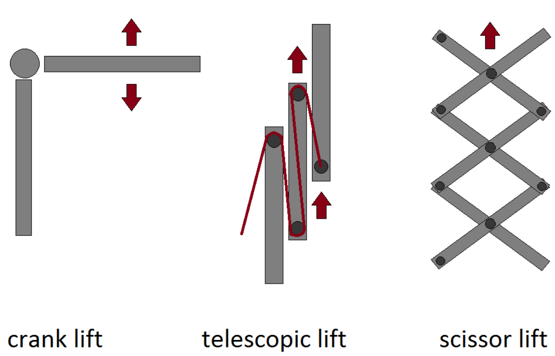


Figure 2: types of elevators

3. The parameters of the box are $9 \times 5.75 \times 6.25$. So, it can contain at most 24 cubes (4 in length, 2 at width and 3 in depth). As for balls, there can't be scored over approximately 10 of them because of their inconvenient shape and ability of top balls to roll out of the box (especially from the upper box, which is turned on 50° from horizontal position).
   This is the reason to implement mechanism for separating debris into cubes and balls. However, there are only 50 cubes on field (12.5 for one robot), so they will run out quickly, so the ability of collecting balls is required as well.
   Additionally, we need to think of how to put cubes into boxes gently so as they will settle down in straight lines. It will allow entire filling boxes with cubes.

4. Solid constructions for pulling up will be too bulky because they have to be strong enough to withstand full weight of the robot. The more reliable and simple solution is steel cable with hook for grasping the bar on it's tail.
   In second case the most difficult objective is to deliver hook to the bar, which can be solved by creating secondary lift for it (the main one is a lift for debris). Mechanism for shooting hook towards the bar is not suitable as it can be dangerous for operators and spectators (if the it will be accidentally activated during the match).

5. The main weight of the robot goes the battery and motors. The weight of the battery is 570g. We have two types of motors: standard TETRIX motor (207g) and "NeveRest 40" motor by AndyMark (334g). The complete control system (phone + controllers + power distributor) weigh about 700g.
   Therefore, total weight of essential components varies from 2926g to 3942g (with 8 motors). With several beams (166g the longest), wheels (117g each) and other construction elements robot will weigh from 6 to 10kg.
   In our primary calculations robot's weight will be accepted as 10kg. However, it is preferable to make robot as light as possible.

6. Wheel bases which are good at climbing mountains are usually less manoeuvrable, than carriages with omni and mechanium wheels. This way, the less robot will turn, the more effective it will compete.
   According to this, it will be more convenient to realise construction that will allow robot to score debris without turning around. Robot can collect debris with gripper on it's front side while moving forward and then go backward to the ramp and score debris with the mechanism on it's back side.
   Furthermore, it will be useful to attach one robot to one ramp in order to prevent them from committing extra movement. Although it seems that two robots can fill the top goal together two times faster, in fact they will just interfere with each other. So, it will be a good tactical step to negotiate with our ally before the match which robot will operate with each mountain.

7. This year field is symmetric with respect to the diagonal. It means that all zones of one alliance are the mirror reflection of another. Consequently, the gameplay depends on which alliance you are playing for.
   So, the robot should be capable of executing equal tasks playing for each alliance. The major inconvenience cause releasing alpinists, as it requires two similar mechanisms from both sides, that will take 2 servos instead of 1. Mechanism For scoring debris should be symmetrical to provide filling boxes from both sides of the ramp. Besides, autonomous program should be twoside as well.

Additional comments: For the next meeting we need to think of two issues:

1. which tasks our robot should be able to execute without loss of efficiency
   and

2. to set the priorities of performing tasks during the game.

3.2 Strategy discussing (22.09.2015)

Time frame: 22.09.2015 17:00-21:00
Preview: Today we put the priorities during the building of the robot and performing tasks of the game.

Detailed explaination:

1. The tasks which robot must complete (We assume that robot can do everything. Tasks located in order of priority) :
   1.1. Autonomous period:
      1.1.1. Push the button and score climbers. It give 60 points (20 - button 10x2 - climbers in autonomous 10x2 - climbers in tele op).
      1.1.2. Ride to opposite mountain and collect balls and bricks. It help us to save a time because when start tele-op we already have 5 bricks.
      1.1.3. Go to middle or high zone of the mountain. It give 40 (or 20) points. Additionally, we start driver control period near the top box. So we can put 5 bricks there immediately.
   1.2. Driver control period:
      1.2.1. Put elements that we collected in autonomous period to the top box.
      1.2.2. Go from the mountain and collect 5 bricks. We decided to collect only bricks because the balls take up much space in the box. So if we collect only bricks we can put more elements to one goal and get more points.
      1.2.3. Put 5 bricks to the top box. After that the top box most likely will be full. So we won't be able to put another five bricks.
      1.2.4. Collect and put 5 bricks to the middle box.
      1.2.5. Start moving to the crossbar and score climbers.
      1.2.6. Turn "all clear" signal.
      1.2.7. Pull-up.
2. Implementation of robot that can perform following tasks (tasks are in order of priority)
   2.1. Stable scoring to the middle box. This task is very simple and give a lot of points.
   2.2. Scoring to the high box. This task is more complex but gives more points.
   2.3. Releasing the climbers on the rope in driver control period. We can do it very fast and get 60 points but for scoring the top climber we must be able to climb to high zone.
   2.4. Scoring climbers in autonomous period. It is very easy task that give 40 points (as 4 bricks in the middle box).
   2.5. Riding to the high zone. It can give 40 points in autonomous period and 40 points in tele-op.
   2.6. Pulling up. This task give the most number of points.
   2.7. Turning "all clear" signal. It gives us 20 points and our opponent lose 20 points.
   2.8. Pushing button. This task is difficult in terms of programming and gives only 20 points.

Additional comments:Task for the next meeting: to elaborate concept of the robot.

3.3 Concept discussing (24.09 - 02.10)

Description: The main purpose the following number of meetings was to develop a concept of the robot. It is an essential step before creating models and developing construction.

Modules:

Modules	Conclusive solutions
Wheel base	Six standard wheels
Lift	Retractable rails with the bucket on it
Bucket for debris	Bucket mounted on rails that can overturn backwards to put debris into the box
Gripper	Rotating brush ahead of the bucket
Scoring autonomous climber and pushing button	F - shaped beam
Scoring climbers in tele-op	Retractable slat
Pulling up	A hook with the winch
Push the clear signal	Servo with beam

Separation tasks between collaborators:

Collaborator	Modules
Gordei Kravtsov	Wheel base
Aleksandr Iliasov	Bucket and mechanism for shifting it
Nikita Safronov	Elevator and winch
Andrew Nemov	Gripper and slopes
Anton Ponikarovskiy	Beam for alpinists

Days inside section:

3.3.1 24.09.15

Time frame: 17:00 - 21:30
Preview: The main purpose for current meeting was to figure out how the modules of the robot should look and how they will be developed.

Modules:

Modules	Solutions
Wheel base	Six standard wheels with leaf suspension
Lift	Scissor lift
Gripper	Rotating brush and bucket
Scoring autonomous climber and pushing button	F - shaped beam
Scoring climbers in tele op	Retractable slats
Pulling	Motor that reel the rope
Push the clear signal	Servo with beam

Detailed explaination:

1. Wheel base will consists of six standard wheels which rotates with help of six DC motors. It allows to climb to low and middle zone fast enough. The leaf suspension ensure stability in the middle zone.

2. We decided to use the lift in our robot. It help us to score elements to high goal from low or middle zone. So we don't need climb to the high zone. We chose the scissor lift because it is compact and extend to a big height .

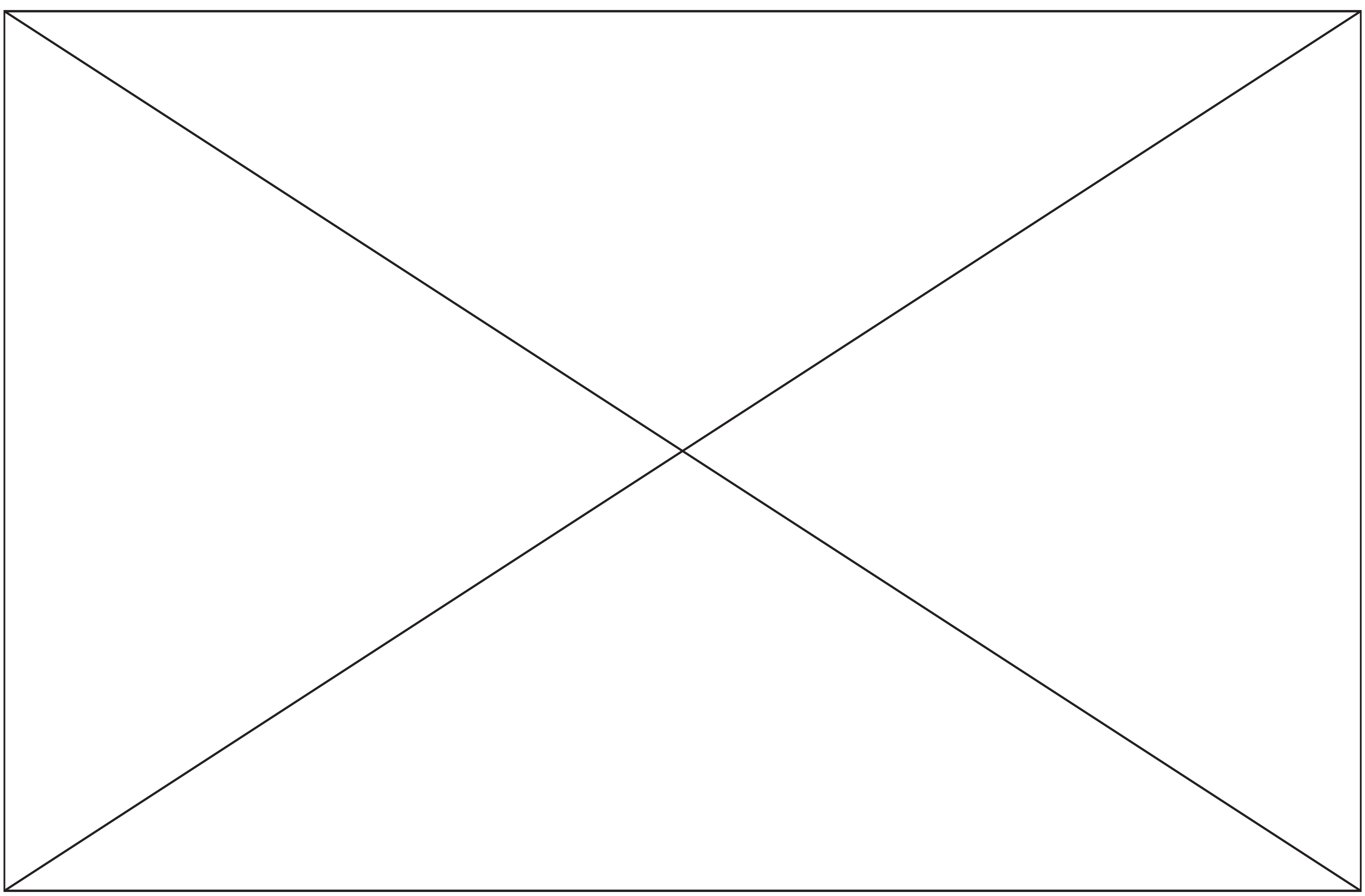
3. The robot will collect elements with help of rotating brush which pull them to the special bucket which connected with the lift. This method is the most simple and fast. After collecting elements the bucket rises by the lift. Then it overturns to the side and elements fall to the box.

4. We decided to make one mechanism for scoring autonomous climbers and pushing the button. It is the F-shaped beam. In the top beam is the bucket for climbers, in the bottom - axle which push button. When we turn this mechanism the axle push the button and in the same time climbers fall to the goal.

5. For scoring climbers in tele-op we decided to use horizontal retractable slat that move to the both sides by the wheel that rotate with help of servo of continuous rotation. When the slat extract it push to the hook that fix zip line.

6. The pulling mechanism is the 2 DC motors that reel the rope which connected with the hook that fixed on the lift. Also this motors rise the lift. When lift is rising the rope is extracting. When the robot pull up rope is reeling and lift is lowering.

7. For pushing clear signal we decided use the servo with beam that fixed on the lift.



3.3.2 26.09.2015

Time frame: 17:00-21:00

Tasks for current meeting: To improve the concept of the robot.

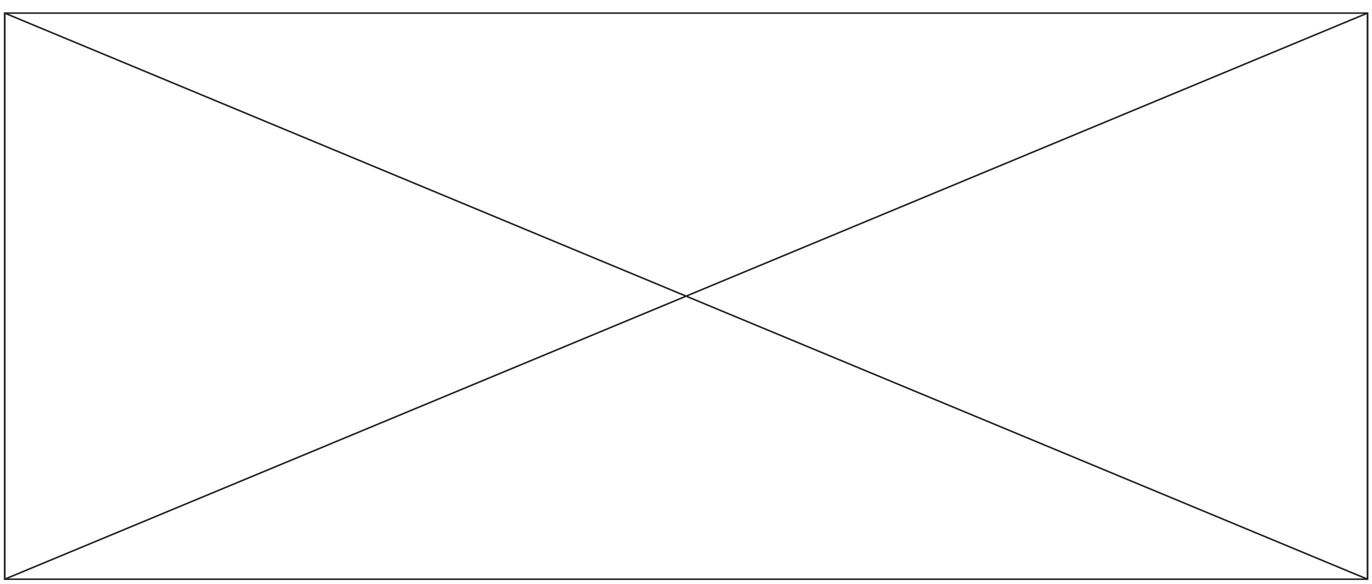
Module	Solutions
Wheel base	6 standard wheels without suspension
Lift	Retractable slats
Scoring elements	Bucket overturns back

Detailed explaination:

1. We decided to refuse from suspension on wheel base because it is too complex and reduce reliability of the robot.
2. We decided to use lift that consists of retractable construction profiles. This system is more reliable.
3. We decided to overturn the bucket back and turn the robot because when we overturn it to the side we need ride to the ramp very accurate. In addition when we overturn it to the side we need very long bucket.
4. We decided to score climbers in tele-op with help of the servo which turn the beam (one servo on each side of the robot). This mechanism is more compact.
5. Also we thought that for scoring elements and pulling we need different angle of inclination of the lift. So we need the mechanism that turn it.

Additional comments: What to do the next meeting.

1. To think of the mechanism that turn the lift.



3.3.3 30.09.2015

Time frame: 16:00-21:00
Tasks for current meeting: To think about mechanism for turning lift.

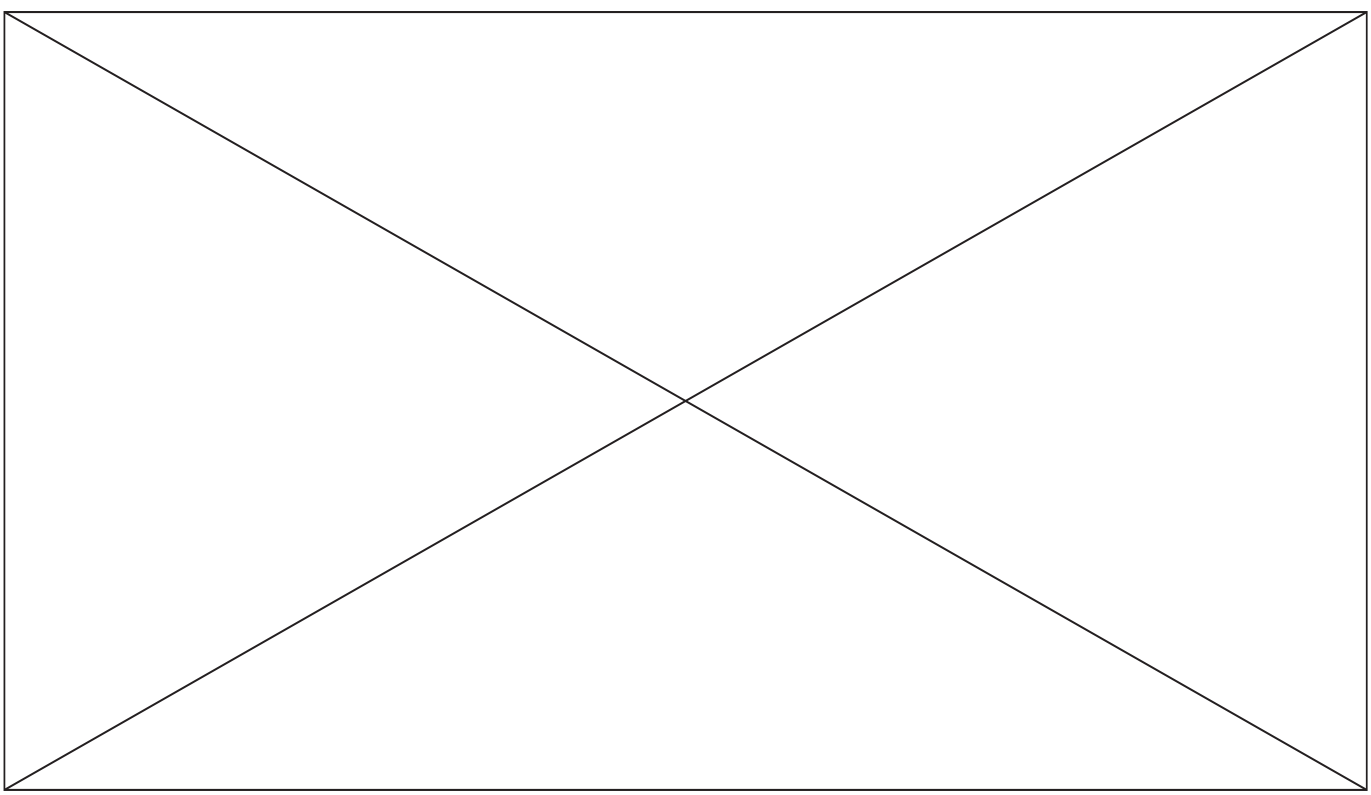
Tasks	Solutions
To elaborate mechanism for turning lift	Servo of continuous rotation with worm gear

Detailed explaination:

1. We made a drawing in GeoGebra where were estimated angles of inclination of the lift for scoring elements and pulling.
2. We looked the variant with DC motor and transmission for power but it take up much space.
3. We decided use the servo of continuous rotation with worm gear. The worm gear will ensure power and allow to keep position.

Additional comments:
Tasks for the next meeting:

1. To make a schematic model of the robot
2. To divide the robot into modules.
3. To make a technical task for each module and start parallel elaborating models of each module.



3.3.4 02.10.2015

Time frame: 17:00-19:30
Preview: The purpose of this meeting was to divide all construction works into 4 groups (one group for one teammate) to elaborate modules in parallel. After that, we wrote the technical specifications for each group of modules to help collaborators follow the requirements.

Technical specifications for modules:

1. Chassis
   1.1. Carriage consists of two lengthwise beams 41.5cm connected at the back. All other modules will be mounted to this base.
   1.2. Wheel base consists of 3 pairs of standard wheels. All wheels at one side are linked to each other and move together.
   1.3. Wheel base is powered by 4 dc motors (2 at one side).
   1.4. Motors should not interfere with the bucket, which will be placed in the front half of the robot.
   1.5. While the robot is climbing the ramp, no construction elements but the wheels should be touching the surface of the ramp.
2. The mechanism that turns the elevator
   2.1. A continuous rotation servo will turn the worm gear.
   2.2. It should be mounted on the side beam of the base.
3. Elevator
   3.1. Elevator consists of retractable construction profiles which connected with help of special elements. The shape and size of these elements should be fit with grooves in profiles.
   3.2. It should be mounted on the turning mechanism.
   3.3. Length of the elevator should be enough for scoring debris into high and middle boxes from low zone and starting pull-up from the middle zone.
   3.4. A thread and block system will provide lifting of elevator.
   3.5. The servo that turn clear signal should be fixed on the top of the elevator.
   3.6. The hook for pulling the robot up will also be mounted on the top of the elevator.
4. Bucket
   4.1. The bucket will be fixed to a beam turned by a servo on the top of the lift.
   4.2. Free space inside the bucket should be 10-14cm at width, 15-17cm in length and 7cm in height. It should be spacious enough to contain 5 cubes of 3 balls.
   4.3. To prevent gathering more than five cubes at once, the bucket will narrow down to the back (cubes will settle as $2 + 2 + 1$).
   4.4. The bucket's movement should not interfere with debris gripper.
   4.5. The entrance hole of the bucket should have the same height and width as the internal space.
   4.6. Bucket should have a turning flap above the entrance which can prevent balls from scoring not on demand. Additionally, the flap will stop debris from falling out of the bucket when it is be flipped over.
5. Gripper
   5.1. Gripper consists of 2 rotating blades which form a 180° angle.
   5.2. Gripper is powered by 1 or 2 continuously rotating servos.
   5.3. Gripper is placed in front the bucket. Blade width should match the bucket entrance.

5.4. Space between axis and field is enough for unhindered passage of balls.
5.5. Gripper should not pose any obstacle for bucket motion.
5.6. At both sides of the blade's working area placed slopes, which are tapering to the bucket.

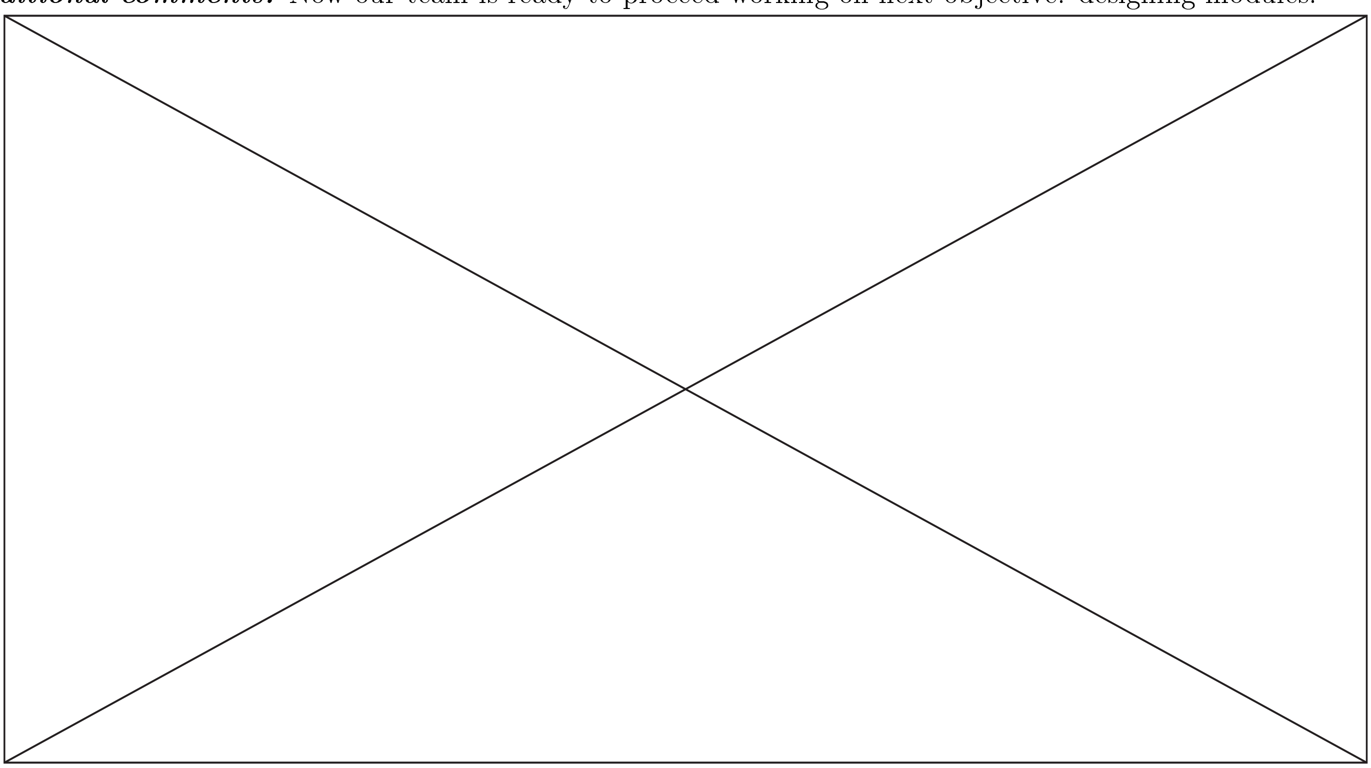
6. Scoring autonomous climbers + pushing button
   6.1. The mechanism for scoring autonomous alpinists will be placed at the front right side of robot. It's definite position will be determined after discussion of autonomous strategy.
   6.2. Mechanism consists of F-shaped beam powered by standard servo.
   6.3. At the end of top beam is a bucket for 2 alpinists. The bottom beam pushes the button.
   6.4. Module should not interfere with gameplay after the autonomous period ends.

