Center of robotics
Physics-Mathematics Lyceum 30

Engineering notebook for
FIRST Tech Challenge Competition

Team PML30 –Y

Saint-Petersburg, Russia
2015-2016

Contents

1 Introduction

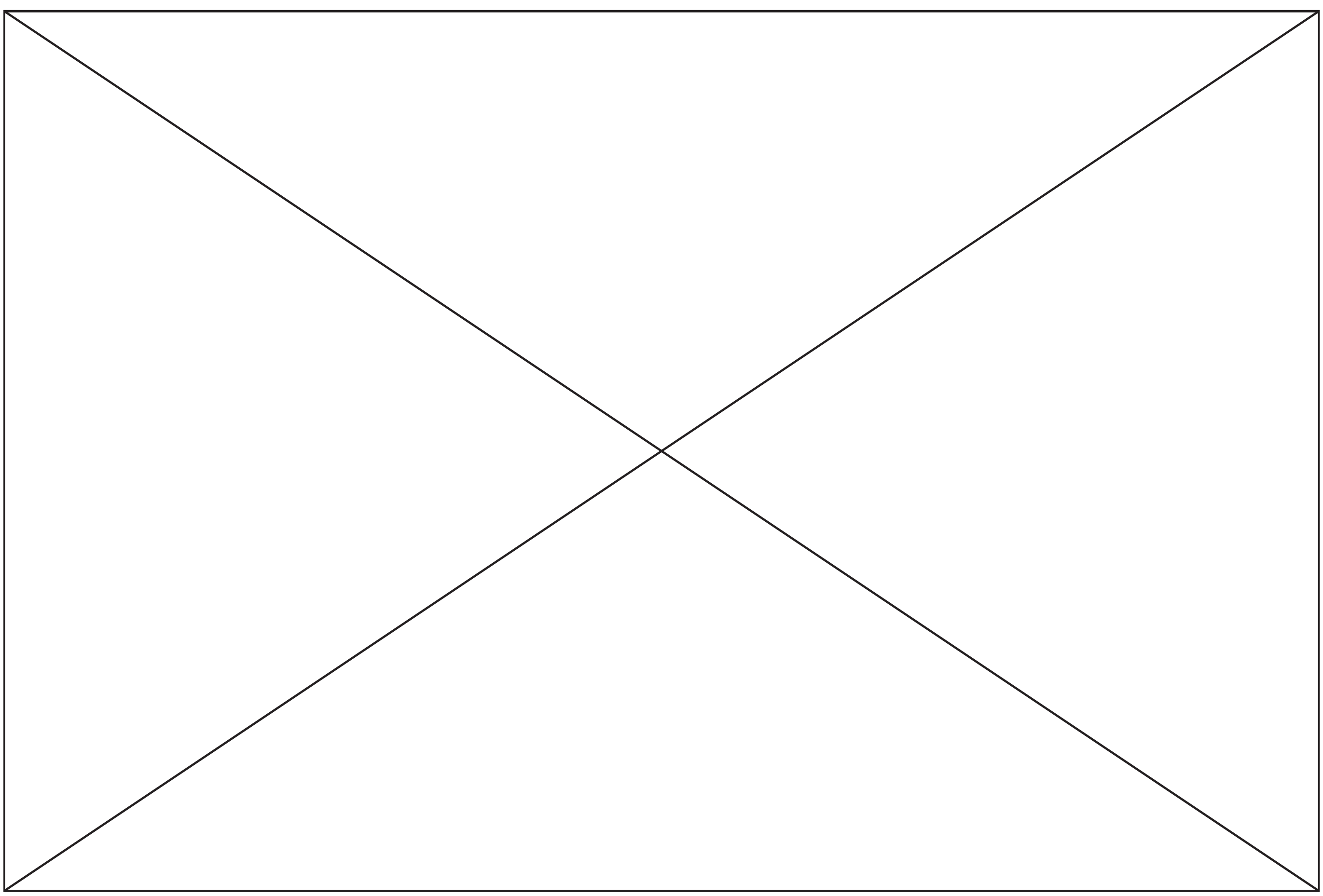
1.1 How to read this book

The book consists of 4 chapters.

1. In the Introduction it is represented information about our team, our instructors and sponsors.
2. In the Business plan it is 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 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 last 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 used in the robot.
   - 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 4 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 the 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 qualyfiers 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 a lot of teams there and shared 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 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/ftcpml30phi. 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. In addition for designing 3D models of the robot we used CAD programme PTC Creo Parametric 3.0.

Spreading information about FTC is very important for our team 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: 26 years old, in robotics 5 years, in FTC 4 years.

Ekaterina Luzina
Professor in Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.
Information: 26 years old, in robotics 5 years, in FTC 4 years.

Anton Fedotov
Professor in 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 4 years.

Georgii Krylov
Professor in 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.

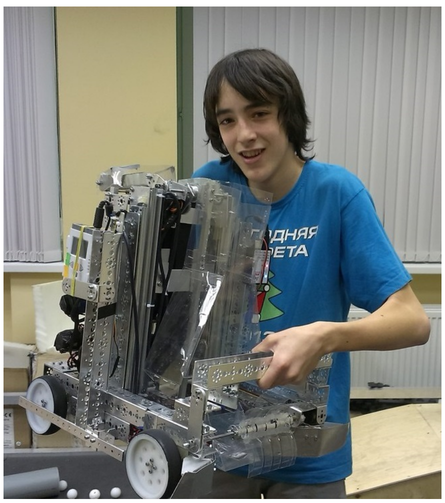
1.2.2 Team members

Nikita Safronov
Role in team: captain, reserve operator-2, responsible for writing the engineering notebook, 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."

Andrew Nemow
Role in team: reserve drive-operator, programmer, 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."



Maksimychev Evgeny
Role in team: developer of mechanism for scoring climbers
Information: 16 years old, in robotics 3 years, in FTC 2 year.
Why I chose FTC: "This is an interesting project that allows to implement some innovative solutions. In addition to the skills of designing robots, we also obtain the skills of the technical documentation and communication with colleagues which makes this competition as close to real engineering problems."

Timur Babadzhanov
Role in team: developer of mechanism for pushing button, responsible for robot decoration
Information: 15 years old, in robotics 2 years, in FTC 1 years.
Why I chose FTC:" It was recommended for me. Also I heared about previous seasons of FTC and decided that it will be interesting for me. Also I wanted to learn working with TETRIX that can be useful for my projects."

Victoria Loseva
Role in team: main programmer
Information: 17 years old, in robotics 2 years, in FTC 1 years.
Why I chose FTC:"I enjoy working on new and unique projects, and FTC is a great way for me to do exactly that: solving the challenging problem of building and designing a robot from scratch, as a team, is all it's about!"

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. 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: PTC company 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 *Y*

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 is organized by Temur Amindzhanov, co-founder of Starline company. As a local organization, they offered their support to us. They help us financially providing with 1000 $ every month, purchasing materials and equipment and sponsoring trips to competitions.

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. They provide us with CAD "Creo Parametrics" that we use in engineering. They also help us with the delivery of parts from the USA. This and the previous year these companies sponsored registration fees for FIRST World Championship.

2.2.3 Program Robototechnika

Program "Robototechnika" sponsored our trip to the USA last year and trip to the Netherlands this year.

2.2.4 Physics-Mathematics Lyceum 30

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

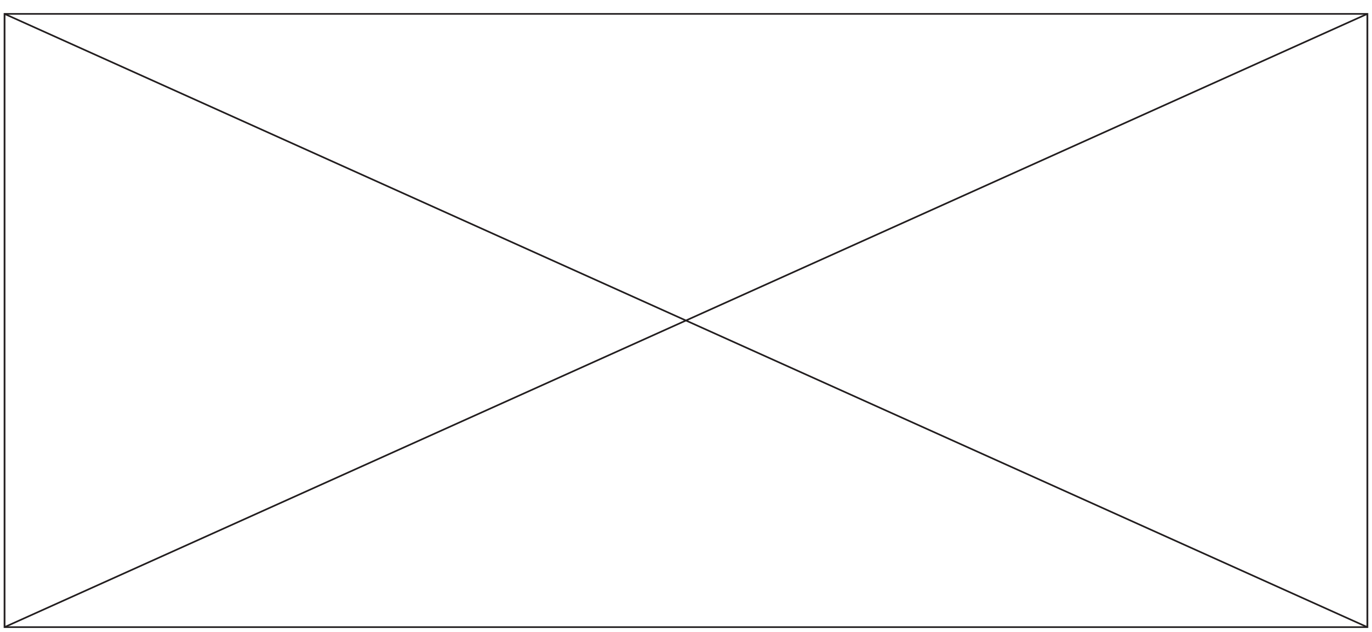
2.3 Our resource and financial situation