7. Mechanism for extracting lift and pulling
   7.1. Two reels that are rotated by 4 DC motors.
   7.2. The rope for pulling and line for extracting lift are in different reels. When the line wound the rope unwound and in other way.
   7.3. It should be mounted on the back beam of the base.

Responsibilities for each module:

1. Carriage and wheel base - Gordei Kravtsov
2. Bucket and mechanism for shifting it - Aleksandr Iliasov
3. Elevator and winch - Nikita Safronov
4. Gripper with slopes and the mechanism for scoring alpinists - Andrew Nemov
5. Mechanism for scoring alpinists - Anton Ponikarovskiy

Additional comments: Now our team is ready to proceed working on next objective: designing modules.



3.4 Team meetings (10.11 - 03.12)

Description: The following section contains a consequence of team meetings with short descriptions. The purpose of this is to present the elaboration of the robot in it's progress. You can find the full information about modules and program in sections "specifications for modules" and "specifications for programs" correspondingly.

Days inside section:

3.4.1 12.11.2015

Time frame: 17:00-21:30

Today it was created the carriage (figure 3). There were applied 7 cm standard wheels with gear ratio 2:1 (speed about $2 \times 7 \times 2 \times Pi = 88$cm/sec). Next motors were connected to motor controllers and an NXT brick (as we didn't have new control system) and it was realised a simple program to test the wheel base. Source code is available in the section "specifications for programs".

The prototype had no problem with movement on the field. However, it's clearance was too narrow and it couldn't climb to the inclined plane. So, it was decided to rebuild wheel base with 10 cm wheels.

It was also created the prototype of the gripper for debris (figure 4).

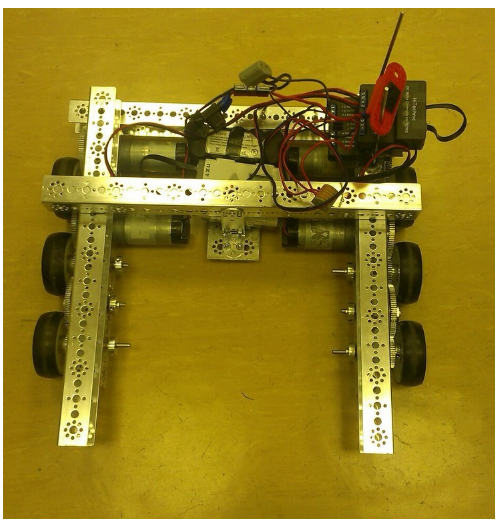


Figure 3: Prototype of the wheel base

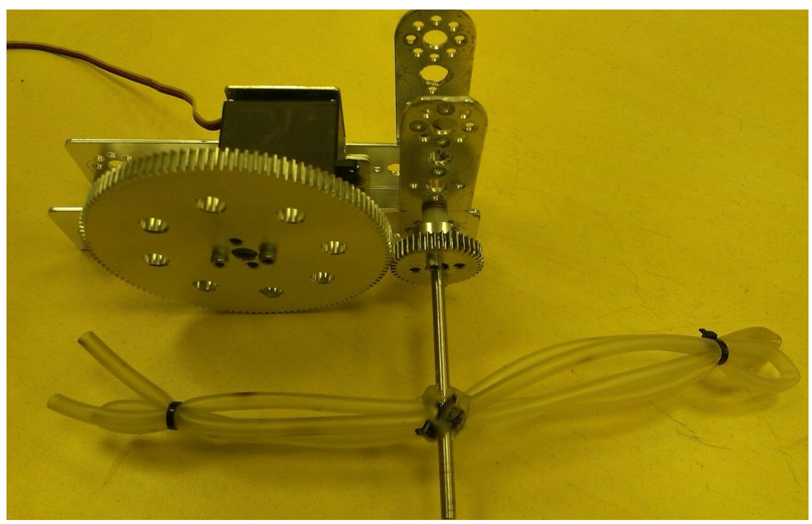


Figure 4: Prototype of the gripper

3.4.2 14.11.2015

Time frame: 17:00-21:30

This day there was tested the improved version of program. It included movement by left stick, choosing speed with buttons A-D (12%, 24%, 48% or 96%) and accurate turns and straight movement (for alignment) with buttons L1, L2, R1, R2. Source code ia available in the section "specifications for programs".

3.4.3 16.11.2015

Time frame: 17:00-21:30

Today the gripper was mounted to the carriage (figure 5). Brushes for debris were not installed yet.

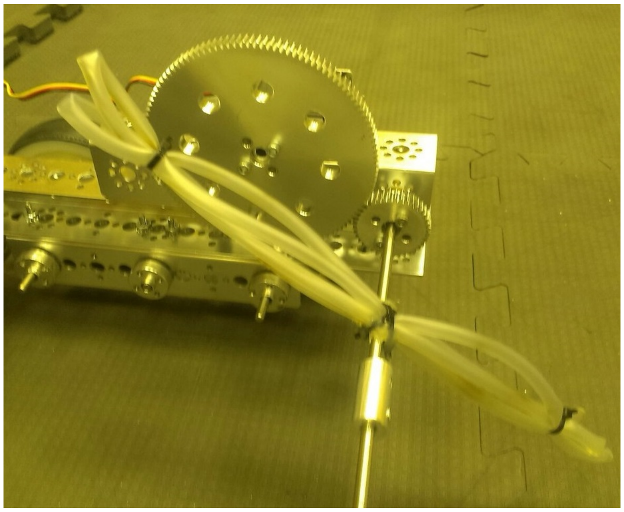


Figure 5: Gripper on the carriage

3.4.4 17.11.2015

Time frame: 17:00-21:30

It was started the creating of a mechanism for shifting the bucket (figure 10). This mechanism is used for delivering the bucket to the box at the horizon direction.

It was also created a mechanism for scoring alpinists in autonomous period (figure 6, 7, 8).

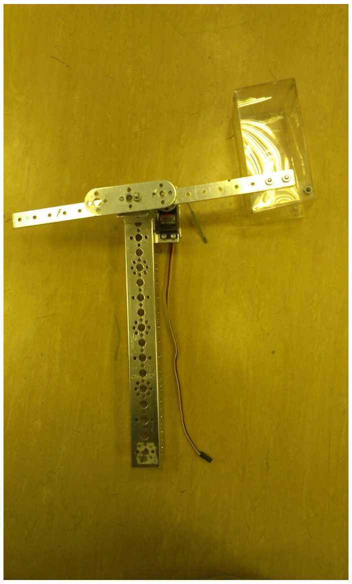


Figure 6: Mechanism for scoring alpinists

Figure 7: Mechanism closed

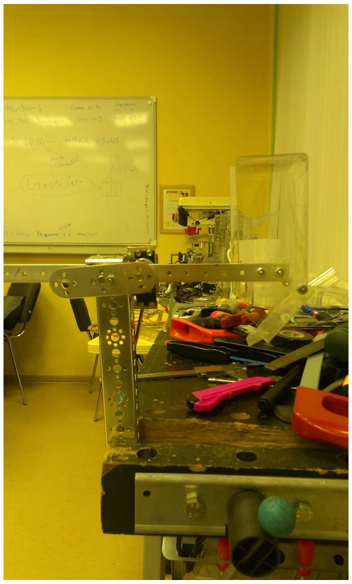


Figure 8: Mechanism opened

3.4.5 18.11.2015

Time frame: 19:00-21:30

It was started the recreating of the wheel base. The left side was rebuilt with 10 cm wheels (figure 9). The gear ratio was changed to 1:1 (speed about $1 \times 10 \times 2 \times Pi = 63$cm/sec).

3.4.6 19.11.2015

Time frame: 17:00-21:30
The recreating of the wheel base was finished (figure 9). There was written the new version of the program. An only thing that has been changed since the previous version are the settings of the stick. Operating area of the stick was divided into 6 sectors with one option in each. The previous version had 8 sectors, so it was more difficult to choose the right one by the thumb.

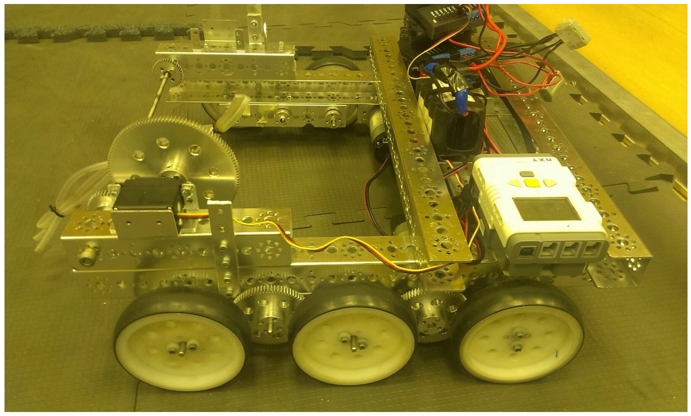


Figure 9: Wheel base with 10cm wheels

3.4.7 21.11.2015

Time frame: 17:00-21:30

The mechanism for shifting the bucket was finished (figure 10).

The gripper was recreated due to the increasing of the height of the robot after installing 10 cm wheels (figure 11). The axis was moved to the demanded height. After that there was created the brush. It was made of silicone tubes tied to the axis by plastic clamps.

Next, the gripper was tested. The brush was capable of collecting debris. As for continuous rotation servo, it was too slow and didn't have enough torque for acceptable collecting of the debris.

One more problem was that the gripper was staggering, because it was made of two axes connected by the sleeve. To avoid this, it was decided to install one TETRIX tube instead of axes.

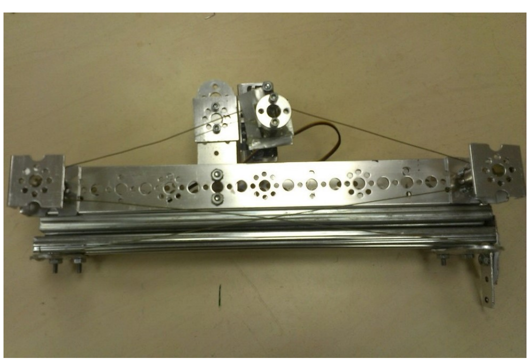


Figure 10: Mechanism for shifting the bucket

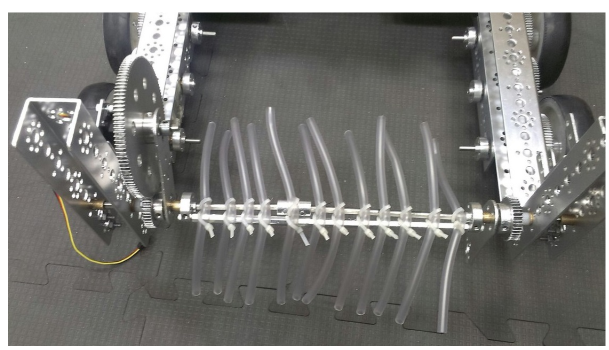


Figure 11: Gripper with the brush

3.4.8 23.11.2015

Time frame: 17:00-21:30

It was created a prototype of the winch for elevator (figure 12). This constriction had gear ratio 1:2.

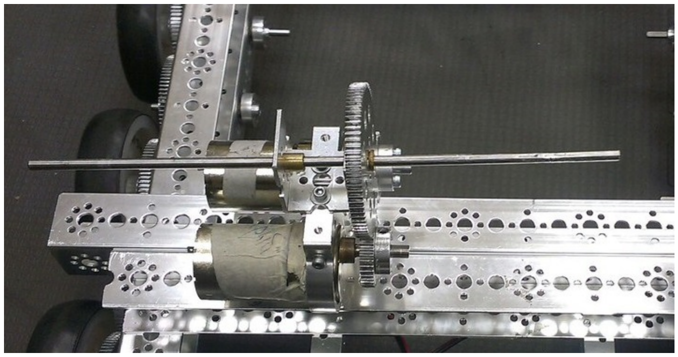


Figure 12: Prototype of the winch

3.4.9 24.11.2015

Time frame: 17:00-21:30

The mechanism for scoring alpinists was recreated (figure 13). The beam for counterweight was removed, as the calculations clarified that it is not necessary. The mechanism became more compact.

Figure 13: New version of the mechanism for scoring alpinists

3.4.10 25.11.2015

Time frame: 19:00-21:30

The aluminium profile for the elevator was cut into segments (figure 14). These segments were prepared for installation onto the slats.

On the rails there were found coincident holes for connecting them (figure 15).

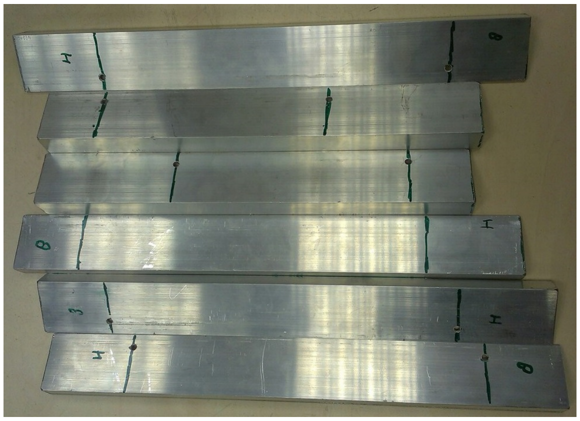


Figure 14: Aluminium profile was cut

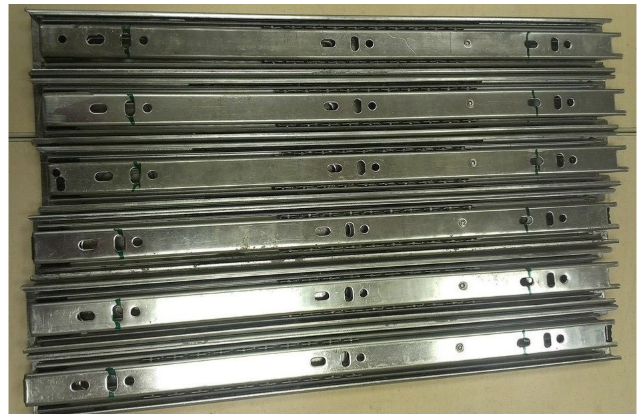


Figure 15: Furniture rails were marked up

3.4.11 26.11.2015

Time frame: 17:00-21:30

Today we received the parcel with the original field. We started assembling it.

The slats were assembled of 3 35cm furniture rails each and installed onto the carriage (figure 17, 18). The angle between direction of extracting of the rails and the surface amounted to 22.5°

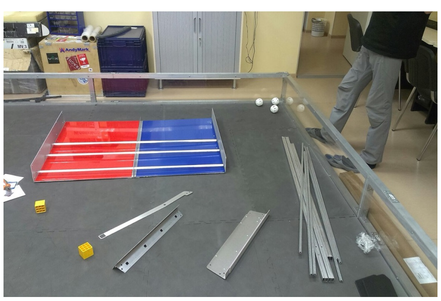


Figure 16: Assembling of the field

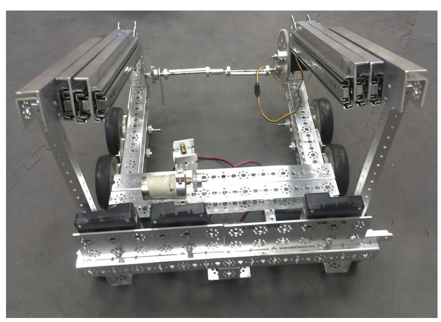


Figure 17: Elevator installed onto the carriage

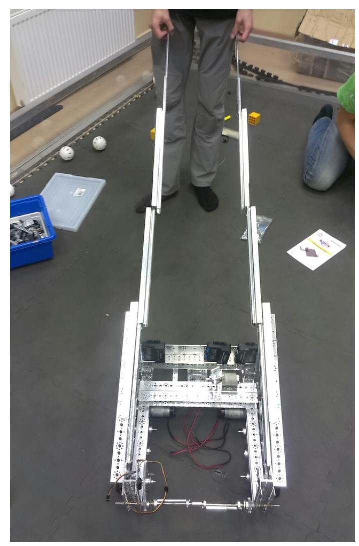


Figure 18: Length of the slats

3.4.12 27.11.2015

Time frame: 17:00-21:30

The work piece of the bucket for debris was cut out of the pet (figure 19). It was no time to craft the bucket at this meeting.

There were installed angles onto the elevator (figure 20). These angles will be used for installing blocks.

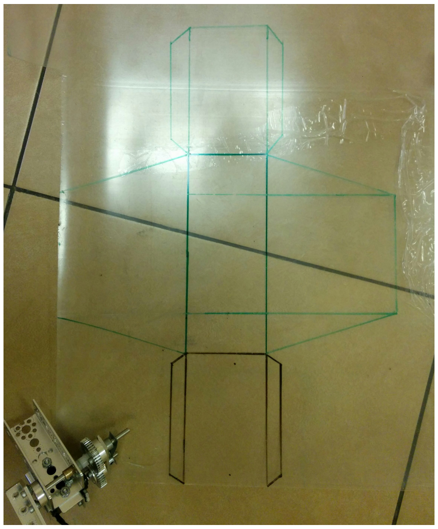


Figure 19: The work piece of the bucket

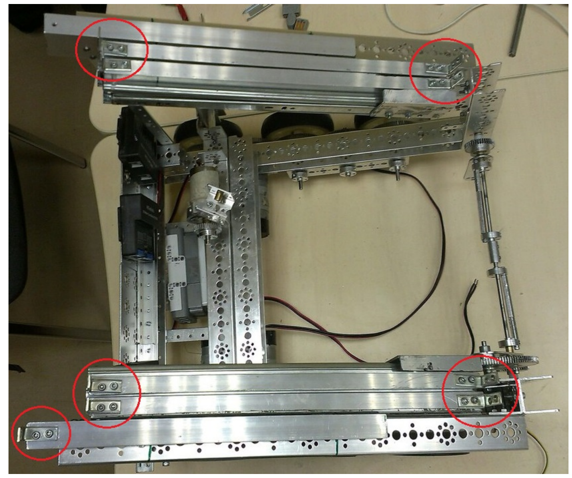


Figure 20: Angles on the elevator

3.4.13 28.11.2015

Time frame: 17:00-21:30

Blocks were installed onto the angles on the elevator (figure 21, 22).

The concept of the winch was changed. It was decided to apply 3 standard DC motors with gear ratio 1:1. 3 standard TETRIX motors with torque 10 kg/cm and speed 2 r/pm are able to pull up robot of 10 kg with a speed $3 \cdot 2\pi \cdot 2 = 38$ cm/s. Including safety coefficient 1.5 the speed will amount to 25 cm/s. Since the overall length of the cable required for pulling up from 1-st zone is about 1m, the robot will be able to pull up in 4 seconds. The time of the full extracting of the elevator would be the same.

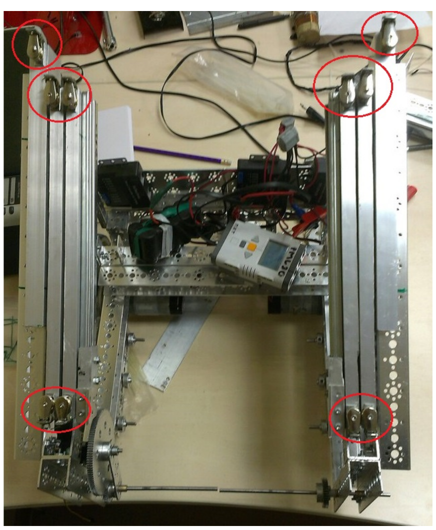


Figure 21: Blocks on the elevator

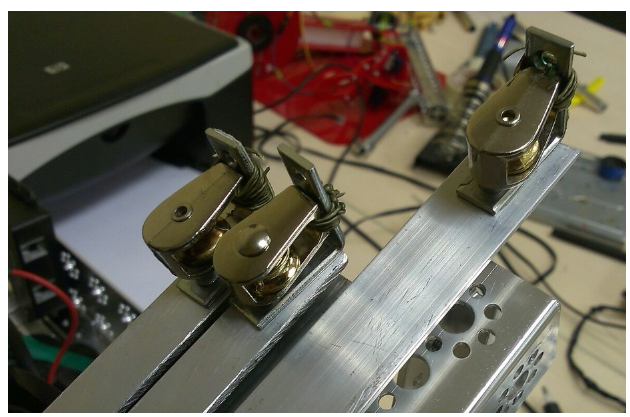


Figure 22: Blocks

3.4.14 29.11.2015

Time frame: 17:00-22:00

The carriage was reshaped in order to provide more space for installation of the winch (figure 23).

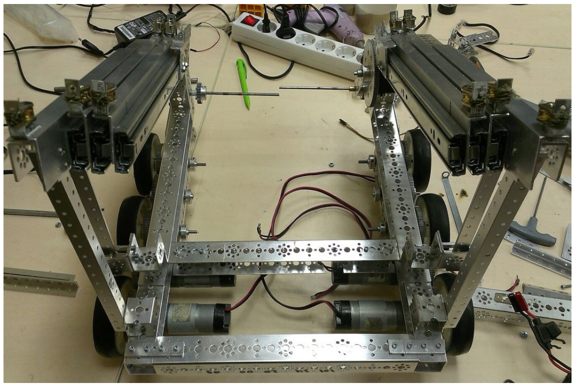


Figure 23: Carriage reshaped

3.4.15 30.11.2015

Time frame: 17:00-22:00

The winch was assembled (figure 24).

It was also created the bucket for debris (figure 25, 26).

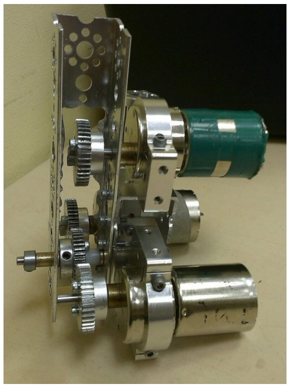


Figure 24: Winch

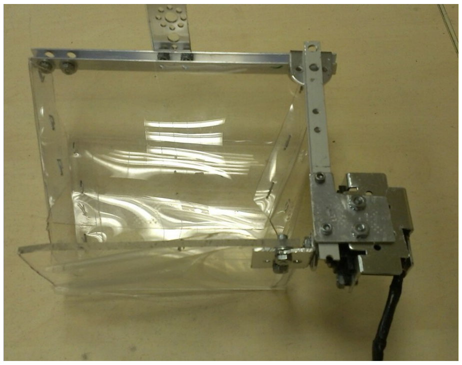


Figure 25: Bucket (front)

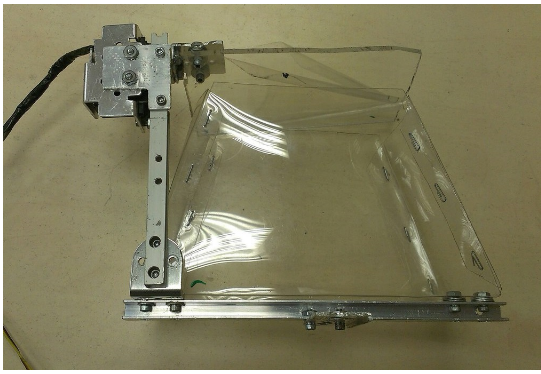


Figure 26: Bucket (back)

3.4.16 01.12.2015

Time frame: 16:00-22:00

The winch was installed onto the robot. The 8mm axis will be connected with the winch. It will keep the coils for rope. There were drilled all the needed holes for fixing coils on the axis (figure 27, 28).

The gripper was reassembled with the TETRIX tube. For powering the gripper it was installed a standard DC motor with gear ratio 2:1.

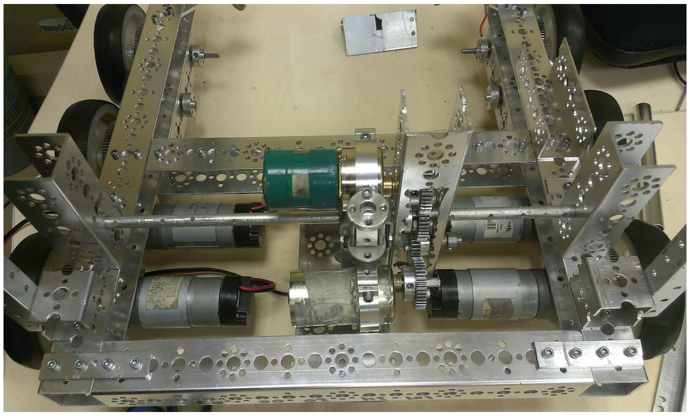


Figure 27: Winch installed onto the carriage

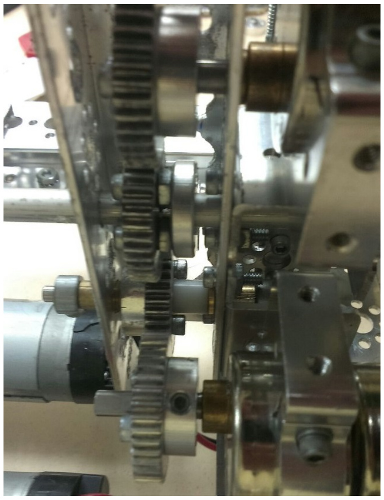


Figure 28: The construction of the winch

3.4.17 02.12.2015

Time frame: 16:00-22:40

Coils were installed onto the axis connected to the winch (figure 29).

NXT brick, battery and 6 controllers (4 motor controllers, 2 servo controllers) were installed onto the robot (figure 30, 31).