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).

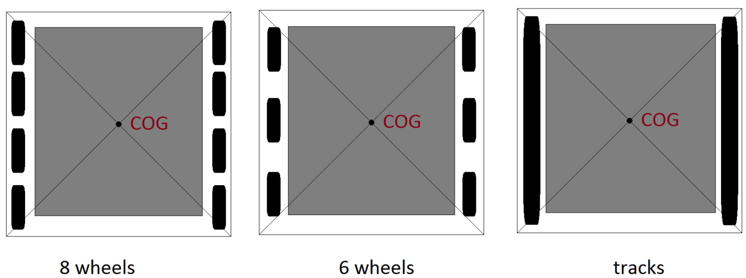


Figure 1: possible wheel bases

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).

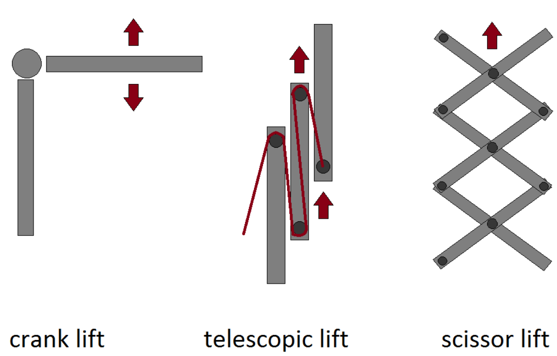


Figure 2: types of elevators

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 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
Evgeny Maksimychev	Beam for alpinists

Days inside section:

3.2.1 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 .

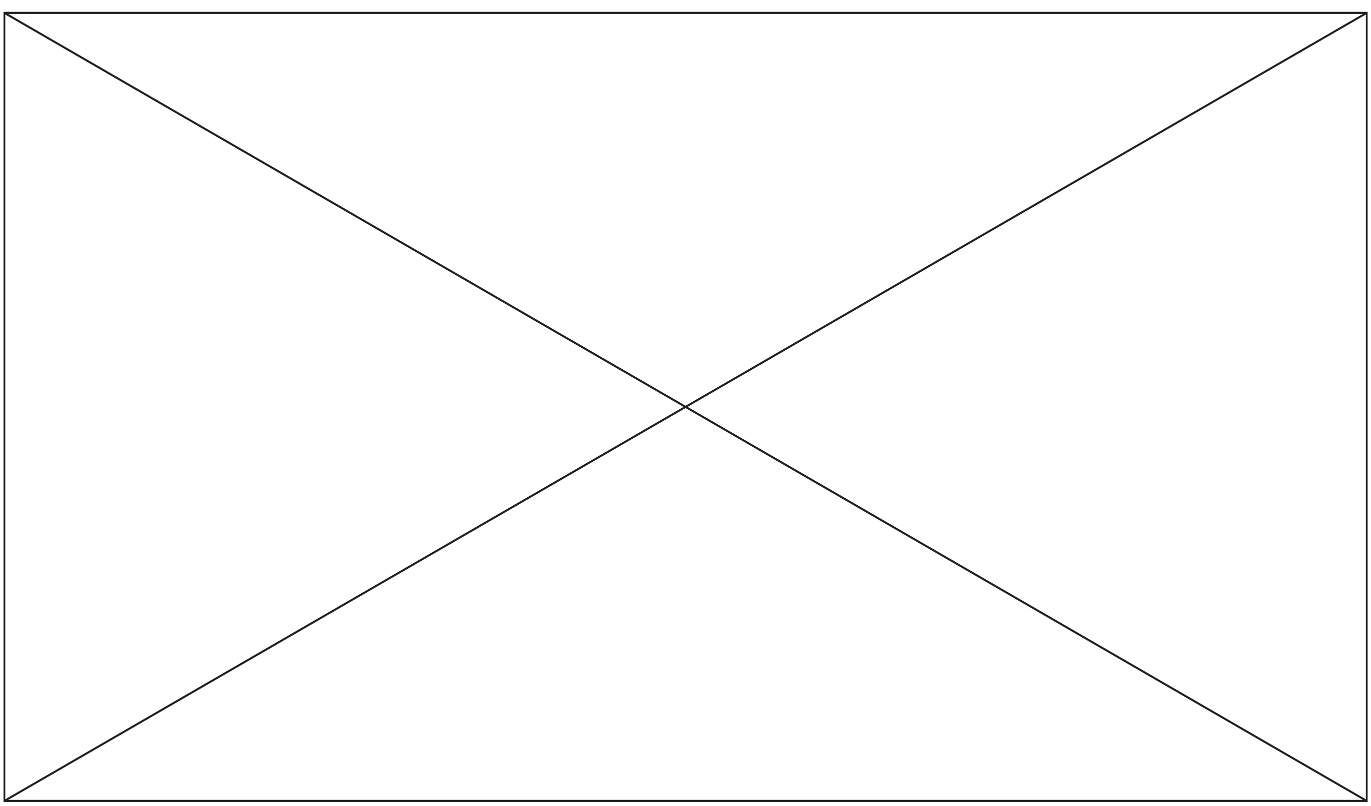
3. The robot will collect elements with help of rotating brush which pull them to the special bucket which connected with the lift. This method is the most simple and fast. After collecting elements the bucket rises by the lift. Then it overturns to the side and elements fall to the box.