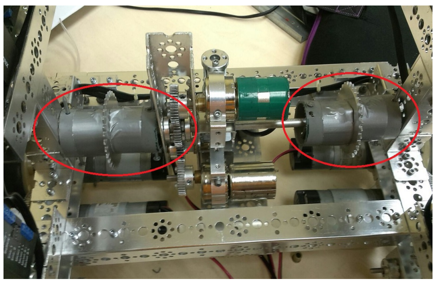


Figure 29: Reels for the ropes

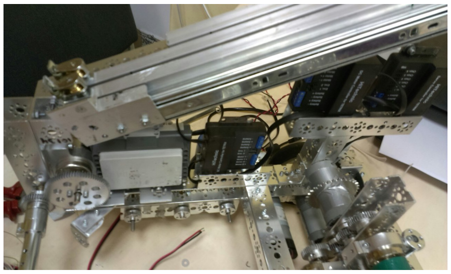


Figure 30: Controllers and NXT on the right side

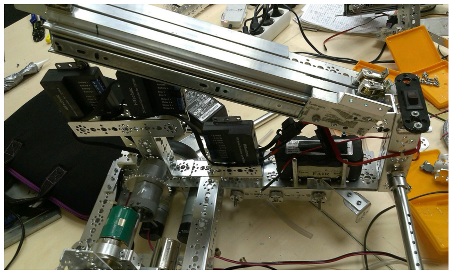


Figure 31: Controllers and battery on the left side

3.4.18 03.12.2015

Time frame: 17:00-21:30

Today the mechanism for shifting the bucket was installed onto the robot. It was mounted to the top pair of slats (figure 32, 33).

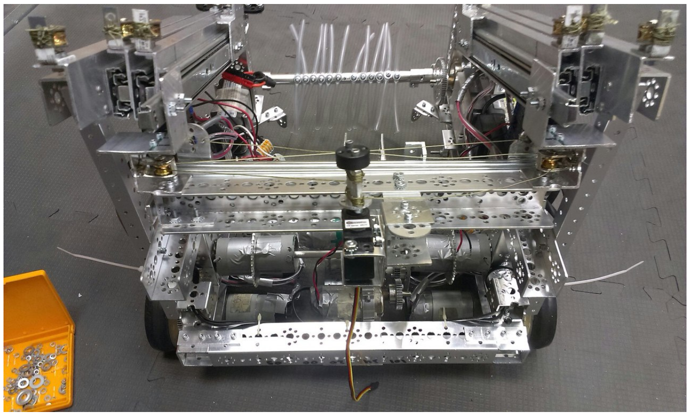


Figure 32: Mechanism for shifting the bucket 1

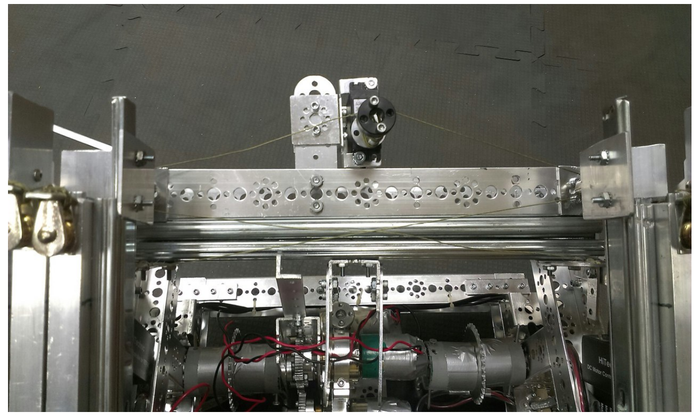


Figure 33: Mechanism for shifting the bucket 2

There were also created brushes for collecting debris on the gripper (figure 34).

The bucket was installed onto the mechanism for shifting bucket (figure 99).

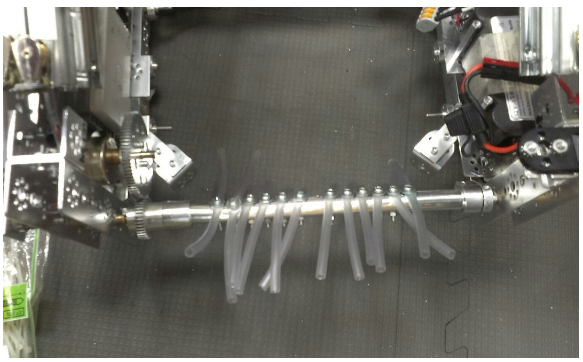


Figure 34: Brushes

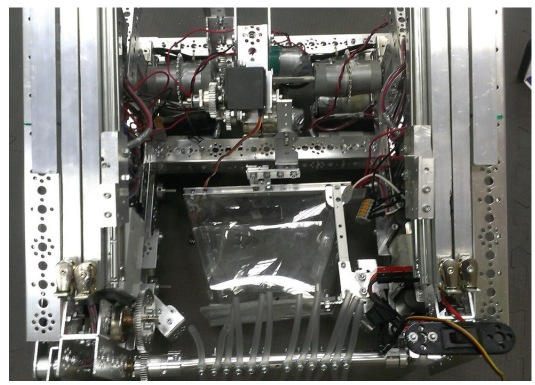


Figure 35: Bucket installed to the elevator

To connect servos which are installed on the elevator there were manufactured special wires (figure 36). They were made of telephone wire by soldering servo connectors. Unfortunately, it was investigated that these wires have too high resistance (9 Ohms each), so it was impossible to power standard servos by them. However, continuous rotation servos worked with these wires with no problem (possibly because of higher inner resistance).

Figure 36: Special wires

3.4.19 04.12.2015 (Competition)

Time frame: 8:00-22:00

Today was the first day of competition. There were only training matches, so we were just preparing robot for the qualifications.

Figure 37: Preparing robot 1

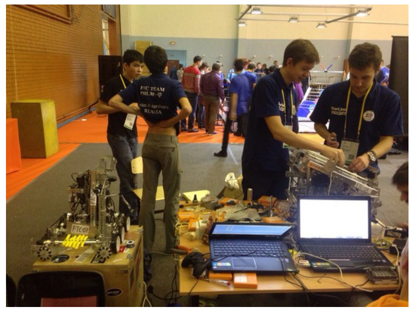


Figure 38: Preparing robot 2

Figure 39: Preparing robot 3

Today the winch was tested for the first time, it was found out, that there is one weak point: the screw that connected the axis with motors carried too much load, so it broke down as soon as the winch started extracting the elevator. Unfortunately, it was a very severe mistake in development and all the mechanism became useless without the connection between motors and coils.

Due to this, the mechanism was totally disassembled. After that, it was decided to create a temporary mechanism for extracting of the elevator for the competition "Robofest South", that took place the next day. There were created two independent coils, powered by one motor each. This construction was also tested, but due to both coils were not synchronised, two sides of the elevator were extracting with different speed and it could break the slats. That's why it was decided to not to use this system at the competition.

3.4.20 05.12.2015 (Competition)

Time frame: 8:00-23:00

Today there were qualification matches. Our team managed to reach the 2-nd place.
After that there were final matches. There were less than 20 teams in the competition, so the final alliances were consisting of 2 teams each. We chose team PML30-X. Due to nice teamwork our alliance won the competition.

Figure 40: Operators during the match

Figure 41: Teams PML30-Y and PML30-X group photo

During the matches it was found out, that the robot has a very high center of mass, so it's easy for it to be overturned while climbing the mountain (figure 42, 43). So, the robot should be operated more carefully.

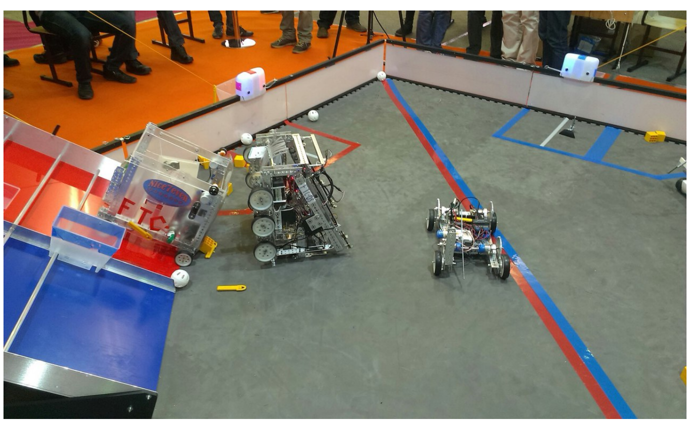


Figure 42: Robot is overturned 1

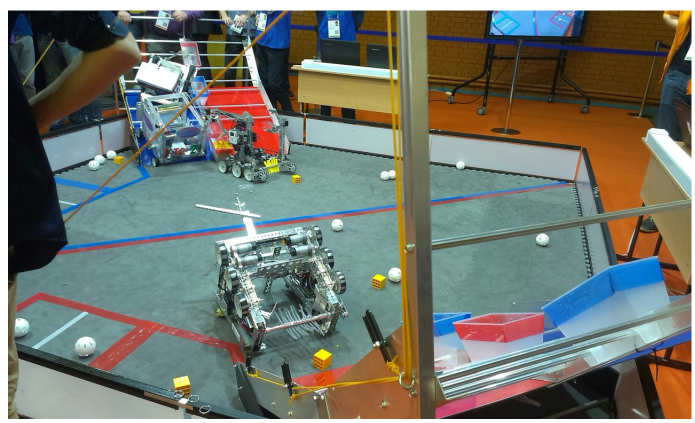


Figure 43: Robot is overturned 2

The elevator didn't work because of no winch, so it was decided to temporarily remove bucket and install the beam, that will be used for scoring alpinists into the shelter and releasing the bottom alpinist at the mountain (figure 44, 45).

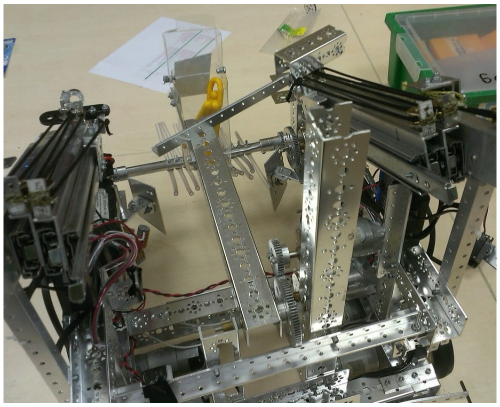


Figure 44: Beam for operating the climbers (closed)

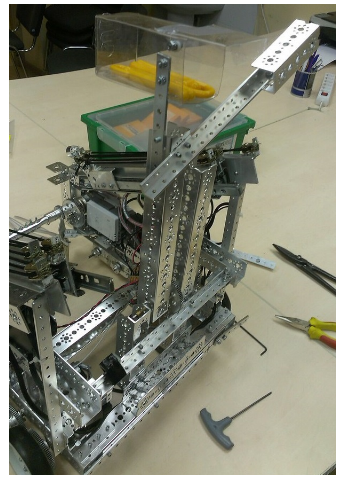


Figure 45: Beam for operating the climbers (opened)

3.4.21 08.12.2015 (Discussion)

Time frame: 18:00-21:30

Today we were discussing the experience we got at the competition in Krasnodar. We thought out what problems does our robot has and how we can improve it. The result of discussion is in following table.

Table 3: Results of discussion of competitions in Krasnodar

Module	Problem	Solution	Responsible
Grab	No problems		
Wheelbase	Motors' bushes' screws come loose Slides off the climbing zone	Use standard motor bushes Make anti-slides engagements	Gordey Gordey
Lift	Lift is placed too high	Move lift lower without changing its' angle	Nikita
Bucket	Irrational using of volume inside the robot Too slow shifting	Move bucket to the back part of robot Intersection with other modules Make fast (3 sec) shifting system	Sasha Sasha Sasha
Moving of debris	Necessarity of moving debris from front to the back of robot	Add 1-2 grabbing bushes inside the robot to move debris Connect bushes with main grab with chain and make the oblique face for debris	Andrey Andrey
Other	High center of mass	Make it lower	Nikita

3.4.22 09.12.2015

Time frame: 17:30-21:00

All the electric components were removed. The beam for scoring climbers was also removed.

After that the slats were moved down on 9.6 cm with preserving the former angle 22.5° of incline (figure 46, 47).

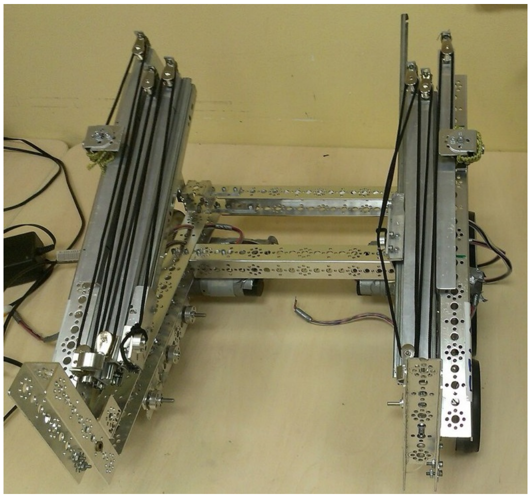


Figure 46: The slats were moved down 1

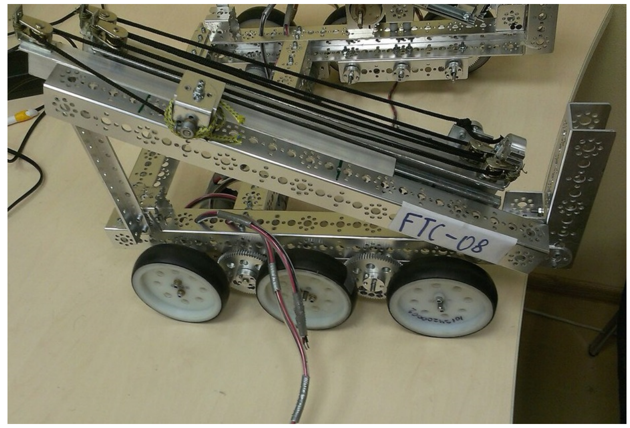


Figure 47: The slats were moved down 2

3.4.23 12.12.2015

Time frame: 16:00-22:00

The opposite pairs of slats on the elevator were connected by the ribs. It strengthened the elevator and made it more stable as from now on both sides will move dependently (figure 48, 49).

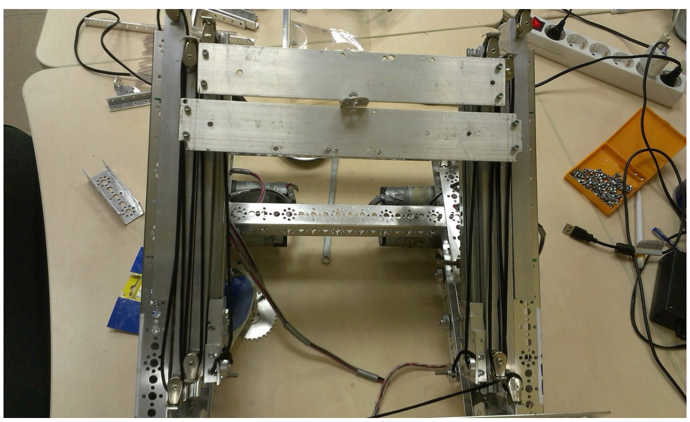


Figure 48: Slats connected by the ribs 1

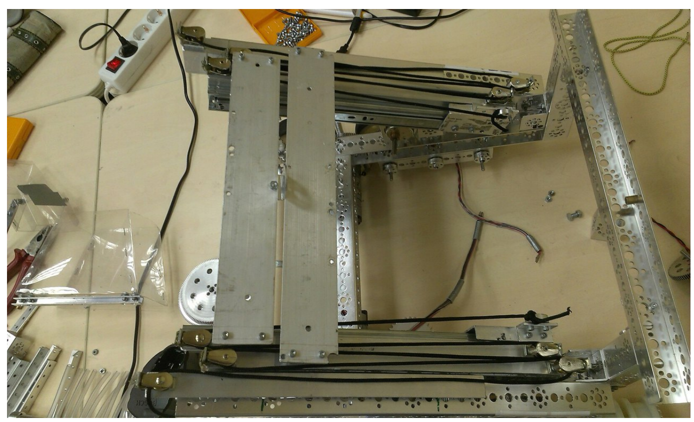


Figure 49: Slats connected by the ribs 2

In addition, it was started the assembling of the winch for extracting lift. It will include two distinct reels for two ropes from both sides of the lift (figure 50).

At first, it was an idea to make each coil from two middle-sized gears with screws between them, but this construction was too bulky. So, it was decided to apply wheels from TETRIX caterpillar tracks as coils.

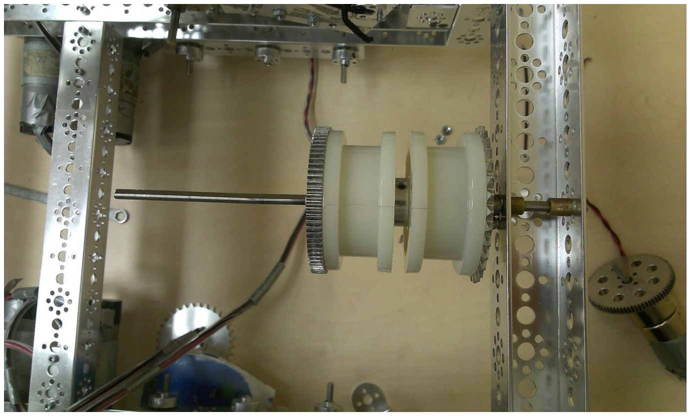


Figure 50: Winch was created

3.4.24 14.12.2015

Time frame: 17:00-21:00

The winch for extracting the lift was reliably fixed on the robot's base (figure 51).

It was installed the axis of a second brush of the gripper (figure 52).

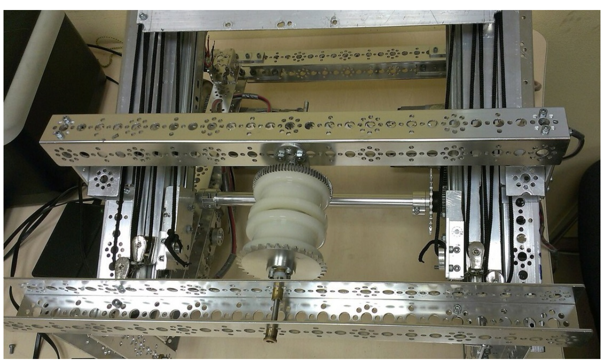


Figure 51: Winch was reliably installed

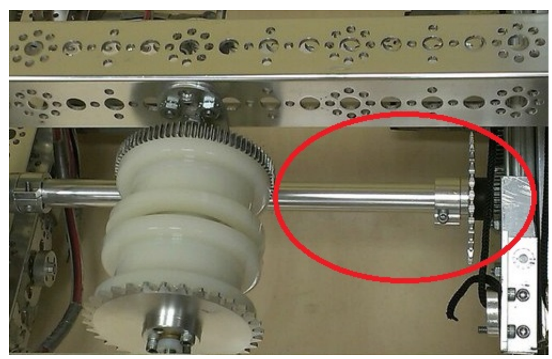


Figure 52: Axis of a second brush

3.4.25 15.12.2015

Time frame: 17:00-21:30

There were installed a pair of blocks for leading cables from the elevator to the winch (figure 54).

Next, 2 standard TETRIX motors for powering the winch were installed onto the robot (figure 53).

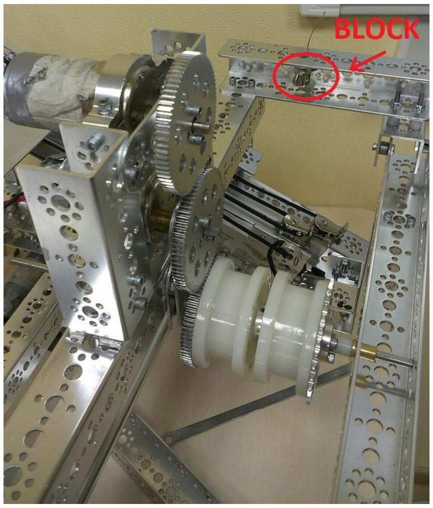


Figure 53: Motors for powering the winch

Figure 54: Block for cable

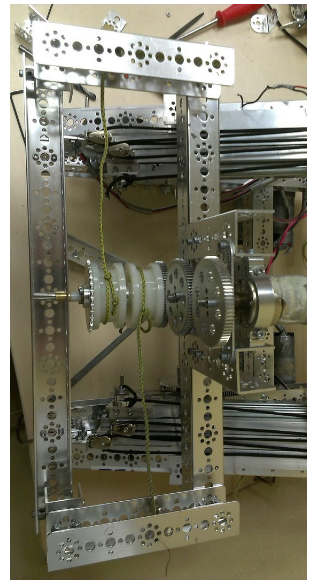


Figure 55: How the cables should go

3.4.26 16.12.2015

Time frame: 19:00-22:00

The mechanism for shifting the bucket was recreated with relation to the last version. In contrast, in the new version there were applied longer slats (40 cm), that will provide enough offset of the bucket. Also, the mount of the mechanism was made of aluminium profile instead of TETRIX parts to save weight (figure 56, 57, 58).

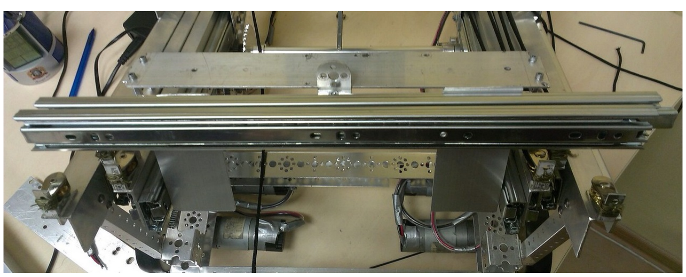


Figure 56: Mechanism for shifting the bucket

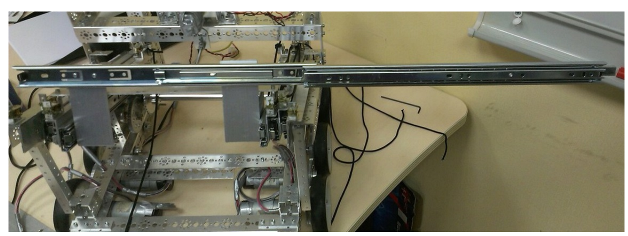


Figure 57: Extracted to the right

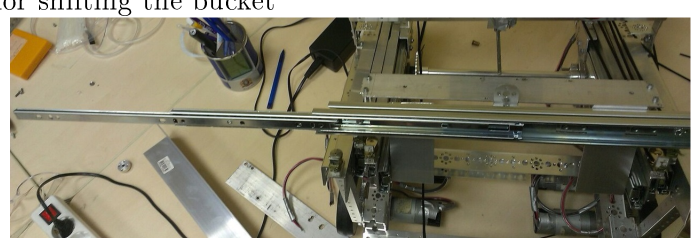


Figure 58: Extracted to the left

3.4.27 17.12.2015

Time frame: 17:00-21:00

There was installed a servo for powering the mechanism for shifting the bucket. Next, there were held the cables (figure 59, 60). Then, the mechanism was tested. It worked ok.

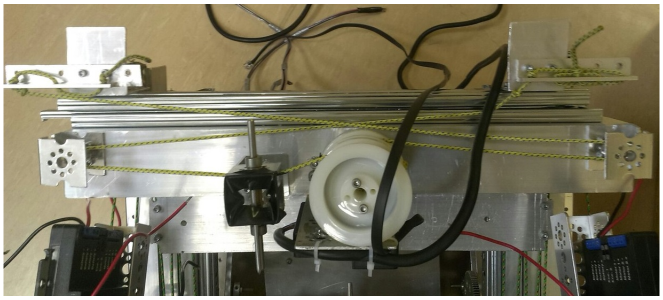


Figure 59: Servo and cables installed 1

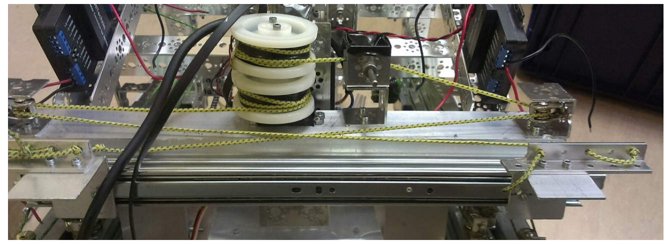


Figure 60: Servo and cables installed 2

The cables for the extracting of the elevator were held (figure 61, 62).

Figure 61: How the cables are tied to the coils

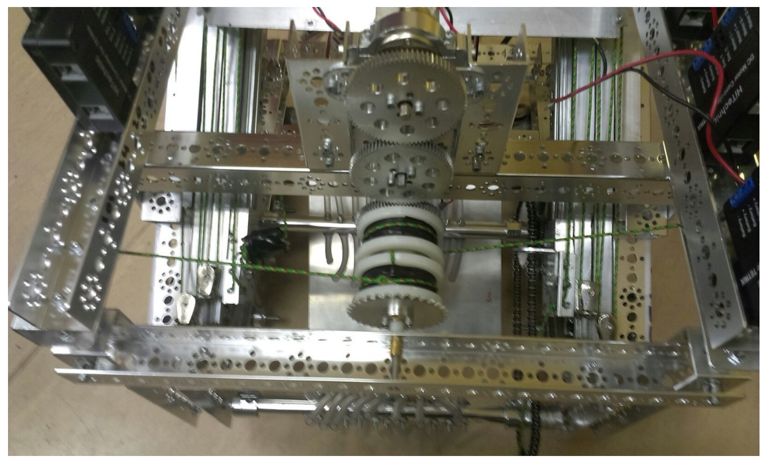


Figure 62: How do the cables go

There was installed a ramp for debris. The brushes were finished (figure 63).

There were installed motor controllers and a servo controller. The wiring wasn't finished yet (figure 64).

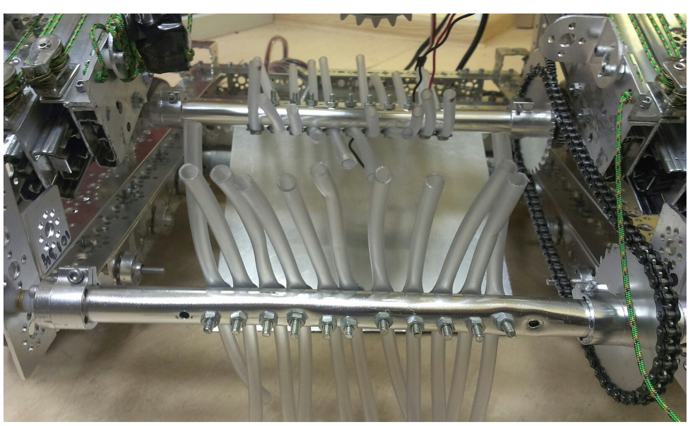


Figure 63: Ramp and brushes for collecting debris

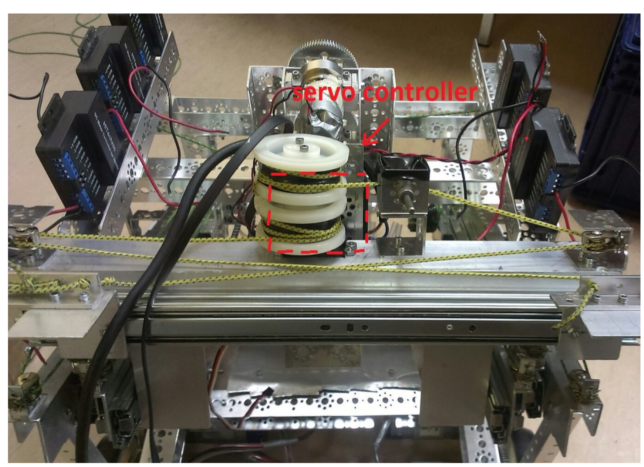


Figure 64: Controllers installed

3.4.28 19.12.2015 (Competition)

Time frame: 10:00-22:00

Today was the first day of competition "Robofest-Ryazan ". Today there were only training matches and time for preparing robots. Our team provided the organisers of this competition with original FTC 2016 playing field. The field was assembled and trainings started.

We tested the elevator, but it was found that the toothing between gears on the winch is not sufficient, so they are slipping. It made impossible to extract the slats because motors couldn't provide the coils with enough power. Due to this, we could only deliver debris to the floor goal during the match.

Figure 65: Testing elevator on the field

Figure 66: Programming and technical inspection

3.4.29 20.12.2015 (Competition)

Time frame: 10:00-22:00

Today there were both qualification and final matches. At the conclusion of the competition our team was in alliance-finalist.

After the competition finished, we disassembled the field and prepared it for transportation. Then we went to the train to return home.

Figure 67: Group photo with team PML30-X

Figure 68: Our team returns home

3.4.30 22.12.2015 (Discussion)

Time frame: 17:00-21:00
Today it was a consideration on results of the competition. After discussion table with problems, way of improving it and responsible for it team member was made.

Table 4: Results of discussion of coompetitions in Ryazan

Module	Problem	Solution	Responsible
Wheelbase	Left wheels are slower than right ones	Fix the axle bushes, make an encoder regulator, check the program	Gordey
	Wheels' radial play	The same	Gordey
	Slides off the climbing zone	Use home-made tires or buy another wheels	Nikita
Gripper	Gears slides	Place chain between motor and outer axis	Andrey
	Chain slacks	The same	Andrey
	Not enough space for balls under the second axis	Lift axis up	Andrey
	No splays	Place	Andrey
	Not inside the size	Use small cogwheel in the front	Andrey
Lift	Not many tests	Test	Sasha
	Motor gears crack and brake	Place motors far from each other and connect with chain	Nikita
Bucket	Bad wires	Change totally all the wiring	Sasha
	Cubes in bucket are in the wrong positions	Change bucket shape or make guides for debris	Sasha
	Too long shifting	Change mechanism	Sasha
Other	NXT and battery are not mounted	Mount	Gordey
	No autonomous climbers scoring mechanism	Don't do anything now	

3.4.31 23.12.2015

Time frame: 19:00-22:00

The winch was recreated with a chain to avoid slipping of the gears (figure 69).

Figure 69: Winch with chain

The wiring was held in a more safe way (figure 70).

The mount for battery was installed (figure 71).

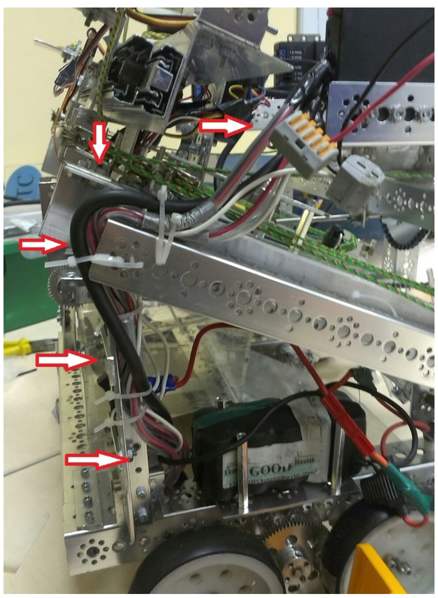


Figure 70: Wiring

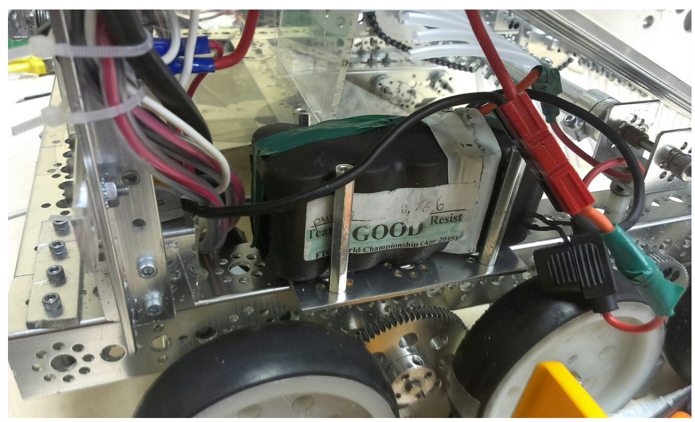


Figure 71: Mount for battery

3.4.32 24.12.2015

Time frame: 17:00-22:00

The elevator was tested while the robot was standing on the horizontal surface (figure 72). It worked OK. The full extraction took 4.5 seconds.

The length of cables on the elevator were adjusted so as make the same tension on both of them. It will help to avoid the bend of the elevator while extracting.

Figure 72: Testing of the elevator

The wiring to the top section of the elevator (to the bucket and mechanism for shifting the bucket) was held (figure 73, 74).

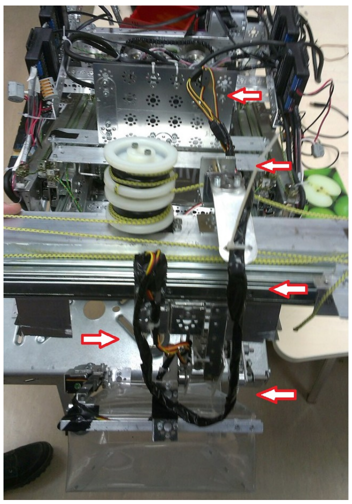


Figure 73: Wiring to the bucket

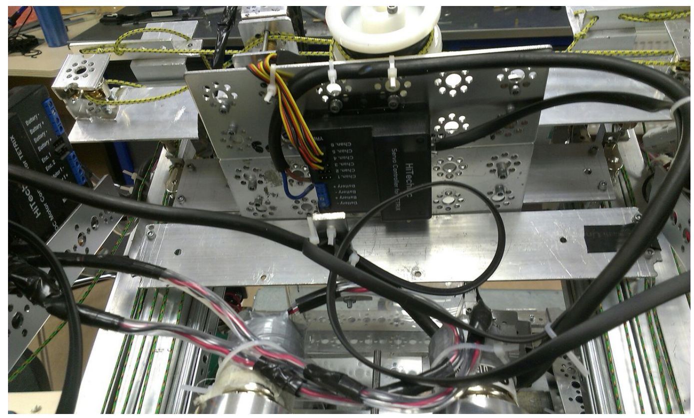


Figure 74: The servo controller

It was investigated that the beams at the sides, to which the blocks attached, are narrowing because of the tension force of the cable. To prevent this bending of beams there was installed another beam between them (figure 75).

There were also installed shores for cables that will prevent them from tangling (only for one cable this day).

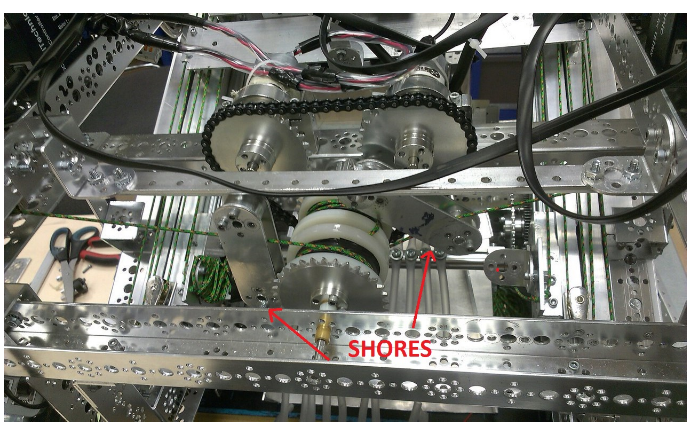


Figure 75: Beam with shores (the current image was taken after all the shores were installed)

3.4.33 26.12.2015

Time frame: 16:00-22:00

A second pair of shores for the prevention of the entanglement of the cables on the winch coil was installed.

On the ramp for debris there were installed special borders for leading scoring elements to the entrance of the bucket (figure 76).

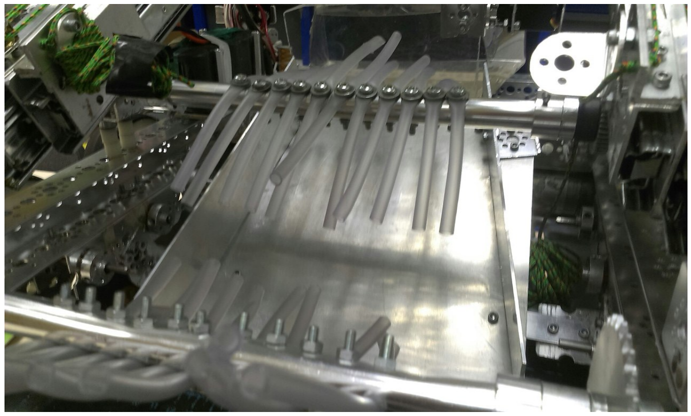


Figure 76: Borders for debris

There used to be a problem that slats, on which the bucket is mounted, bend a lot under it's weight. This day it was found a solution to this problem: it is possible to install a special plate, that will be fixed on the top slat and slide along the surface to which the bottom slat is attached. This plate will rest in the surface and prevent construction from bending.

Today it was created a prototype of this construction (figure 77, 78).

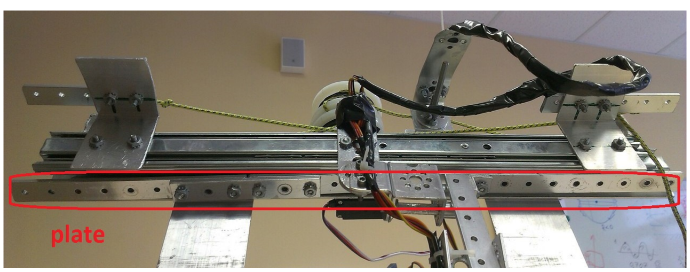


Figure 77: Special plate

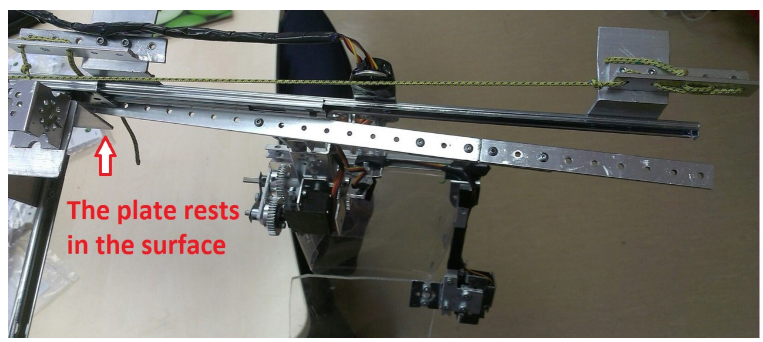


Figure 78: How does it work

3.4.34 28.12.2015

Time frame: 16:00-22:00

Today the operators were practising in driving the robot.

During the trainings it was found out that the ramp for debris scrubs the field. So, it was moved up.

It was also investigated that the robot will not overturn while climbing to the mountain if the elevator is extracted on about 30 cm or more. However, after the wheels stop moving, the robot slips down from the mountain. So, it was essential to make a mechanism for grasping the lower hurdle of the second zone to stay at the mountain.

It was revealed that the brushes are turning in opposite direction. So, it was decided to install once more gear to inverse the direction of rotation of the first brush.

The mechanism for shifting the bucket and the servos for overturning the bucket and opening the cover were tested. Both of these systems worked fine.

It was investigated that the power of 2 standard TETRIX DC motors is nit enough to extract the elevator to the full height. It was the reason why one of the motors broke down.

It was decided to install 3 motors instead of 2 and replace standard TETRIX motors with AndyMark motors because AndyMark motors are more reliable concerning to stalling.

3.4.35 29.12.2015 (Discussion)

Time frame: 16:00-22:00

The main theme of this meeting was discussion of working plans for winter holidays. As a result of it was made the following table of tasks.

Table 5: Results of discussion of holidays working plan

Task	Responsible
Study out why does the lift's motors break	Nikita
Test bucket	Nikita
Make crossbar engagements	Nikita
Finish the gripper	Andrey
Think of more convenient mechanism for autonomous climbers	Andrey
Create autonomous program	Andrey

3.4.36 04.01.2016

Time frame: 12:00-21:00

The mechanism for shifting the bucket was recreated (figure 79). In the new version of this mechanism the shaft of the servo doesn't suffer from bending because the coil that is fixed on it is now attached to the axis at it's other side.

This mechanism is not finished yet.

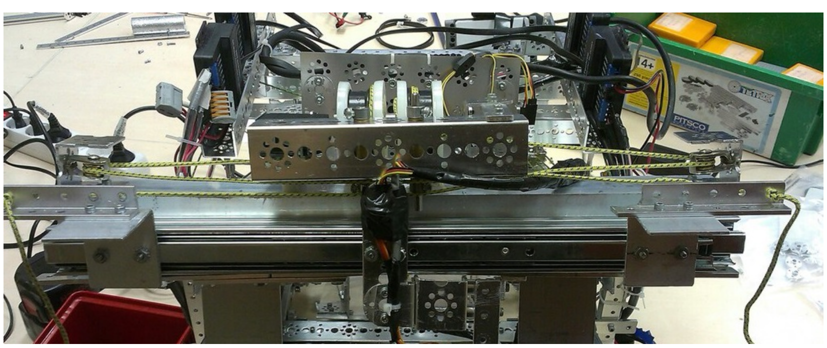


Figure 79: Servo for shifting the bucket is fixed more reliably

3.4.37 05.01.2016

Time frame: 17:00-21:30

The mechanism for shifting the bucket was finished.

The assembling of the new version of the mechanism for scoring autonomous alpinists was started (figure 80, 81, 82).

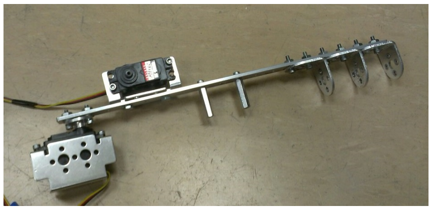


Figure 80: New mechanism for scoring alpinists

Figure 81: How does it work 1

Figure 82: How does it work 2

2 standard TETRIX motors at the winch were replaced with 3 NeveRest AndyMark motors (figure 75). Firstly, it 2 times increased torque at the coil (3 AndyMarks give torque of $3 \cdot 25 = 75 kg \cdot cm$, while 2 standard - only $2 \cdot 20 = 40 kg \cdot cm$). Secondly, it raised the reliability of the construction, as the AndyMark motors can cope with stalling for a long time (about 2 minutes), so they will not break down if the movement of the elevator is blocked.

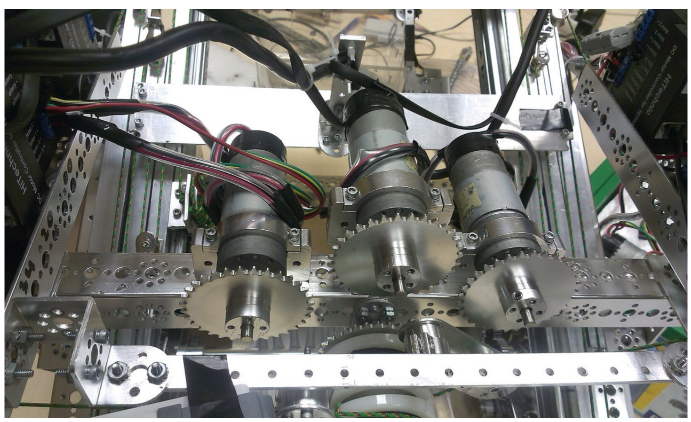


Figure 83: Three motors for powering the winch are installed

3.4.38 06.01.2016

Time frame: 14:00-22:00

Today it was created the working version of a device for preventing the bending of slats for shifting the bucket (figure 84, 85). After that, the device was tested. It worked ok.

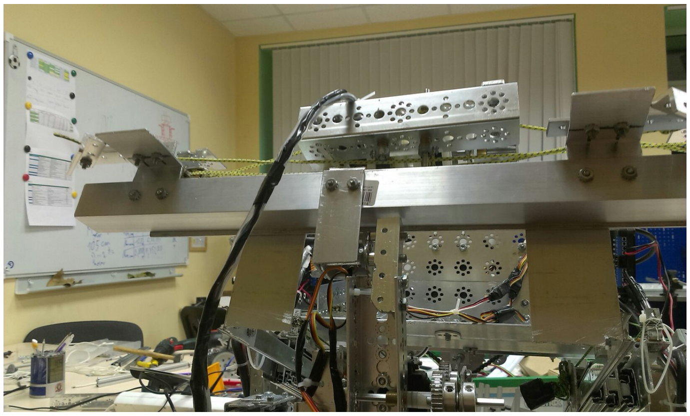


Figure 84: Device for the prevention of bending of the slats

Figure 85: How does it work

The chain at the winch was installed (figure 86).

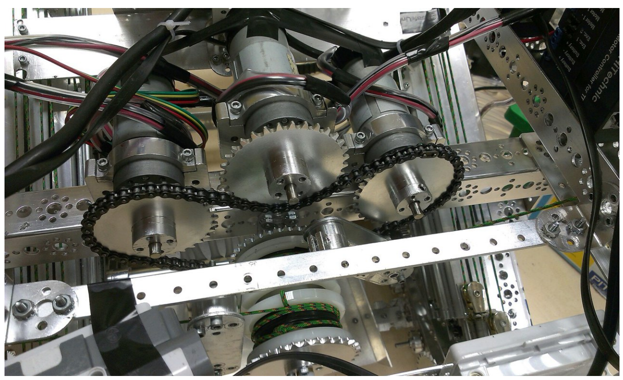


Figure 86: Chain is installed

Today it was also continued the development or the mechanism for scoring autonomous alpinists. It was created a mechanism for releasing the climbers (figure 87, 88, 89).

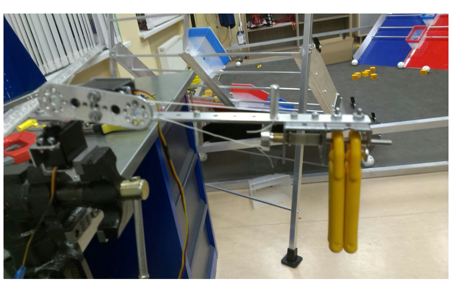


Figure 87: Releasing alpinists 1

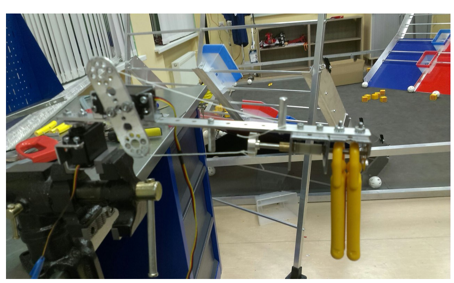


Figure 88: Releasing alpinists 2

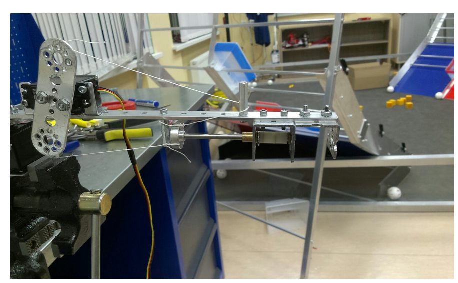


Figure 89: Releasing alpinists 3

The elevator was tested.

Firstly, it was found out, that one pair of blocks is fixed not reliable enough. The problem was that due to the cable was not in a plane of the block, it was pulled up by the cable. To compensate this pressure there were installed two plastic clamps (figure 90). However, it was a temporary solution.

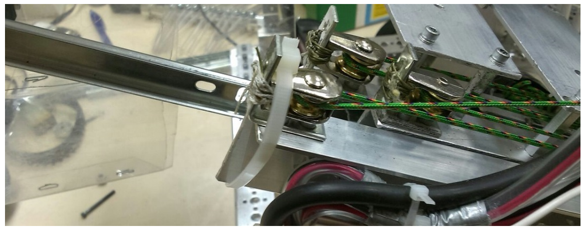


Figure 90: Clamp at the block

Secondly, the power of 3 motors still was not enough to extract the elevator to the full. The problem was that the second section (with respect to the bottom) required more power for extraction than the first one and the third section required the most power. So, it was assumed, that the problem caused by overloading the friction of the blocks: in the current system one cable at each side was held through all the blocks (figure 91) and a large part of power was wasting on friction.

In this case, to reduce the power that spends on fighting the friction, it was decided to use another system of holding the cables (figure 92). The new construction required 3 blocks instead of 5 at a side and the cable from the winch went only through one of them. However, this construction required three times higher torque and three times less length of the cable to reel for extracting. So, the diameter of the coils should be changed correspondingly.

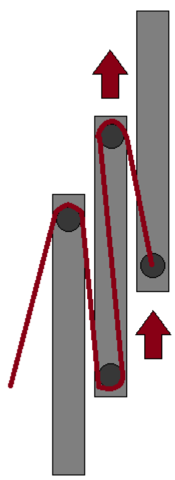


Figure 91: Current system of using blocks

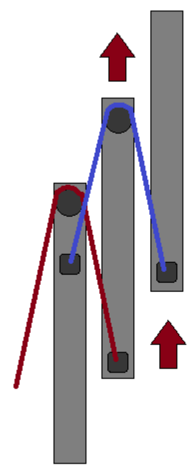


Figure 92: New system of using blocks

3.4.39 08.01.2016

Time frame: 15:00-22:00

The mechanism for scoring the autonomous alpinists was installed onto the robot.

After some tests it was investigated that it should be moved a bit higher and the axis of the servo that turns the module should be strengthened.

3.4.40 10.01.2016 (Discussion)

Time frame: 16:00-20:00

Today the cables at the elevator were held in a new way (figure 93). As the construction couldn't be tested by motors (the coils weren't recreated yet), it was tried by the arms. There were not noticed any problems.

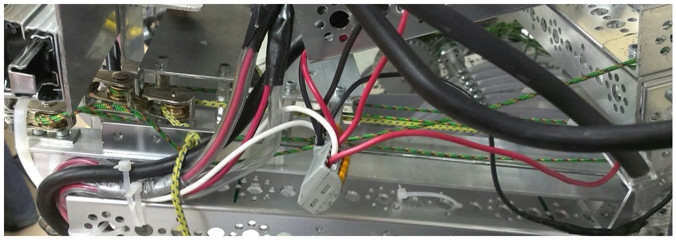


Figure 93: Cables are held in a new way

The bucket was detached from the elevator to provide separate development of the bucket and the elevator. Also results of holidays work was discussed and new tasks were set. The following table (Table 6) shows new tasks.

Main theme of meeting was discussing of working plans for winter holidays. As a result of it was made the following table of tasks.

Table 6: Results of discussion of work on holidays

Module	Problem	Solution	Responsible
Lift	Motors are not powerful enough	Make simultaneous separation	Nikita
Bucket	Bucket skews while shifting	Create part in CREO, taking maximum slats bending angle into account	Sasha
	Shape and size are not optimal	Change the bucket (after drawing new shape)	Sasha
Gripper	Module is not done	Finish module without small cogwheel	Andrey
	or think of and draw construction with small cogwheel	Andrey	
Autonomous alpinists mechanism	Radial play of the servo mount	Fix the mount better	Andrey
Autonomous period	No button push	Think how to realise it	Everyone
	No autonomous period program	Create and test	Andrey
Crossbar engagement	Not done, but needed	Draw and make Nikita's idea	Nikita

3.4.41 12.01.2016

Time frame: 17:00-21:00

The mechanism for scoring autonomous alpinists was improved (figure 114). The axis if the servo was strengthened by the U-shaped detail.

There were created hooks for grasping the low hurdle of the second zone of the ramp (figure 95).

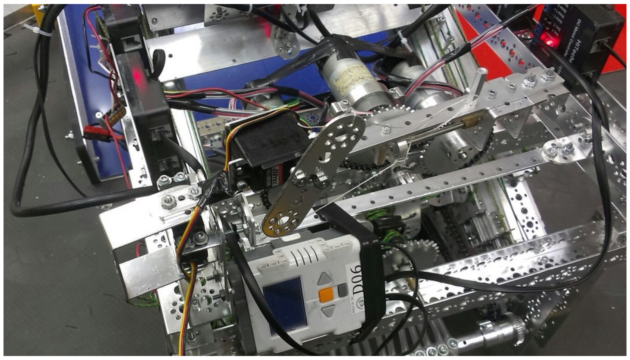


Figure 94: Mechanism for scoring alpinists

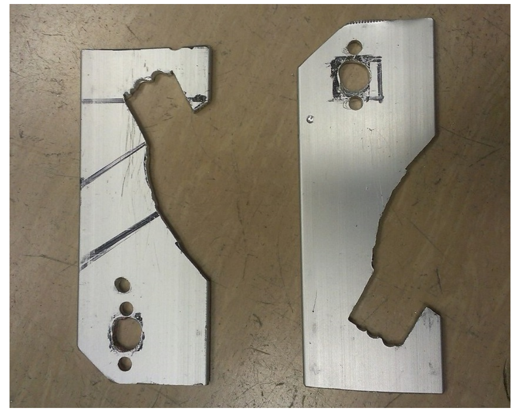


Figure 95: Hooks

3.4.42 13.01.2016

Time frame: 17:00-22:00

Today the coils were recreated. Their diameter was reduced (figure 96).

Next, the elevator was tested. It worked, but the power was not enough for the full extracting. The reasons of this problem were not found.

Figure 96: Coils of new diameter

3.4.43 14.01.2016

Time frame: 19:00-21:00

There were found two reasons of the problem of the elevator.

Firstly, the battery at the previous test was low.

Secondly, the ribs that connect two sides of the elevator caused a bend. it was because the cables at both sides were not the same length, so the sides of elevator were extracting differently.

To solve this problem, it was decided to make the mounts of the ribs mobile. So if there appear some bend, the ribs will merely slide along the movable mount (a kind of small slat).

3.4.44 16.01.2016

Time frame: 16:00-21:30

There was created a moving mount for one of the ribs at the elevator (figure 97).

It was also developed a prototype of a mechanism for grasping the hurdle at the ramp. The construction of the transfer between the servo and the hooks will prevent the servo from breaking down (figure 98).

Figure 97: Moving mount of a rib

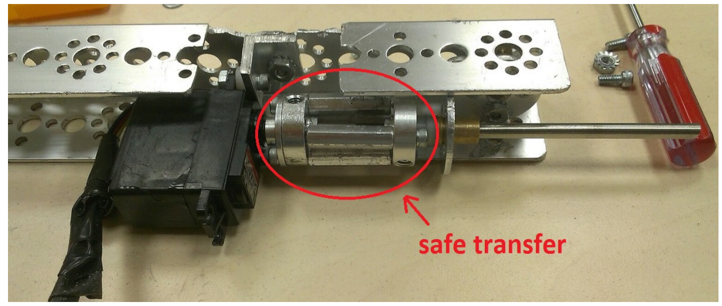


Figure 98: A prototype of the mechanism for grasping the hurdle

3.4.45 18.01.2016

Time frame: 18:00-22:00

The new mount of the servo for overturning the bucket was created (figure 99).

In the new construction the servo was fixed on the bucket, which made construction more compact. With new construction, the mount of the bucket will not touch the rails while shifting, so it will have the free movement.

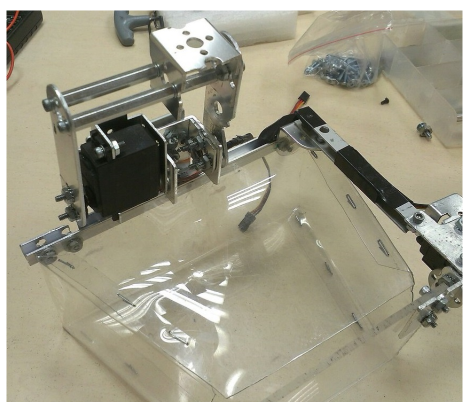


Figure 99: New mount of the servo for overturning the bucket

3.4.46 19.01.2016

Time frame: 17:00-22:00

There was crafted the moving mount for the second rib on the elevator (figure 100).

It was also started the assebling of the mechanism for grasping the hurdle (figure 101).

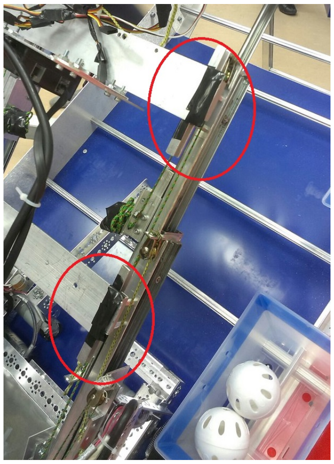


Figure 100: Ribs with movable mounts

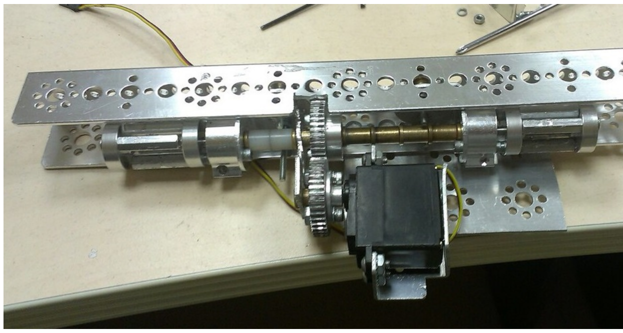


Figure 101: Mechanism for grasping the hurdle

3.4.47 20.01.2016

Time frame: 19:00-21:30
The assembling of the mechanism for grasping the hurdle was finished (figure 102, 103). The hooks were not installed on it yet.

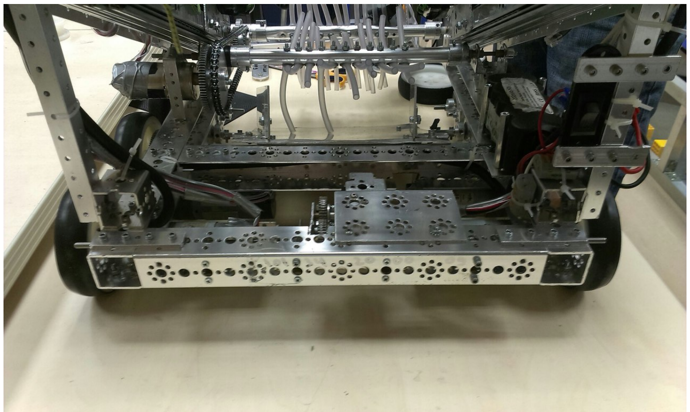


Figure 102: Mechanism for grasping the hurdle 1

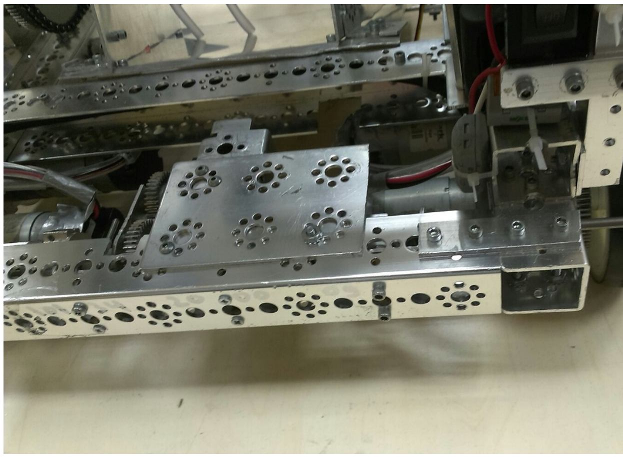


Figure 103: Mechanism for grasping the hurdle 2

3.4.48 21.01.2016

Time frame: 16:30-22:00
The hooks were installed onto a mechanism for grasping the hurdle (figure 104, 105, 106).

Next, it was tested without powering the servo. The construction worked ok.

Figure 104: Hooks rised up

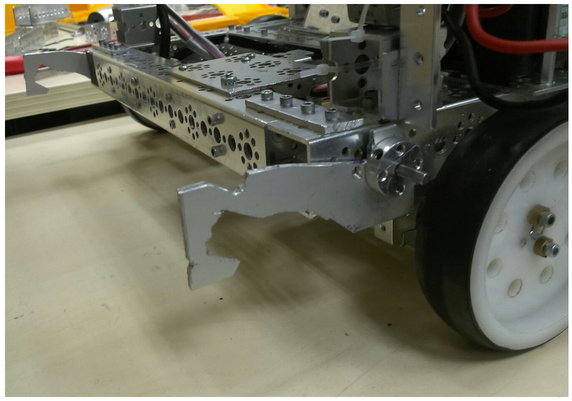


Figure 105: Hooks turned down

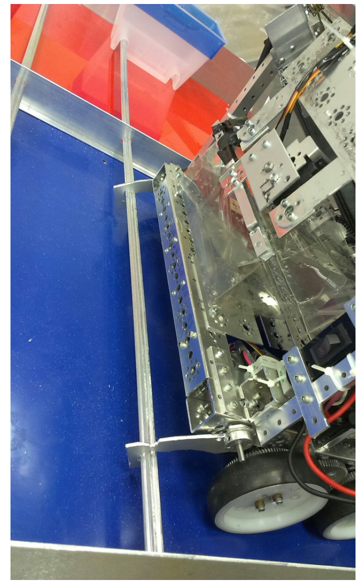


Figure 106: How does the module works

There was found a problem in the wheel base. The holes for middle wheels were drilled out because of friction with the wheels' fixations (figure 107).

The wasted beams were replaced with new ones. In order to prevent the appearance of this problem in future, there were installed bronze collars into the holes, in which the axles of middle wheels rotate (figure 108).

Figure 107: Drilled out holes

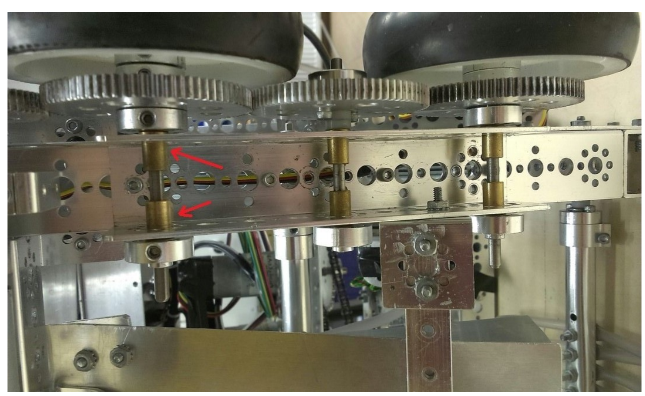


Figure 108: The bronze collars were installed

The bucket was installed onto the robot and it's servos were connected to the controller (figure 109).

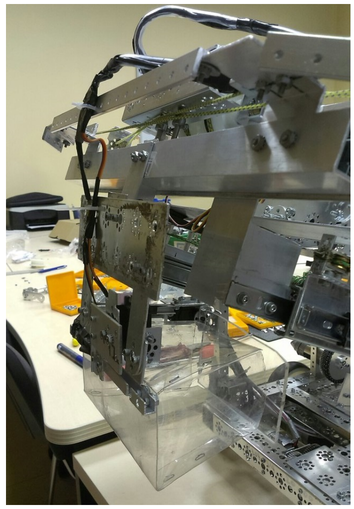


Figure 109: Winch installed onto the carriage

3.4.49 23.01.2016 (Competition)

Time frame: 17:00-22:30

This day our community organised a private competition on our own field. There were 3 teams including ours. There were held several matches 2 vs 1, which were played according to the entire game rules. This event provided teams with an experience of a true gameplay and allowed to test all the systems of the robots. It also was a source to find mistakes in construction and understand what should be improved in it.

During the competition, there were introduced some changes of the construction.

Firstly, the servo on the mechanism for grasping the hurdle was changed from standard to continuous rotation. This was made to increase it's reliability. The continuous rotation servo doesn't keep the angle, so it doesn't break down if the external force changes this angle. It is important feature, because, when the hooks are adjusting to the hurdle, the servo can be turned by the outer force.

Secondly, the ends of the hooks were wrapped by the tape to prevent the damage of the field or other robots by the sharp corners.

Into the driving-control program there was added a function for operating the mechanism for scoring alpinists into the shelter. During the matches, this mechanism was tested.

It was decided to put the brushes on the gripper into a position, when they rotate in the same phases to find out, if this will be more effective, or not. The practice showed, that this position of brushes is inconvenient.

During the games it was found out, that the robot has plenty of areas, where the debris can get stuck, increasing our possession of it. These areas were aside the ramp for debris and under the bucket. The second area was temporarily covered by plates so as to prevent cubes from getting stuck in it.

At the mechanism for shifting the bucket it was revealed, that the cables, which pull the moving part, often get behind the pins, which causes the inability of shifting the trolley to the corner. This problem should be solved.

It was found out, that it is nit possible to collect more than 4 cubes into a bucket in game conditions. The problem was that cubes didn't settle down in a bucket as it was expected.

3.4.50 25.01.2016 (Discussion)

Time frame: 18:00-21:00

Main theme of meeting was discussing of the Saint-Petersburg competitions. Table with problems, their solutions and responsible for it team member was created.

Table 7: Results of discussion of Saint-Petersburg competition

Module	Problem	Solution	Responsible
Wheelbase	Too fast accelerations	Make slower accelerations in program	Andrey
Grab	Grab works bad because of parallel brushes	Make the brushes be perpendicularly	Andrey
	Cubes jam in the back of the robot	Make the solid plate in the back of robot	Andrey
Lift	Crossbars disconnect	Connect the limiters with screw, allowing them to move free	Anton
Bucket shift	Bucket skews while shifting	Check the possibility of using structural profile instead of slats	Sasha
	Slow shift	If the problem remain after fixing previous problems	Sasha
		use rollers on the mechanism	Sasha
Bucket	Shape is not optimal	Create new shape	Sasha
	Cover does not close in low position	Saw off sides of cover	Sasha
Autonomous	No autonomous	Create	Andrey
Other	Bad location of autonomous alpinists	Make mechanism indifferent to alliance colour	Andrey
	Only one hook clings	Fix it	Nikita
	Electronic is not covered	Cover	Gordey
	NXT is not mounted well, no color marking of wires	Fix it	Gordey

3.4.51 26.01.2016

Time frame: 17:00-21:00

The moving mounts for ribs on the elevator were recreated (figure 110, 111). There were applied white collars, which were sliding along the 10 cm axes. This construction had less friction and was more reliable. These details were not finished during the current meeting.

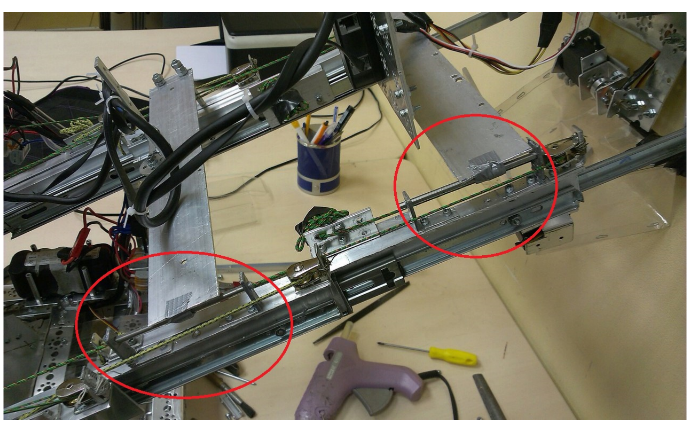


Figure 110: Convenient movable mounts of the ribs

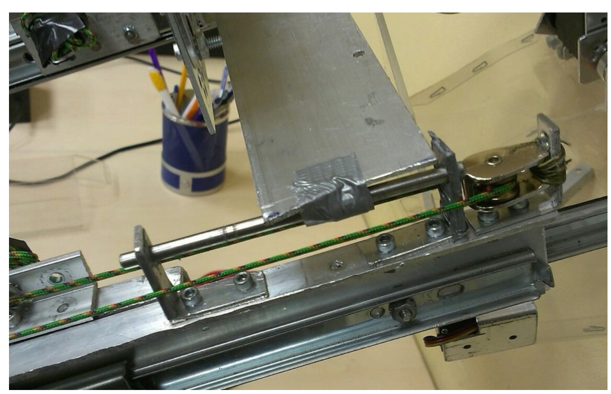


Figure 111: The mount of the rib

After a number of tests, the brushes on the gripper were set in the most effective position.

It was created a protection from debris at the back of the robot (figure 112).

The protection of the area under the bucket from debris was recreated with a layer of PET (figure 113).

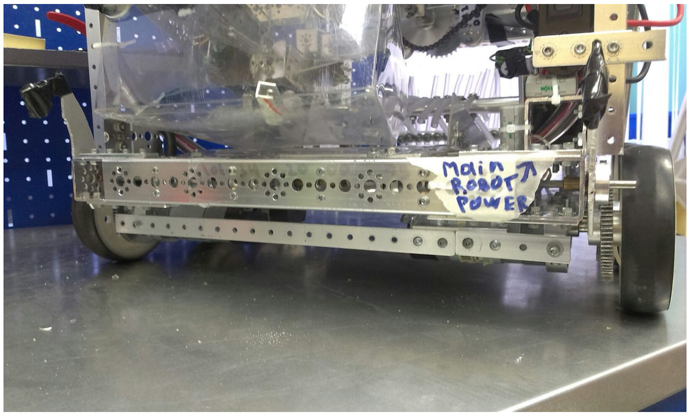


Figure 112: Protection from debris 1

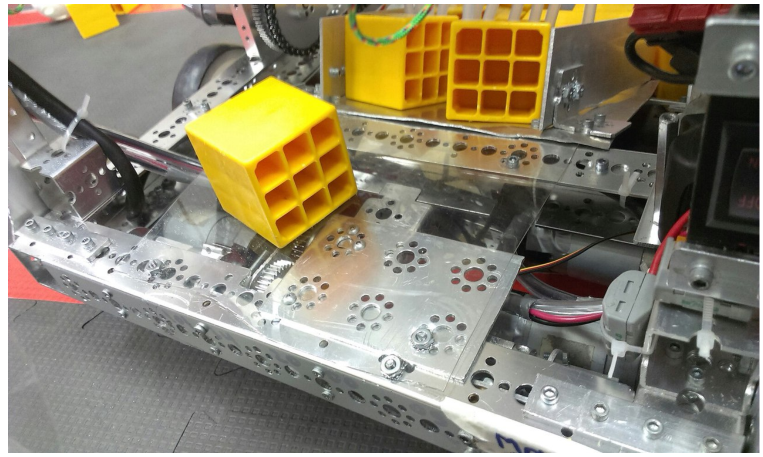


Figure 113: Protection from debris 2

3.4.52 27.01.2016

Time frame: 19:00-21:00

It was created a surface for pushing the button on the beacon (figure 114, 115).

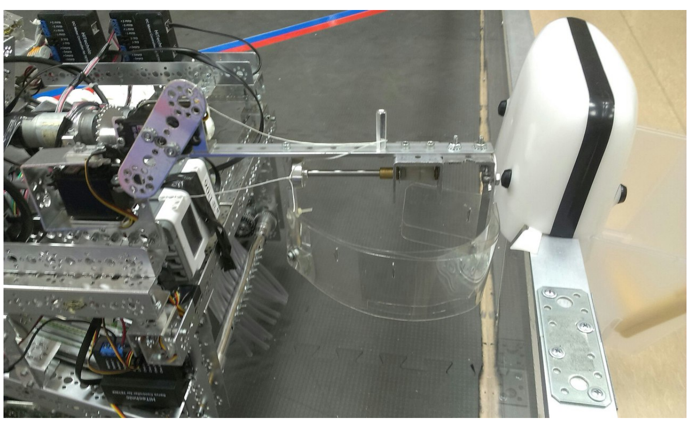


Figure 114: The surface for pushing the button

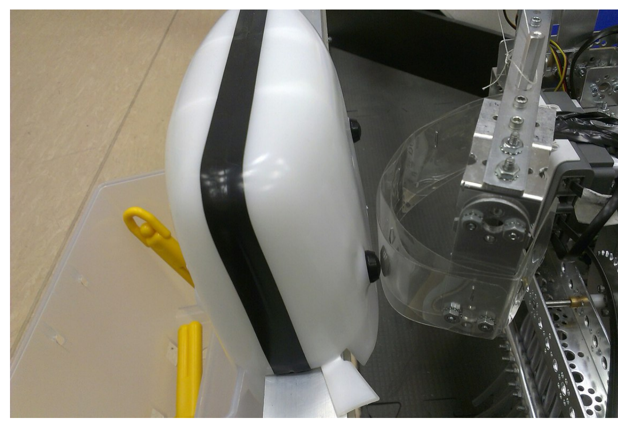


Figure 115: How does it works

3.4.53 28.01.2016

Time frame: 17:00-22:00

It was started the development of the protection of the servos' wires on the bucket from grasping the elements of construction while shifting (figure 116).

It was also created a protection from the engagement of the cable with the axis at the mechanism for shifting the bucket (figure 117).

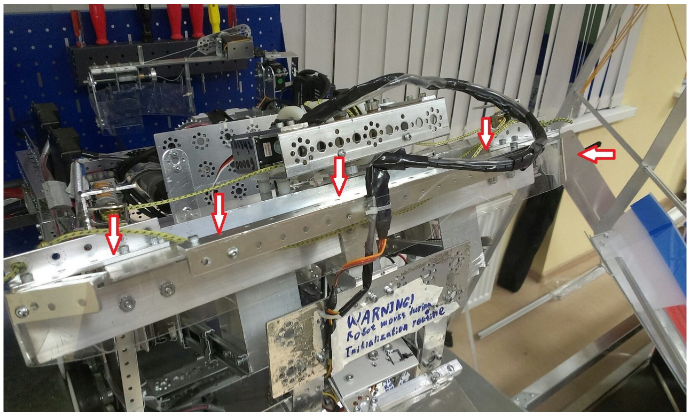


Figure 116: Protection for wire

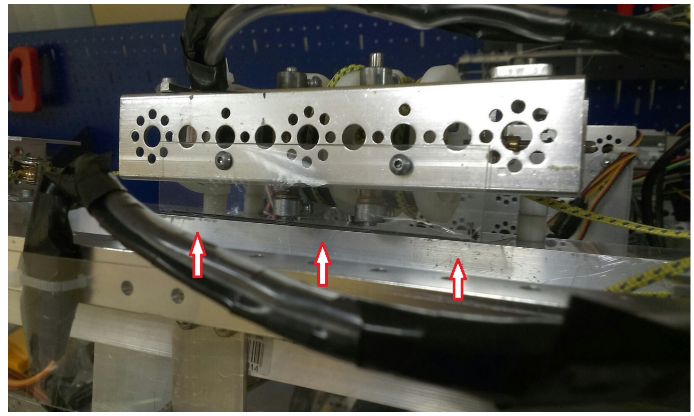


Figure 117: Protection for cables

The mount of the second block on the elevator was strethened.

It was started the creating of the borders at the sides of a gripper, that will prevent debris from getting into the areas beyond these borders. There were taken all the needed measurements. After that, a part of these borders was cut out from PET.

3.4.54 30.01.2016

Time frame: 16:00-21:30

The borders for debris were installed at both sides of the gripper (figure 118, 119). The extension of these borders was installed at both sides of the bucket (figure 120).

The moving mounts of the ribs were finished (figure 121).

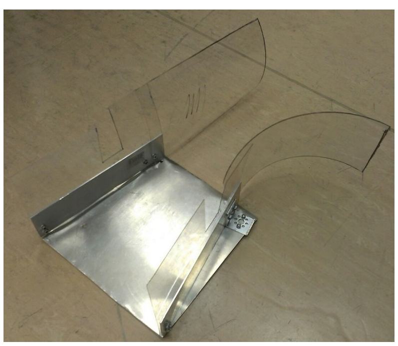


Figure 118: Borders for debris

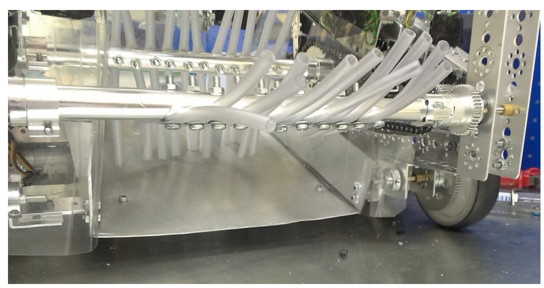


Figure 119: Borders for debris (front)

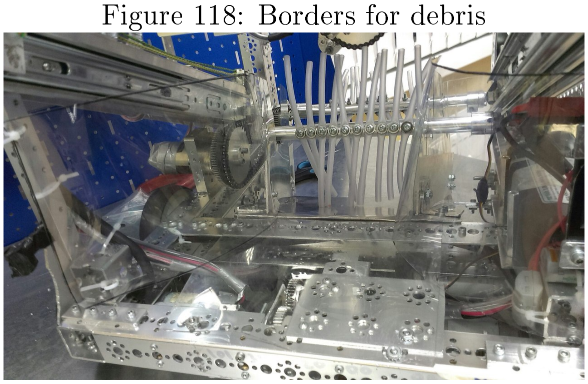


Figure 120: Borders for debris (back)

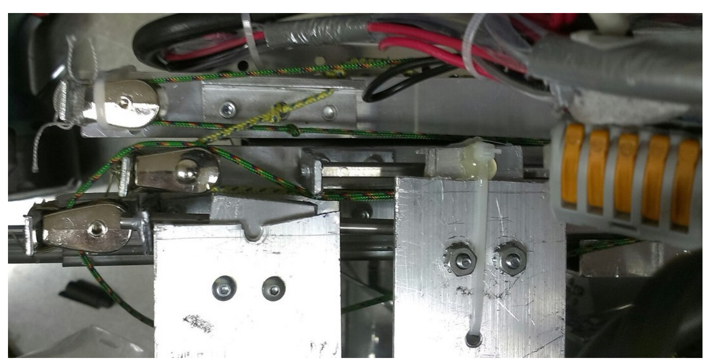


Figure 121: The moving mounts of the ribs

The protection of the servos' wires on the bucket from grasping the elements of construction was finished. This protection will prevent wires from getting to the areas where it can get stuck (figure 122, 123).

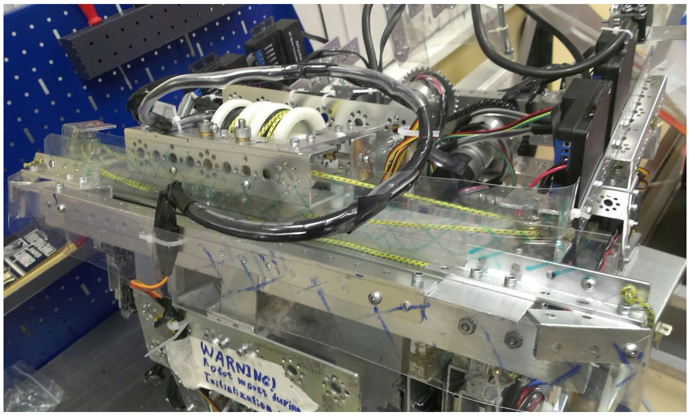


Figure 122: Protection for wire

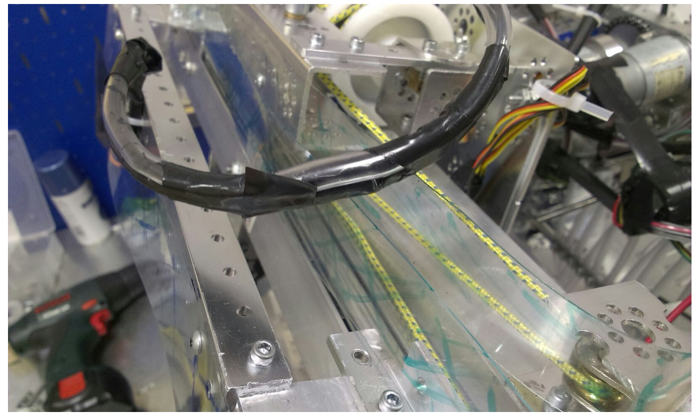
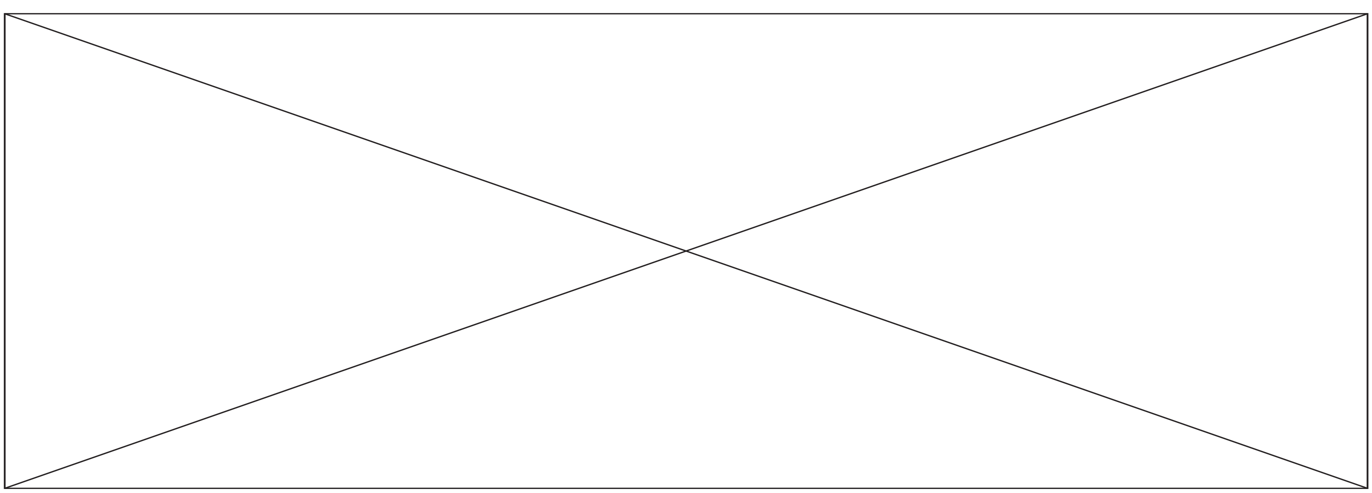


Figure 123: How does the protection works

It was created a new bucket for debris (figure 124, 125). It's shape allowed to collect 5 cubes at once, but was more convenient, than the previous.

Figure 124: Bucket 1

Figure 125: Bucket 2



3.5 Specifications for modules

Description: This section contains detailed information the process of elaboration of each module in particular.

3.5.1 Carriage and wheel base

1. The current module has two functions. At first, it provides movement of the robot, and secondly it carries all the other modules. Due to this, it was divided into two submodules: a wheel base, and a frame.

   The frame should have 2 lengthwise beams of 41.5 cm, which will be used for mounting wheel base. These beams should be reliably connected to each other by the cross beams. The cross beams can be installed only at the back side of the robot, because at the front side there should be a gripper for debris and a bucket. Above the gripper it can be installed an additional cross beam, but this connection won't be strong enough as it will be placed far from lengthwise beams. That's why it was decided to apply 2 main cross beams as it depicted in the figure 1.

   In the wheel base it was decided to use the construction with 6 standard 10 cm wheels. Firstly, the wheels are more reliable, than tracks, because tracks can run over during the match, and in this case the robot would be disabled. Secondly, the constriction with 6 wheels provides better rotation than 4 and 8 standard wheels (explanation at page ...). Omni wheels can't be used in this construction because they're working unstable at the ramp. The decision of using 10 cm wheels instead of 7 cm is caused by two reasons: firstly, they're more convenient to install so that the robot will be capable of climbing the ramp (figure 2). Secondly, the middle sized gears and chain gears have sizes a bit less than 7 cm, so if they will be used with 7 cm wheels they can scratch the field if the robot will bend the floor covering too much.

   It was decided to use 4 NeveRest motors by AndyMark for movement, because these motors are more reliable than TETRIX DC motors. Due to calculations, it was revealed, that to climb the ramp with 10 cm wheels the gear ratio 2:1 on motors is not enough, so it was decided to apply the gear ratio 1:1.

   It was decided to use middle sized gears for connecting wheels instead of chain, as the chain requires more space and also inconvenient for connecting axes that stand along the one line.

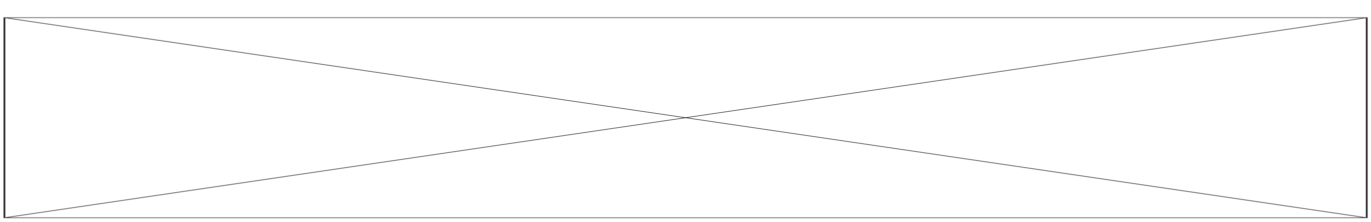
   On the October 12^th it was assembled the first prototype of the chassis. It had 7 cm wheels and a gear ratio for speed (2:1). It's test drive showed that 7 cm wheels can't be applied.

   On the October 19^th it was assembled a second version of the chassis. Each side consists of 3 wheels and 5 middle sized gears. Motors are placed at the back, so the space between 3 forward pairs of gears is free. 3 forward axes are fixed on the 16 cm beam, so it is easy to remove them if it is needed.

   On the October 23^th, when the assembling of the winch started, it was found out, that the cross beams waste too much space inside the robot and there is not enough space for the winch. Since then, the former cross beams were replaced with more compact construction.

   At the first competition (...) it was investigated, that back DC motors are fixed to the frame not strong enough, so they unscrew very often. This problem was solved on .... The motor's mounts were fixed with more screws and with washers.

   On ... there was installed the mount for the winch above the gripper. It also strethened the frame of the robot.



3.5.2 Gripper

1. **Module tasks:** this module should collect game elements which lies in front of the robot into the box in the back side of the robot and also it prevents to fall out game elements while driving.

2. **Construction:** module presents as two axes which connected with a chain and also inclined plane (figure 126).

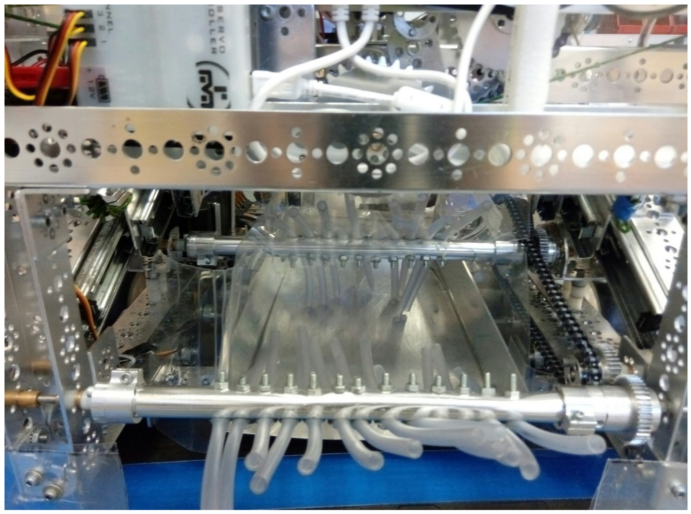


Figure 126: Gripper falities

There are DC motor which connected to axis with step-up gear 1/2 for speed increase, this axis located in the middle of the robot. Second axis which located in the forward side of the robot driven with chainsaw and gearing for synchronises movement with first axis. For collecting game elements there are rubber pipes 0.5cm diameter and 16cm length all along axes for game elements collecting. Axes presents as hollow metal pipes 1.5cm diameter with apertures for the screws which fix rubber pipes (figure 127).

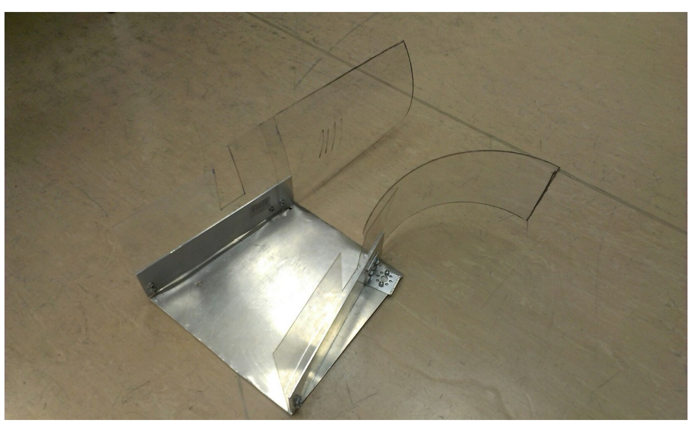


Figure 127: Blades on a axis

Inclined plane uses to uplift game elements to the box and slopes serve as protection against game elements ingress in other parts of the robot and to direct game elements into box (figure 128).

Figure 128: Side view of beams onto which the bucket is mounted

Inclined plane made from aluminium plates, slopes made from aluminium and plastic. For calculations of angles, lengths had been used GeoGebra (figure 129).

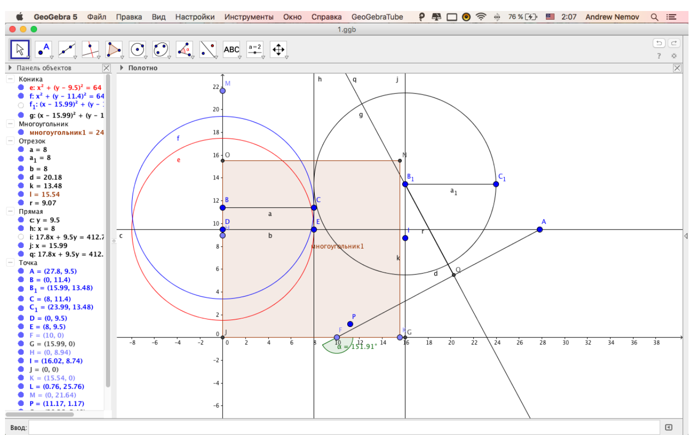


Figure 129: GeoGeabra workspace with open scheme f gripper

3. **Stages of realization** in first version had been used two continuous rotation servos fixed on both edges of axis instead of on one DC motors but after tests this construction was rejected because of lack of speed and power. Also in first version was only one forward axis but second one had been added because of box had been replaced in the backward side of the robot and higher that it was in the beginning

3.5.3 Elevator

1. The current module was divided into 3 submodules. Next, there were composed technical specifications for each submodule:
   1.1. Lifting mechanism
      1.1.1. The lifting mechanism will be used to deliver the bucket for debris to the second and the top goal and the hooks for grasping to the pull-up bar.
      1.1.2. The lift should be telescopic. It should have two guides that move along parallel lines. Each guide should consist of a cascade of segments which do not exceed the start cube but can be extracted after the match starts.
      1.1.3. The guides should be extracted by the cables (one cable for a guide). When the cables are pulled by the reeling mechanism, the guides are going up. The full extracting should take no more than 4 seconds.
      1.1.4. The length of the guides should be enough to perform it's tasks.
   1.2. Turning mechanism
      1.2.1. The turning mechanism will be used to vary the angle of tilt of the lifting mechanism. It is demanded to provide the robot with two positions of elevator: in the first position it extracts so that we can through debris to the top box from the low zone, in the second position the angle of incline allows us to grasp the pull-up bar from the second zone.
      1.2.2. The turning mechanism should be powered by a continuous rotation servo to save DC motors.
      1.2.3. It should be used a worm gear on the shaft of the servo to provide one-direction force and prevent the platform with reeling mechanism to move itself.
   1.3. Reeling mechanism (winch)
      1.3.1. The main option of the reeling mechanism is extracting of the lifting mechanism. The second option, that can be realised with it is the pulling up.
      1.3.2. The reeling mechanism should consist of two coils for reeling the cables from guides. Using distinct coils will help to avoid the entanglement of the cables. However, both coils can be mounted to one axis. Coils can be powered by 2-4 DC motors.
      1.3.3. To provide the pulling up there are needed two additional coils for reeling the strong cables. The principle of work is following: when the first pair of coils pulls the cable and extracts the elevator, the another pair of coils releases strong cables used for pulling up. When the elevator is fully put forward, so does the pull-up cable. Next, when all the coils rotate backwards, they pull the pull-up cable and release lifting mechanism's cables causing it to fold back.
      1.3.4. Two cables are needed to provide the steady pulling up. The strong cables should detach from the lifting mechanism after the hooks will be put to the bar to prevent damage of the elevator.
2. According to the technical plan our team created beforehand, the lifting mechanism was to consist of several construction beams connected to each other with special parts. To create these parts, we first thought through the concept and 3d-modeled them in Creo Parameteric 3.0. These parts are something akin to a brace and will stabilize one beam in relation to another. There are two types of braces: for the central gaps, and side gaps of the beams. Let us consider the simplest way to connect the two beams with these braces. Beam A will be fixed in place to the base of the robot, and beam B will be fixed relative to beam A. Then we can can connect the first three braces to the top of beam A and the second three braces to the bottom of beam B, allowing for maximum freedom of movement for one of the beams against the other. For greater stability we use two groups of three on each end of the beams. The models of braces were created in Creo Parametric. Then there was created an assembly of the lifting mechanism (figure 130, 131).

   We must find such a height and length of the lifting mechanism that there would be an angle of tilt that would allow the robot to throw debris into the highest and middle bucket goals from the low zone,

and grab the pull-up bar from the middle zone. To find required parameters of lifting mechanism, there were held some calculations in GeoGebga (figure 132).
The length of the elevator needed to reach the top goal an the pull-up bar was 105 cm. Knowing that the individual beams are 350mm long, we calculated that in order to reach this height, we need four beams.
Lifting four beams requires a block system - e.g. we need to add blocks with twine that, when reeled in, would lift the system. It was decided to use the system of blocks when one cable is used to extract all the segments at one guide (figure 133).

Figure 130: Model of construction profiles connected by braces

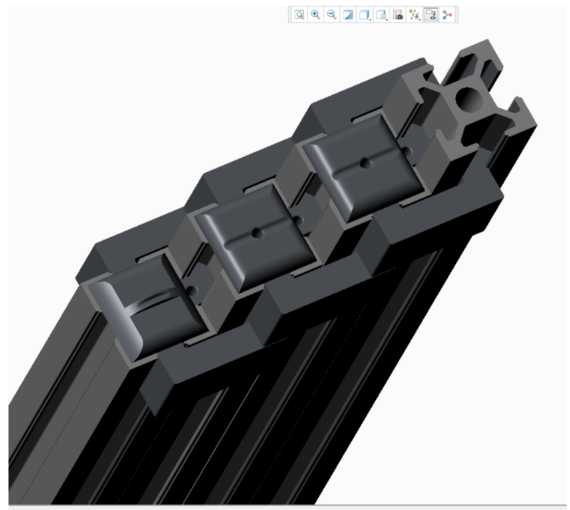


Figure 131: Braces

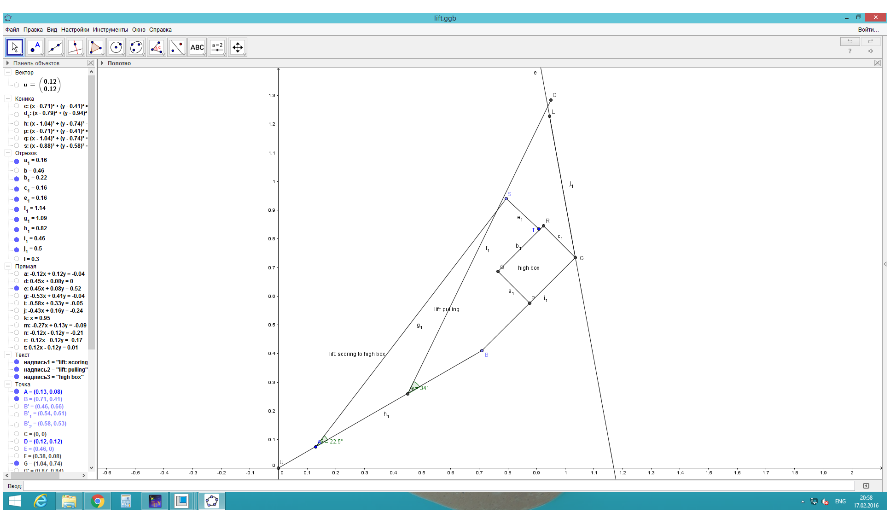


Figure 132: Drawing in GeoGebra

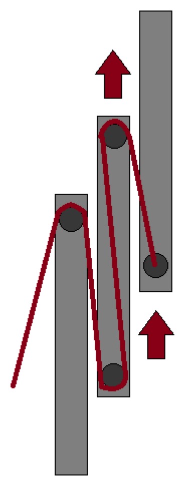


Figure 133: The principle of holding cables

3. At the 25th October it was decided to reconsider the concept of the module.
The reason was that the progress in creating of the module was too low. Firstly, the plastic details for connecting the profiles to each other were not created in material as there was nowhere to make them. Secondly, this system was never made before, so it could have some latent problems. However, first competition was taking place in a week so there was needed a working system.

According to this, it was decided to find simpler solutions.

3.1. It was decided to use the furniture rails instead of construction profiles because our team had used them in 2 previous FTC seasons and we have an experience in developing the elevator with furniture slats.

3.2. It was decided to not to create the turning mechanism, because it expected to be bulky and difficult in realisation. Instead of it, it was decided to fix the guides in position that allows to score debris into second and high goals. There was no need to change the angle of the elevator for grasping the bar, as the hooks can be delivered to it by additional servo mounted on the top of the lift.

4. In the following week, there was assembled a lifting mechanism. The angle of incline of the guides was $22,5°$. This angle was made using standard holes (without drilling new ones) in TETRIX beams, so the assembly was accurate.

   Each guide was made of 3 furniture slats and surfaces for mounting blocks made of aluminium profiles. Blocks were mounted to these surfaces (figure 134).

   Next, there was assembled a winch (figure 135). It was powered by 3 standard TETRIX DC motors. 4 coils were mounted to one axis. The gear ratio on motors was 1 : 1 and the diameter of coils was 4 cm, which was enough to pull the robot up: $frac20 \cdot 32 = 30$ kg (we assume that the robot weighs 10 kg, which is 3 times less).

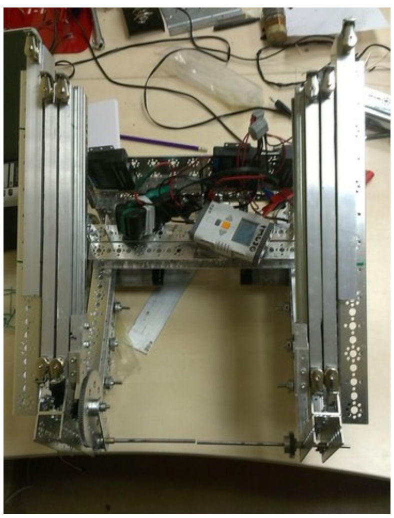


Figure 134: Elevator

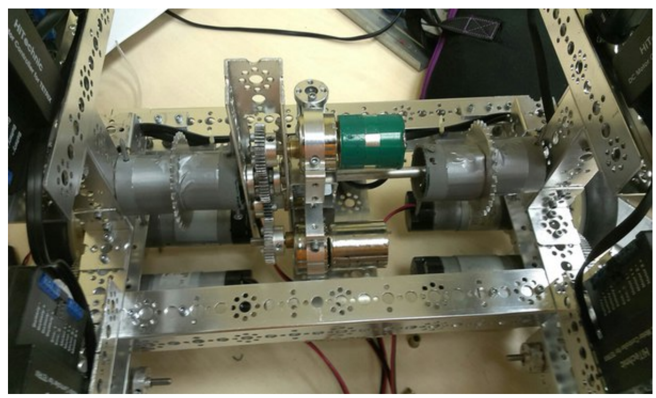


Figure 135: Winch

5. At the 8th December there were discussed the results of the competition that took place on 4-5th December.

5.1. Firstly, there was a severe mistake in creating of the previous version of the winch. The problem was that the force from motors was transmitted from motors to the coils through the axis. However, the mount of the gear on the axis was not strong enough and broke down. To avoid this problem, it was decided to connect gear to the coils and transmit the force from gear to gear.

5.2. Secondly, it was decided to move guides down for 10 cm in order to lower the center of mass. It was needed to prevent the robot from overturning while climbing the mountain.

5.3. Thirdly, as the concept of the bucket was reshaped, the winch had to be moved to another place. It was decided ti install it above the gripper at the front part of the robot.

5.4. Lastly, it was decided, to stop developing the pull-up option and create a working elevator. If we have time, we can realise pulling up too, but it is not a priority.

6. Then, the guides were moved down and the mount for winch was installed to it's new place (figure 136,

137).

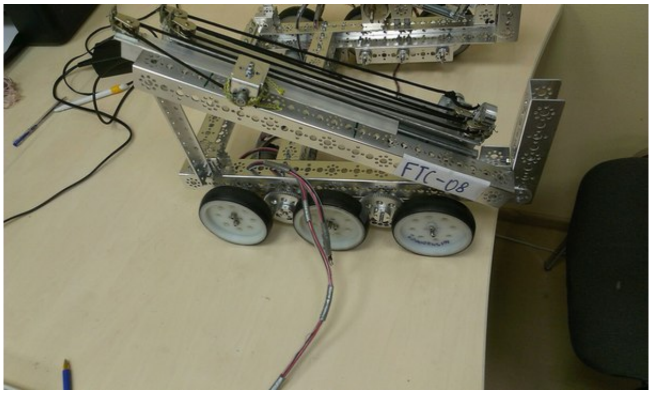


Figure 136: Elevator

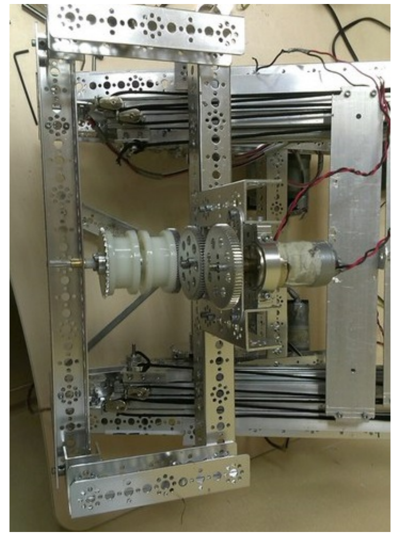


Figure 137: Winch

7. To discover, what gear ratio is needed on the elevator, there was measured the force, needed to extract the elevator at the ramp. It amounted to 4-5 kg at the each side, which gave us a total of 10 kg.
   It was decided to use caterpillar wheels as coils. The diameter of coils was 5 cm. The optimal solution was to power coils with 2 standard TETRIX DC motors (torque $20kg \cdot cm$, 2 rounds per second) with gear ratio 1:1. It provided safety coefficient over 1,5: $frac20kg \cdot cm \cdot 210kg \cdot 2,5cm = 1.6$. The speed of extracting was $2rounds/sec \cdot 5cm \cdot \pi \approx 31,5cm/sec$, which provided extracting of the elevator to the full in 3,5 seconds.
8. The winch was installed onto the mount. There also were installed blocks for leading ropes from the elevator to the coils. The mechanism was tested and it was found out that gears were slipping because of not perfect toothing between them. So, it was decided to install a chain transmission instead of gear one (figure 138).

Figure 138: Winch with chain

9. The elevator was tested in the position, when the robot was standing on the horizontal surface. It was able to entirely extract the elevator in 4.5 seconds, which was a bit more than pre-calculated time of extracting.
   During the testing there were fixed some minor problems.

9.1. Firstly, at one side the cable was stretched more than at another side. It caused a light bias of the lifting mechanism. This problem was solved by adjustment of the length of cable.
9.2. Secondly, the high load on the blocks pulled mounts of the blocks towards the coils. To avoid the deformation of the beams, there was installed a cross beam, that strengthened the construction.
9.3. Another problem is that sometimes ropes can leave the coils. To prevent this, it was decided to make shores for the ropes.

10. After that, the elevator was tested in the position, when the robot was standing on the low zone of the mountain. It was found out, that the power of two TETRIX DC motors is not enough to extract the elevator to the full.

    To solve this problem, it was decided to increase the power of the winch. There were installed 3 NeveRest AndyMark motors instead of 2 standard TETRIX ones (figure 139). It increased torque 2 times (3 AndyMarks give torque of $3 \cdot 25 = 75 kg \cdot cm$, while 2 standard - only $2 \cdot 20 = 40 kg \cdot cm$).

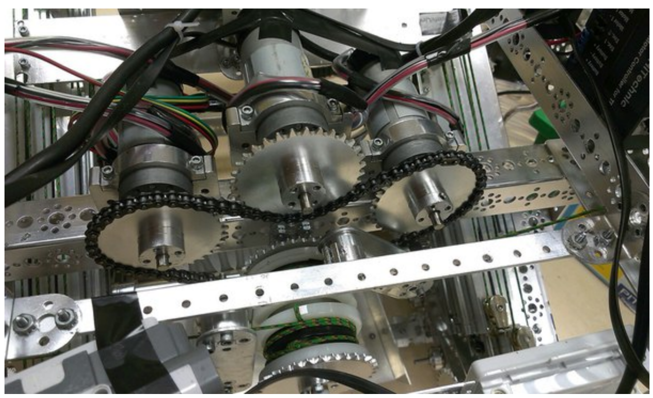


Figure 139: Winch with 3 motors

However, it didn't take effect. The power still was not enough to extract the last segment of the lifting mechanism. The principle of extracting the segments of the guides was such that they are extracted one-by-one. So, if there was no friction, the top segment would be extracted before others.

In fact, the second section (with respect to the bottom) required more power for extraction than the first one and the third section required more power than the second, so the consequence of the extraction was the opposite: the bottom section was going first. According to this, it was concluded, that in the current system there is too much friction.

To solve the problem, it was decided to hold the cables in another way (figure 140).

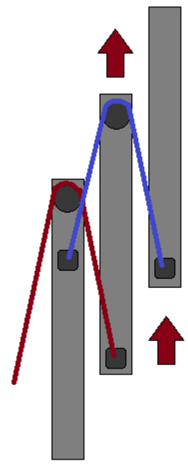


Figure 140: New way of holding cables

11. The system of blocks and cables at the lifting mechanism was changed (figure 141). The coils were also recreated (figure 142).

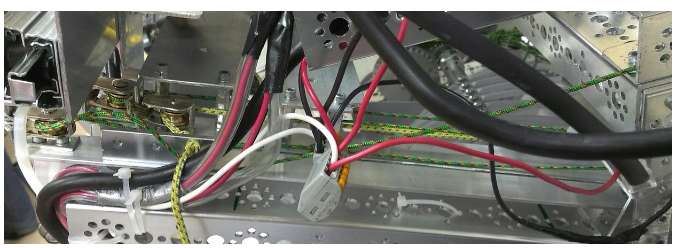


Figure 141: Elevator with new cables

Figure 142: Winch

12. The elevator was tested when the robot stood on the mountain. That time it was possible to extract the elevator to the maximal height. However, the ribs that connected pairs of rails together obstructed the movement of the segments.

    That problem occurred because the cables at both sides had different lengths, so each guide was extracting distinctly. But ribs were preventing rails from extracting differently because of inflexible mounts.

    The solution was to make the mount of the rib to one of the rails in a pair flexible. In this construction ribs would still protect the lifting mechanism from bending, but not interfere with it's movement.
13. After that, there were created flexible mounts for the ribs. These mounts allowed ribs to slide along the axis coincident with the direction od extracting of the lift (figure 143, 144).

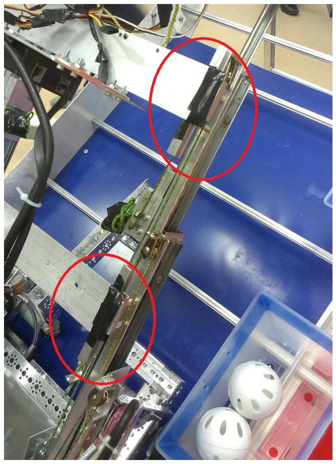


Figure 143: Flexible mounts (prototype)

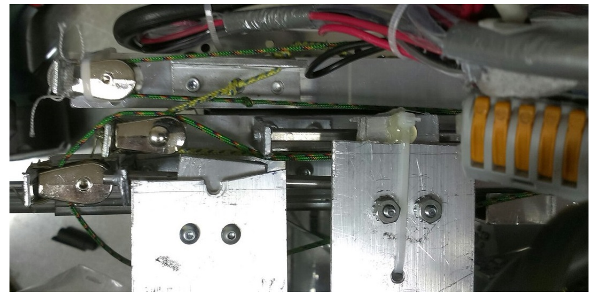
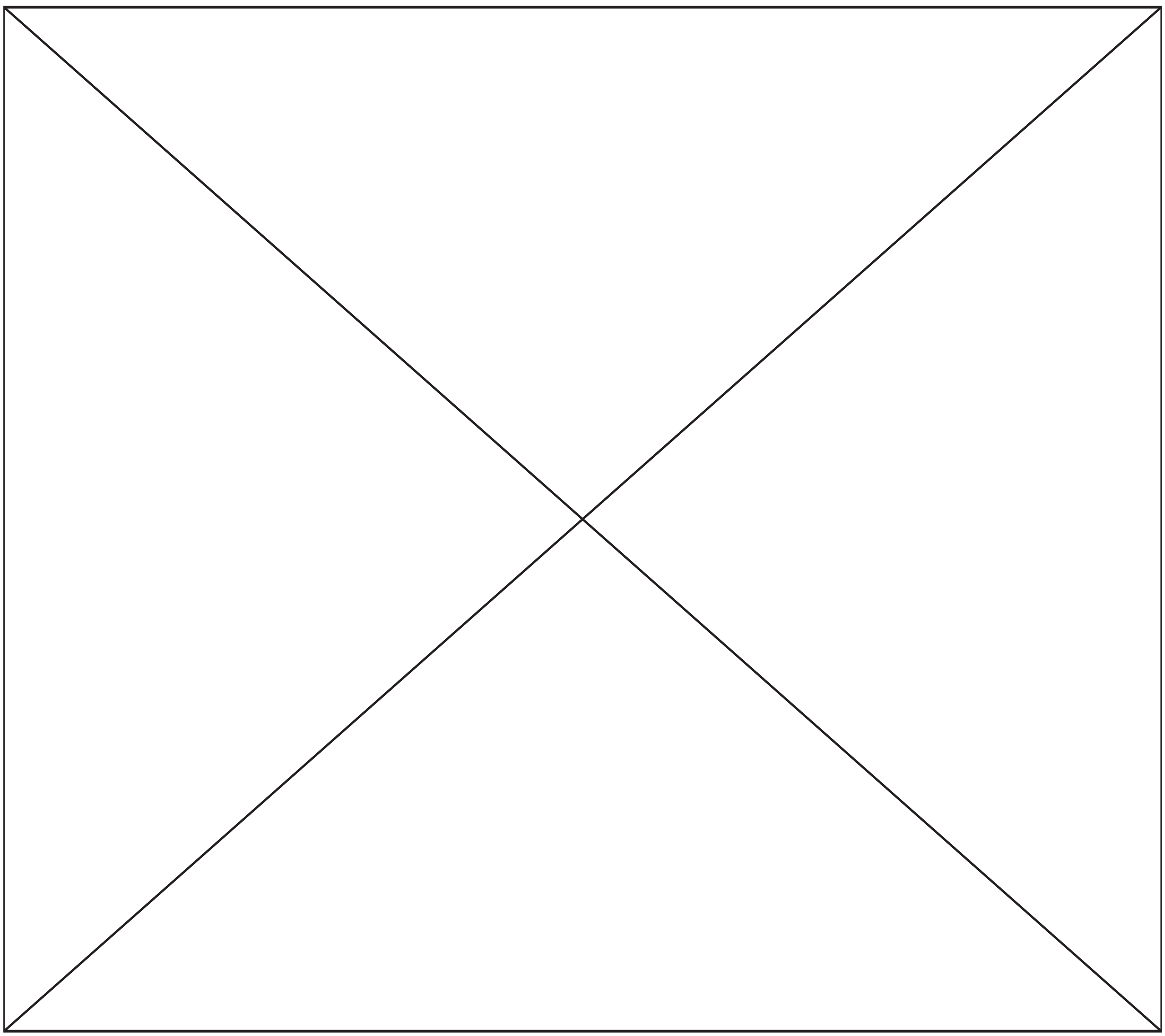


Figure 144: Flexible mounts



3.5.4 Bucket

1. The main requirements for the module were:
   - Maximum capacity: five cubes and three spheres
   - A mechanical limiter on the amount of debris in the bucket
   - A closing mechanism for the bucket
   - Delivery mechanism for putting the debris into the goals should work in both directions.
2. The first stage of development was creating the general concept of the module, its structure and method of operation. In result, was decided on the following mechanism: The bucket is shifted outside of the robot and turned 90 degrees around an axis parallel to the axis of shift; both movements are done by one servo. This allows to place the bucket opening to be parallel to the ground and increase the accuracy of debris delivery. Movement in two planes at once is accomplished through sloped guide rails, which turn the beams with the bucket during their sideways movement. To prevent premature release of debris from the bucket, the bucket opening will be closed.
3. The next step was developing the closing mechanism. To minimize the load on the servo completing the turning movement, the center of mass of the module has to be situated as close as possible to the mounting point on the lifting mechanism. Thus, the following system was developed:
   - On the beam which is mounted to the lifting mechanism, is installed a reel with twine.
   - The twine is fixed in such a way that when the reel turns in one direction, one of the ends is pulled taut while the other slacks, and vice versa.
   - The twine wraps around several fixed blocks along all the beams which support the bucket.
   - Above the bucket opening there is another axis with another reel identical to the first, and the surface which blocks the opening.

   This allows to open and close the bucket without adding any additional significant load on the servo which turns it. To make sure that such a mechanism for transmitting rotational movement indeed works, a simplified model was assembled. The results of our tests showed that this transmission is operable, but the angle between the extreme positions is slightly more than 135 degrees, rather than 180 degrees, but this is still enough to complete the task.
4. After that the parameters of the guiding rails (slope relative to the vertical direction, maximum height) were calculated depending on where they are mounted: The bucket, mounted on the beams, which in

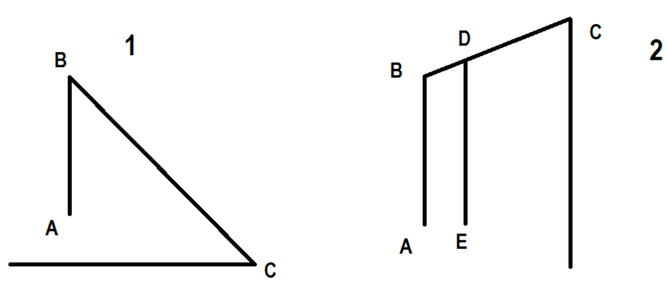


Figure 145: Side view of beams onto which the bucket is mounted

turn are mounted on the slats are in point A and move together. CB can rotate around point B. DE is the maximum height of the guiding rails. Position 1: the bucket is lying on the ground and collecting debris. Position 2: the bucket is perpendicular to the ground and can deliver the debris to the goals. The needed ratios can be found from the easily derived formula: $< C = /(DE - BA)$.

5. At the time the above process was completed, the qualification rounds were not far away, and so was decided to temporarily use two servos for shifting and turning the bucket, since the structure of the module would become significantly simpler and would require less time to complete. Were connected two slats in such a way that their uppermost part could move in both directions. After that on one of the ends of the slats were added limiters that depending on their position do not let one of the slats move. This does not prevent the robot from working properly, as we know our alliance before the match and thus in which direction we need to extend the bucket. This means we can adjust the limiters before the match. (Note: in the figure both limiters are set to the closed position, in which neither slat can

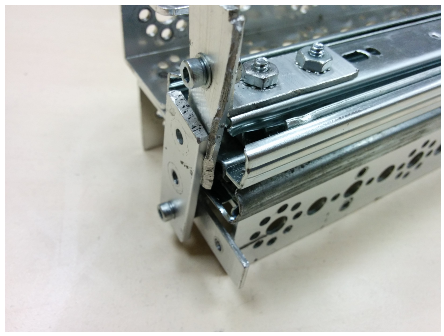


Figure 146: Structure of limiters

move; during the game itself one of the limiters will be set in the open position).

6. Then the servo with reel for the twine moving the slats was fixed on. Blocks were attached to the ends of the fixed beams and wound the twine around them; the ends of the twine are tied to the ends of the slats, which allows them to move as needed. The servo direction of rotation defines the direction of movement of the slats and the bucket.

7. After that was come up, tested and made another, less complicated, trapezoidal bucket with the opened part smaller than closed. The construction of the guides on the top of bucket would make debris fall in sequence 2-2-1 from the bottom, that way the scoring goals will hold maximum number of debris.

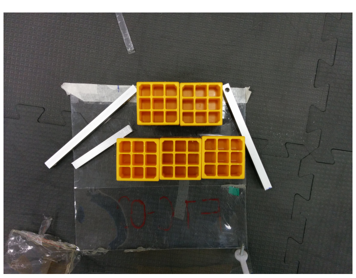


Figure 147: Structure of guides

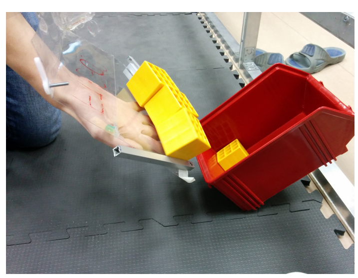


Figure 148: Process of guides testing

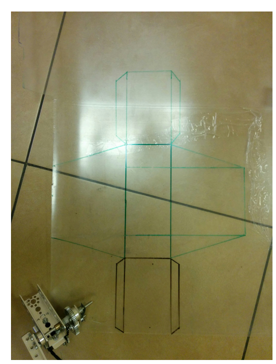


Figure 149: Marking of bucket

Tests showed that guides work well, so was decided to use them in construction of bucket. The pair of front makes debris fall to the scoring goals more accurately, the asymmetric guide slows one debris to make all the debris fall as 2-2-1, not 2-3.

8. After that was stretched the line to move the slats. Servos for moving the slats and turning the bucket were placed on the slats.

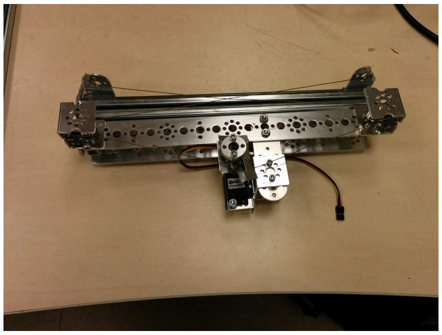


Figure 150: Construction of line and pulling it servo

Figure 151: Final construction of the slats

9. Next done part of module is closing mechanism. The difficulty in it is that axis of servo has to be as close as possible to the front-top edge of bucket.

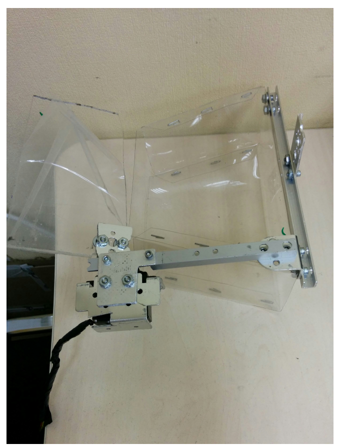


Figure 152: Final construction of the bucket with closing mechanism

10. After that bucket was installed on bracings on the slats. Then all the module was mounted on the lifting mechanism. It was done in the way to make the bucket turning axis as low as possible. It would make the volume, used by bucket less, because with that place of the bucket it was necessary to turn it while lifting because otherwise bucket intersected with other parts of robot while lifting. So the lower axis made the radius of bucket turning less and reduced the capacity on the servo by shortening the shoulder of buckets weight. By the time it was done, the first competitions had almost started so the slats weren't mounted on the lift because of time troubles.

11. After the end of competitions slats were replaced by longer ones (40 cm instead of 35) to make bucket shifting completely out of robot theoretically possible. Also the shifting servo was changed to faster and more powerful servo in order to make bucket shifting faster and more reliability. Then possible work process of bucket was estimated and it turned that fast lifting was impossible. It was so because the bucket was to be turned in case not to intersect with other parts of robot to be lifted. And generally bucket was close to catch parts of robot while moving from front of robot to its end during the lifting. To solve these problems was decided to place the bucket into end of the robot above two beams. It would make lifting easier because bucket would move inside robots projection much less time than before, also it is easier to transport debris throw the robot than to transport the bucket.

12. Then the slats were mounted on this lift in the way to place bucket in the end of robot. The next problem was not much space so the beam, on which the bucket was mounted intersected with lifts slats while shifting. So the mount of the bucket was changed. With that construction servo was turning with the bucket. It made the non-intersection beam possible. After that bucket was mounted on the sift mechanism without any intersections, so the problem was solved.

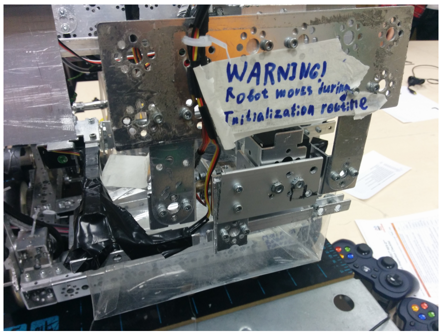


Figure 153: Construction of bucket

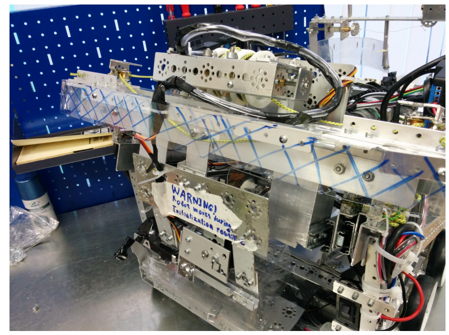


Figure 154: The bucket mounted on robot

13. The next step was testing bucket and the whole robot. In the process of it was found two problems: the closing mechanism was able to work only when the bucked was a bit lifted and bucket couldn't hold 5 cubes, caught by grab mechanism. First problem was solved by cutting sides of partition, closing bucket. The second problem weren't solved by adding guides to move first cube sideways (grab couldn't move the cube so). Because of it was decided to change the shape of bucket.

14. After that the new shape was devised.

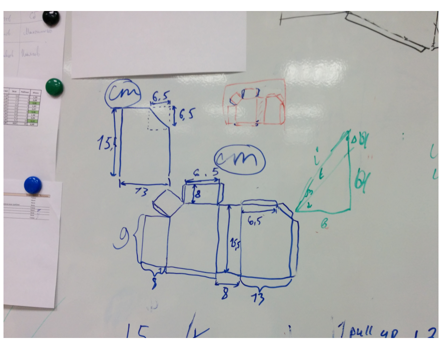


Figure 155: Shape and scan of the bucket

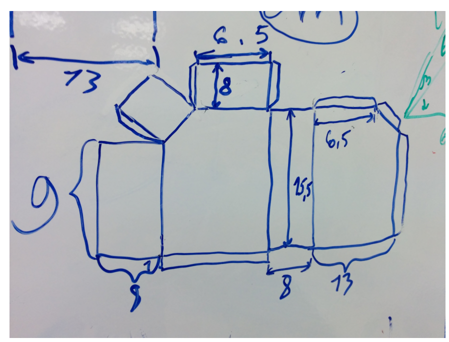


Figure 156: Closer view of the scan

This shape was chosen because:

- It was easier to fill by the grab mechanism
- It was big enough to hold 5 cubes
- It was not enough spacious for 6 cubes
- It has output hole with width of 2 cubes and that made cube falling vore direct and allows to score cubes.

15. Then the new bucket was marked and cut from a sheet of plastic (the same was used for the first bucket). Next, bucket was assembled and tested (not on robot). Tests showed that bucket was able to hold 5 cubes and score them directly to the high scoring bucket.

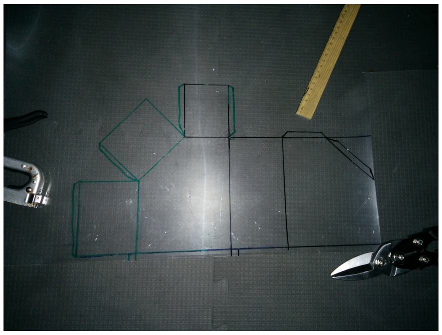


Figure 157: Marking of bucket on the plastic sheet

Figure 158: Fully assembled bucket with cubes inside

16. After that was made protection for wires that could get into slats and break there. Also was made protection for rope of shifting mechanism that could catch on parts of robot because of which shifting stopped. Both protections are plastic strips.

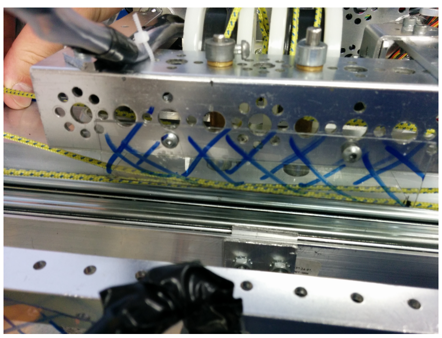
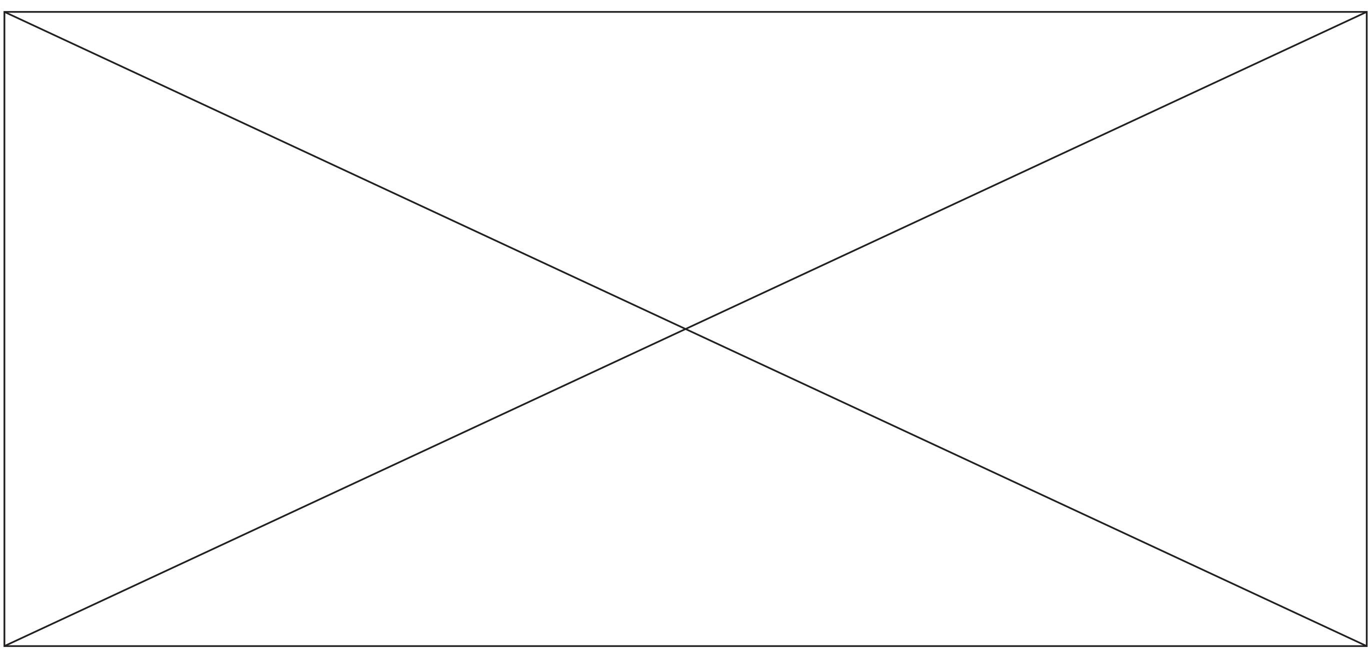


Figure 159: Protection of rope

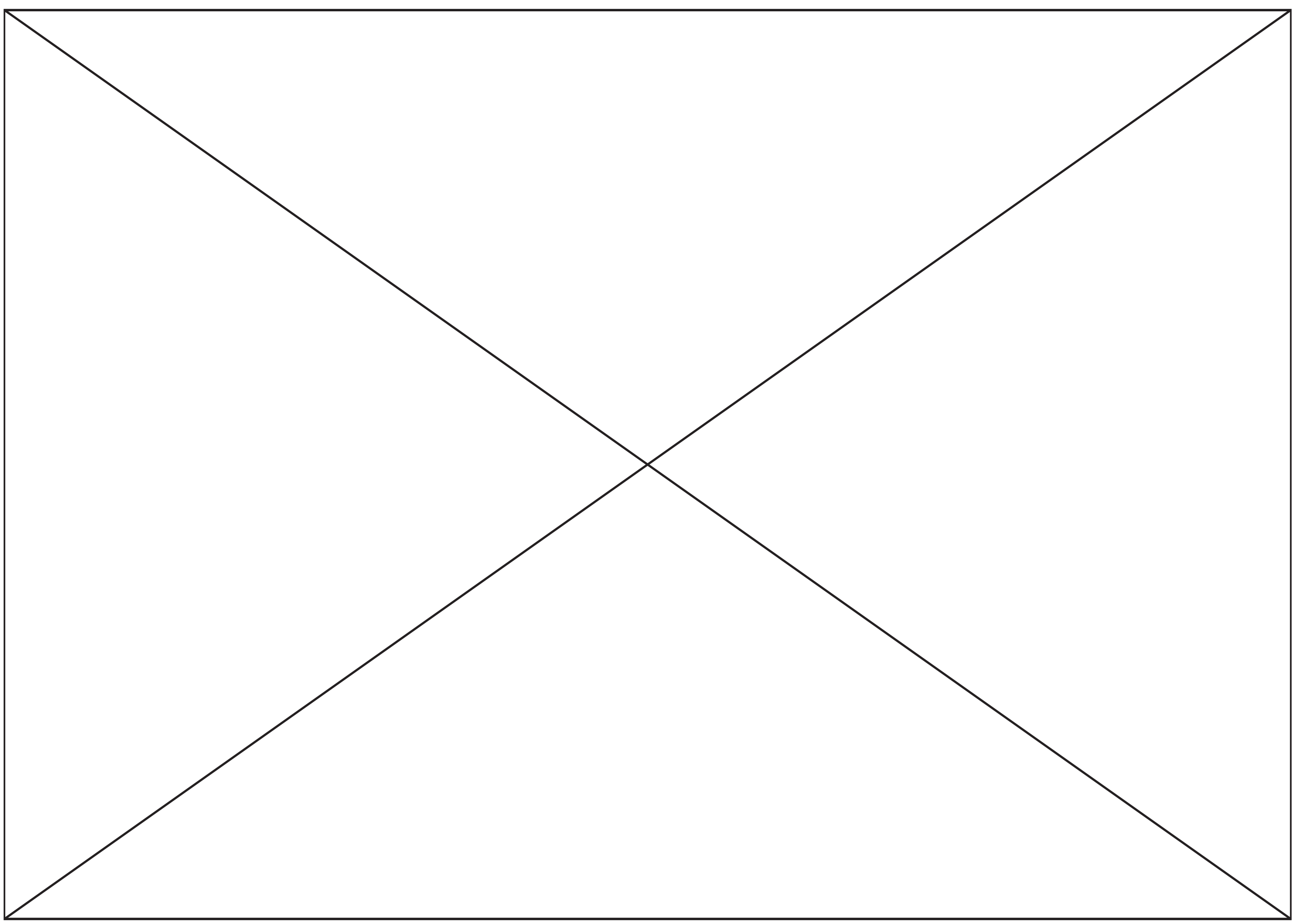
Figure 160: Test of new bucket



3.5.5 Mechanism for scoring alpinists

Engineering tasks included in this module:

1. The first step was find all the sizes of climbers and elements of field that essential for creating module. The size of the box for climbers is the same to the box for debris: 14.6 x 5.75 . The height of the border is about 30 cm. The parameters of the climber 11.6 x 2 x 3 cm. It's weight is approximately 10-20g .
2. After that it was invented the image of the mechanism for scoring climbers into the box. The lever with a container for climbers turns around the axis, which is placed higher than the edge of the border. The container is closed by a cover with a latch, that is tied to the mount of the axis by thread. When the container overturns, the thread stretches and releases the latch. It allows to throw climbers vertically with high accuracy and prevent them from accidental falling out of the container during the movement.
3. According to this idea it was created the model of the bucket in Creo Parametric. To prevent the servo from breaking down, it was provided a second lever opposite the bucket, that can be charged with contraweight. It was also created a blueprint of a bucket and a cover. These elements will be made of PET.
4. Next, the first version of the module was assembled and tested. The latch for cover was working stable. However, after the implementation in real details it was acknowledged, that the module is quite bulky because of the lever for contraweight. So, there were held calculations of the moment on the servo to investigate whether it can operate without a countraweight or not.
5. The module was tested. It worked, but it was too bulky ant took too much space in the robot, so it was decided to refuse this construction.



3.6 Specifications for programmes

Description: This section contains detailed information about elaboration of remote-control program program.

3.6.1 Driver control program

1. As soon as the first prototype of the wheel base was assembled on November 12th, it was elaborated a program for test-drive. It included straight movement and turning around in 4 grades of speed. With this program, there were tested the abilities of the present wheel base.
   Here is the source code of first version:

```
#pragma config(Hubs,  S1, HTMotor,  HTMotor,  none,     none)
#pragma config(Sensor, S1,     ,               sensorI2CMuxController)
#pragma config(Sensor, S2,     TIR,            sensorI2CCustom)
#pragma config(Motor,  mtr_S1_C1_1,     LF,            tmotorTetrix, openLoop, reversed)
#pragma config(Motor,  mtr_S1_C1_2,     LB,            tmotorTetrix, openLoop, reversed)
#pragma config(Motor,  mtr_S1_C2_1,     RF,            tmotorTetrix, openLoop)
#pragma config(Motor,  mtr_S1_C2_2,     RB,            tmotorTetrix, openLoop)
//*!!Code automatically generated by 'ROBOTC' configuration wizard               !!*//

#include "JoystickDriver.c"
int k = 1;
int speed = 12;

void movement()
{
if (joy1Btn(1)) // 1 speed
{
k = 1;
}
if (joy1Btn(2)) // 2 speed
{
k = 2;
}
if (joy1Btn(3)) // 3 speed
{
k = 4;
}
if (joy1Btn(4)) // 4 speed
{
k = 8;
}
if (joystick.joy1_TopHat == 6) // tank turn to left
{
motor[RB] = motor[RF] = speed * k;
motor[LB] = motor[LF] = -speed * k;
}
if (joystick.joy1_TopHat == 2) // tank turn to right
{
motor[RB] = motor[RF] = -speed * k;
motor[LB] = motor[LF] = speed * k;
}
if (joystick.joy1_TopHat == 0) // forward
{
motor[RB] = motor[RF] = speed * k;
```

```
motor[LB] = motor[LF] = speed * k;
}
if (joystick.joy1_TopHat == 4) // backward
{
motor[RB] = motor[RF] = -speed * k;
motor[LB] = motor[LF] = -speed * k;
}
if (joystick.joy1_TopHat == -1) // stop
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;
}
}

task main()
{
while(true)
{
getJoystickSettings(joystick);
movement();
wait1Msec(50);
}
}
```

2. Results of the test drive were analysed so as develop a convenient control system. At first, turning around on high speed is inaccurate. So, the speed of turn was reduced proportionally to speed of straight movement. There also were added extra active buttons for accurate movement. Main drive control was moved from TopHat to a left stick. The operating area of the stick was divided into 8 zones. Zones 3 and 5 are not used because of inconvenience of back semi-turns.
   Here is the source code of second version:

```
#include "JoystickDriver.c"
int k = 2;

int joy_result()
{
int horison_in = joystick.joy1_x1;
int vertical_in = joystick.joy1_y1;

int option = -1;
int sector = 0;

//determining sector
if (vertical_in > 90) sector += 1;
if (vertical_in < -90) sector += 4;
if (horison_in > 100) sector += 2;
if (horison_in < -100) sector += 8;

//set option
if (sector == 1) option = 0;
if (sector == 3) option = 1;
if (sector == 2) option = 2;
if (sector == 6) option = 3;
if (sector == 4) option = 4;
```

```
if (sector == 12) option = 5;
if (sector == 8) option = 6;
if (sector == 9) option = 7;

return option;
}

int setspeed()
{
if (joy1Btn(1)) // 1 speed
{
k = 1;
}
if (joy1Btn(2)) // 2 speed
{
k = 2;
}
if (joy1Btn(3)) // 3 speed
{
k = 4;
}
if (joy1Btn(4)) // 4 speed
{
k = 8;
}

return k;
}

void joy_accomplish()
{
int speed = 12;
int turnspeed = 6;
int option = joy_result();
int k = setspeed();

if (option == 0) // forward
{
motor[RB] = motor[RF] = speed * k;
motor[LB] = motor[LF] = speed * k;
}
if (option == 4) // backward
{
motor[RB] = motor[RF] = -speed * k;
motor[LB] = motor[LF] = -speed * k;
}
if (option == 6) // tank turn to left
{
motor[RB] = motor[RF] = turnspeed * k;
motor[LB] = motor[LF] = -turnspeed * k;
}
if (option == 2) // tank turn to right
{
motor[RB] = motor[RF] = -turnspeed * k;
motor[LB] = motor[LF] = turnspeed * k;
}
```

```
if (option == 7) // semi turn to left
{
motor[RB] = motor[RF] = speed * k;
motor[LB] = motor[LF] = 0;
}
if (option == 1) // semi turn to right
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = speed * k;
}
if (option == -1) // stop
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;
}
}

void accurate_turn()
{
if (joy1Btn(5) || joy1Btn(6) || joy1Btn(7) || joy1Btn(8))
{
int speed = 24;
int turnspeed = 12;
int timeDelay = 100;

if (joy1Btn(8)) // accurate forward
{
motor[RB] = motor[RF] = speed;
motor[LB] = motor[LF] = speed;
wait1Msec(timeDelay);
}
if (joy1Btn(7)) // accurate backward
{
motor[RB] = motor[RF] = -speed;
motor[LB] = motor[LF] = -speed;
wait1Msec(timeDelay);
}
if (joy1Btn(6)) // accurate right
{
motor[RB] = motor[RF] = -turnspeed;
motor[LB] = motor[LF] = turnspeed;
wait1Msec(timeDelay);
}
if (joy1Btn(5)) // accurate left
{
motor[RB] = motor[RF] = turnspeed;
motor[LB] = motor[LF] = -turnspeed;
wait1Msec(timeDelay);
}

motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;
wait1Msec(50);

//while (joy1Btn(5) || joy1Btn(6) || joy1Btn(7) || joy1Btn(8)){}
}
```

```
}

task main()
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;

while(true)
{
getJoystickSettings(joystick);
accurate_turn();
joy_accomplish();
}
}
```

3. Due to testing it was discovered, that optimal course speed to turn speed proportion varies non-linearly from one speed mode to another. So, it's more preferable to set speed mode by exact values of both speed parameters instead of common coefficient. In addition, it was decided to reduce the number of sectors on main stick's from 8 to 6 because 2 sectors were not in use .
   Here is the changed fragment of the code:

```
    int joy_result()
    {
int horison_in = joystick.joy1_x1;
int vertical_in = joystick.joy1_y1;

int option = -1;
int sector = 0;

//determining sector
if (vertical_in > 10) sector += 1;
if (vertical_in < -10) sector += 4;
if (horison_in > 80) sector += 2;
if (horison_in < -80) sector += 8;

//set option
if (sector == 1) option = 0;
if (sector == 3) option = 1;
if (sector == 2) option = 3; // sectors 3 & 5 won't be used
if (sector == 6) option = 2;
if (sector == 4) option = 4;
if (sector == 12) option = 6;
if (sector == 8) option = 5; ////
if (sector == 9) option = 7;

return option;
    }
```

4. Then the program was rewritten in Android Studio.

3.7 Key summary

Description: Here are marked the tactical and technical characteristics of the final version of the robot.

Table 8: Tasks that the robot can perform according to its construction.

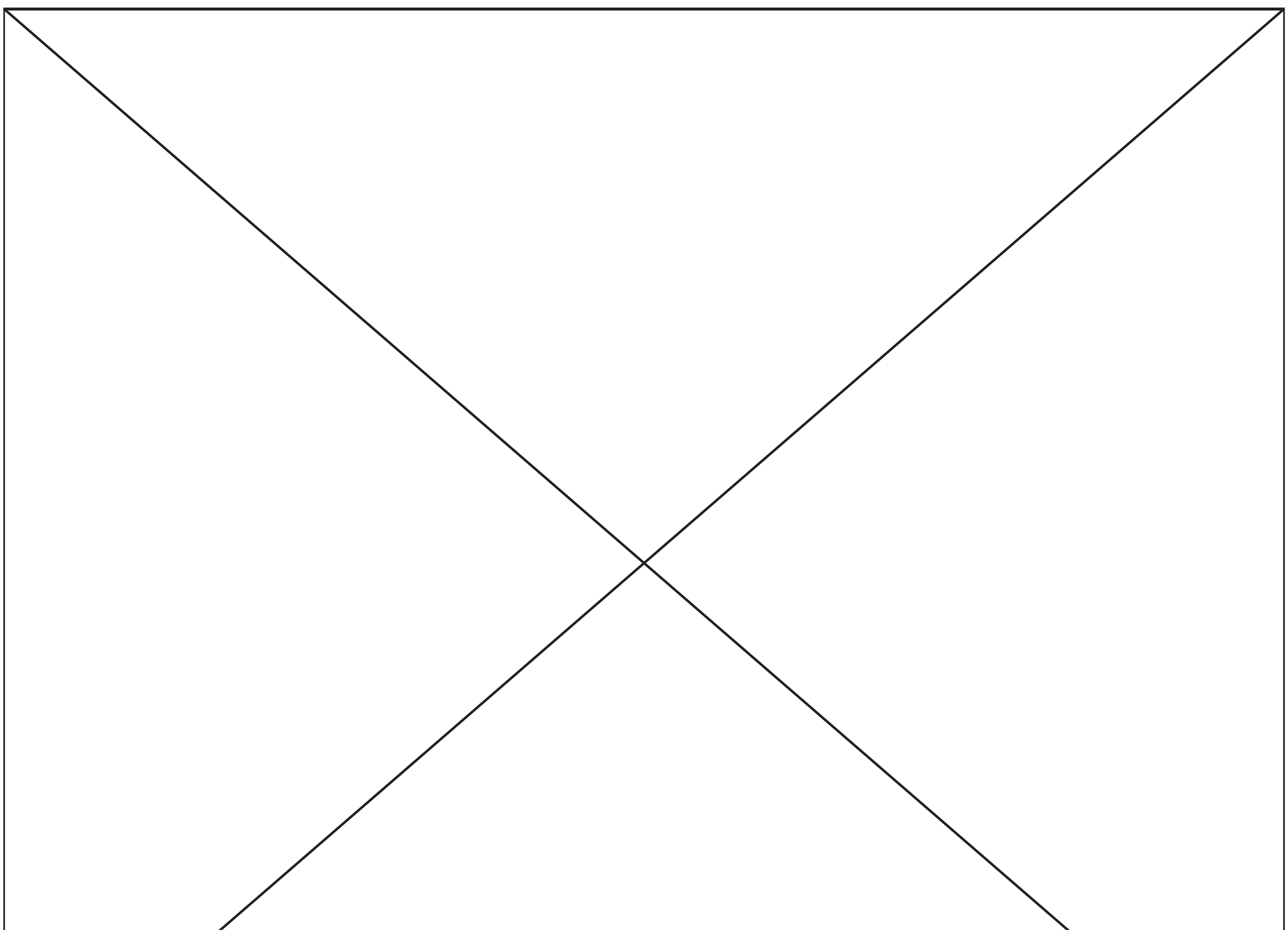
Tasks	Ability
Score climbers into shelter in autonomous period.	Yes.
Push the button on rescue beacon in autonomous period.	No.
Stay in beacon repair zone at the conclusion of autonomous period.	Yes.
Climb on mountain in autonomous period.	No.
Block the opponent's autonomous movement.	No. We consider that blocking is unfair.
Score zip-line climbers in tele-op period.	Yes, first and second ones.
Score debris in floor goal.	Yes.
Score debris in every mountain goal.	Yes.
Stay fully in low zone at the conclusion of tele-op period.	Yes.
Stay in second or top zone or pull-up at the conclusion of tele-op period.	No.
Turn the "All Clear" signal.	Yes.

Table 9: Consequense of performing tasks in the match

Task	The time needed to perform (sec)	Points
Autonomous period		
Score climbers into shelter.	20	40
Stay in beacon repair zone.	10	5
Autonomous total	30	*45*
Tele-op period		
Score low and second zip-line climbers	15	40
Score 10 cubes ($5 cubes \cdot 2 times$) into the top goal.	90	150
We can score 10 cubes ($5 cubes \cdot 2 times$) into the second goal instead of top if it would be pre-discussed with ally.	90	100
Turn the "All Clear signal"	15	20
Stay in low zone at the conclusion of tele-op period.	—	10
Tele-op total	120	*220 (170)*
Game total	150	***265 (215)***

Table 10: Actions in extraordinary situations

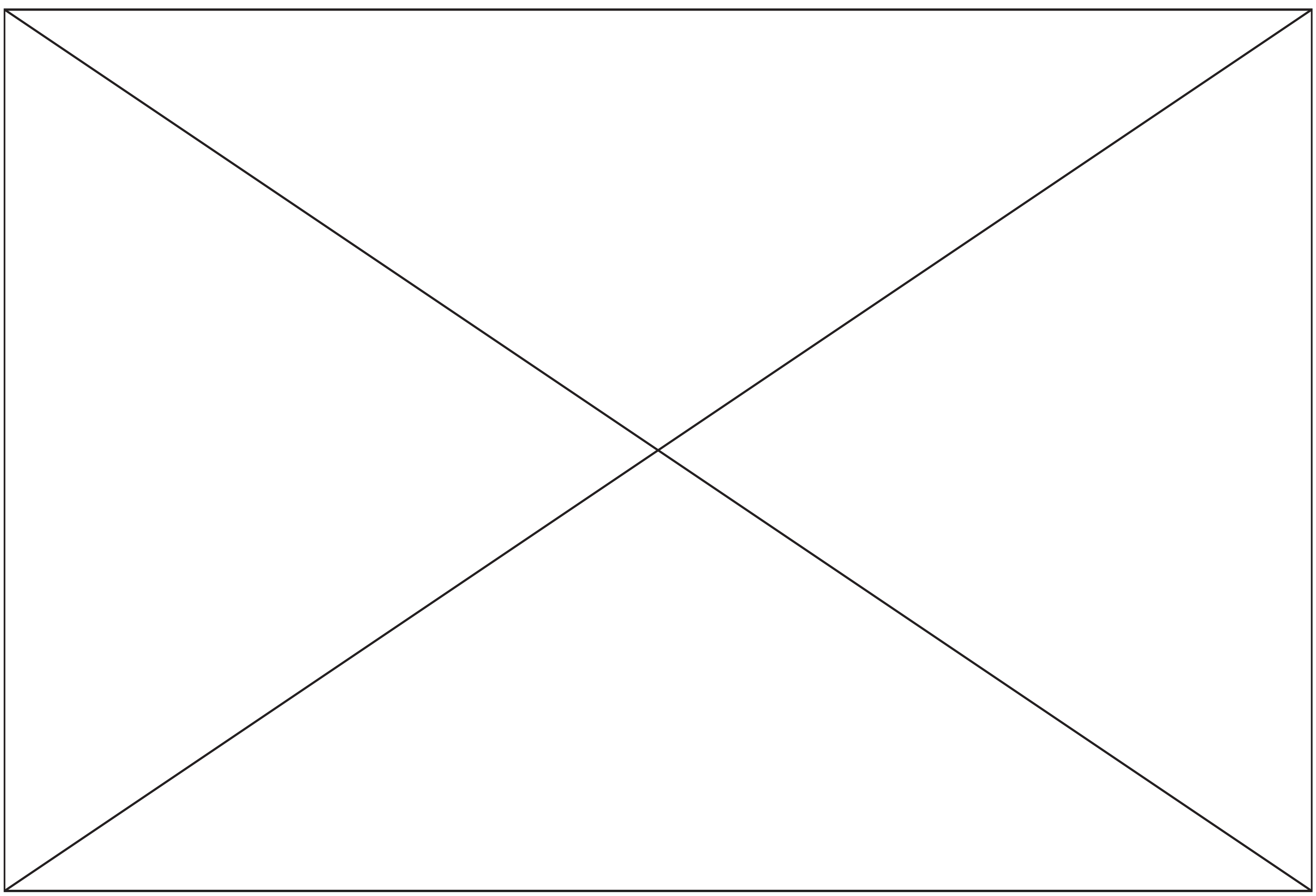
Situation	Action
The autonomus program didn't run.	Score climbers into shelter in tele-op period.
Scoring debris into mountain goals is impossible due to break.	Score debris into floor goal.
Our ally lost ability of scoring debris into mountain goals in case he was to score debris into the top goal.	Firstly, we ask ally if we can score debris into the top goal instead of them. If he confirms that we can perform his game objective, we start scoring debris into top goal as it gives more points. If he rejects the suggestion (if, probably, alliance robot cann't leave the mountain), we continue performing our game objective



4 Appendix

4.1 Supplementary materials which were used in the robot's construction

1. Aluminium axis 1m × 8mm. 1 piece.
2. Aluminium L-shaped profile 2m × 40mm × 40mm × 2mm. 1 piece.
3. Aluminium U-shaped profile 1m × 10mm × 10mm × 1,5mm. 1 piece.
4. Furniture slats 35m. 6 items.
5. Sheet of PET 1 m × 80 cm. 1 piece.
6. Sheet of plexiglass 3m × 2m (cut). 1 piece.
7. Blocks for rope. 12 items.
8. Steel angles 30mm × 30mm × 10mm. 10 items.
9. Garden hose 20mm × 25m. 1 piece.
10. Plastic clamps.
11. Hot melt adhesive.
12. Tape.



4.2 Information for judges

Team PML30-Y (FTC-15)

The basic principle we followed in engineering is modular. Our robot was divided into several modules and for every module there was appointed a responsible person from the team members. There are 4 main modules in our robot. They are:

1. Wheel base - a system that provides movement of the robot. Responsible - Gordei Kravtsov.
2. Gripper - a system for collecting debris. Responsible - Andrew Nemov.
3. Bucket - a system for keeping debris until it will be put into a goal. Responsible - Aleksandr Iliasov.
4. Elevator - a system for delivering the bucket to middle and top goals of the mountains. Responsible - Nikita Safronov.

In our technical documentation there is a special section named "Specifications for modules" which is dedicated to the development process of modules in particular. In this section you can find more information about modules mentioned above.

Software specifications are available in section named "Specifications for programs".

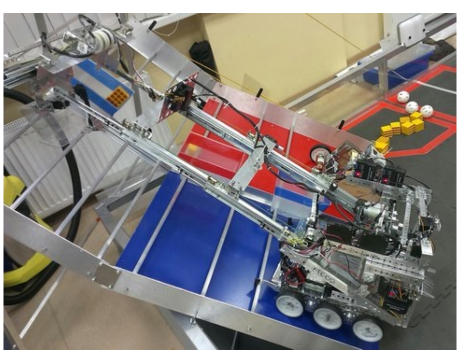
General development of the robot in progress is represented in chronological section. This section contains information about all the team meetings including discussions and days of competitions (it mentioned in the title of meeting).

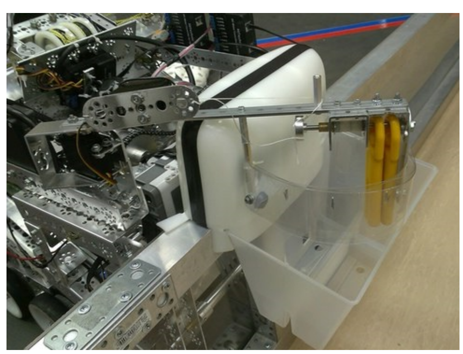
Our abilities and our strategy in the game are provided in section "Key summary".

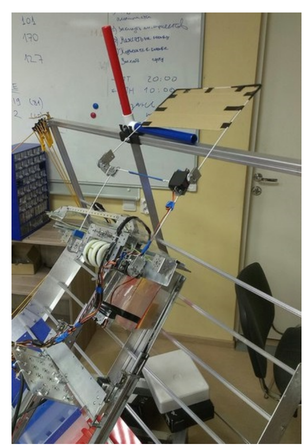
In the section "Appendix" you can find":

1. The list of raw materials used in robot.
2. The example of leaflet with our robot's characteristics that we intend to distribute among other teams to make them know about our abilities.
3. The information list for judges (which you are reading right now).

You can learn more about the structure of our technical book in the section "How to read this book".







4.3 Leaflet for teams

Team FTC-15

PML30-Y

Figure 161: Dmitry Luzin, coach

Figure 162: Nikita Safronov, captain

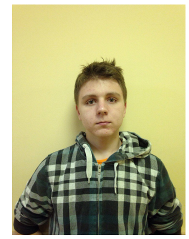


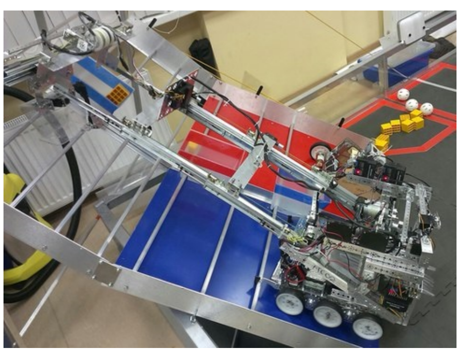
Figure 163: Andrea Nemov, programmer

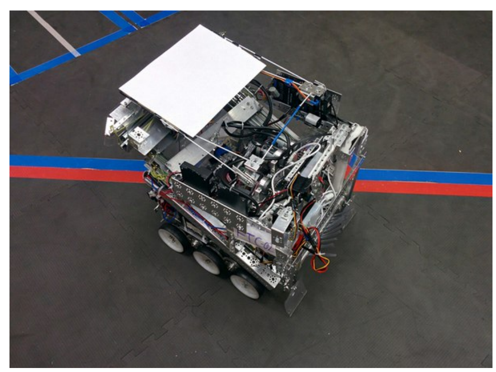
Figure 164: Anton Ponikarovsky, communication manager

Figure 165: Gordei Kravzov, operator

Figure 166: Alexandr Iliasov, operator

Our robot





Our score

Autonomous period	Score climbers into shelter, stay in beacon repair zone.	45 points
Tele-op period	Score low and second zip-line climbers, score 10 cubes into the top goal, turn the All Clear signal, stay in low zone	220 points
Game total	***265 points***	