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.



3.2.2 26.09.2015

Time frame: 17:00-21:00

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

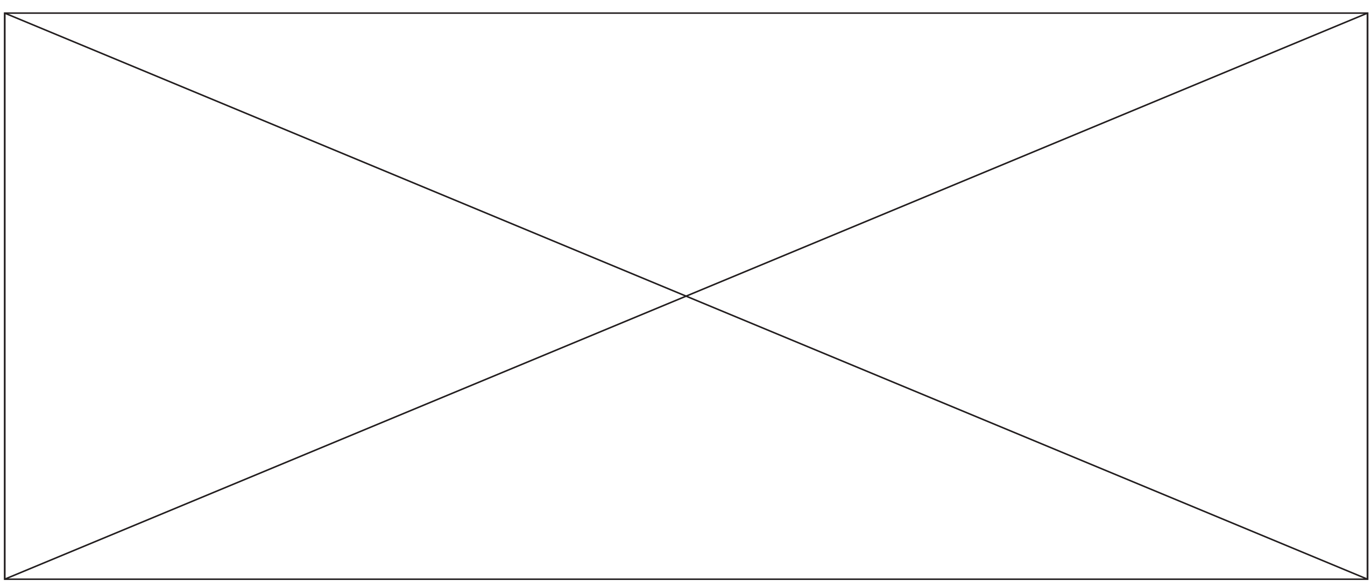
Module	Solutions
Wheel base	6 standard wheels without suspension
Lift	Retractable slats
Scoring elements	Bucket overturns back

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.



3.2.3 30.09.2015

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

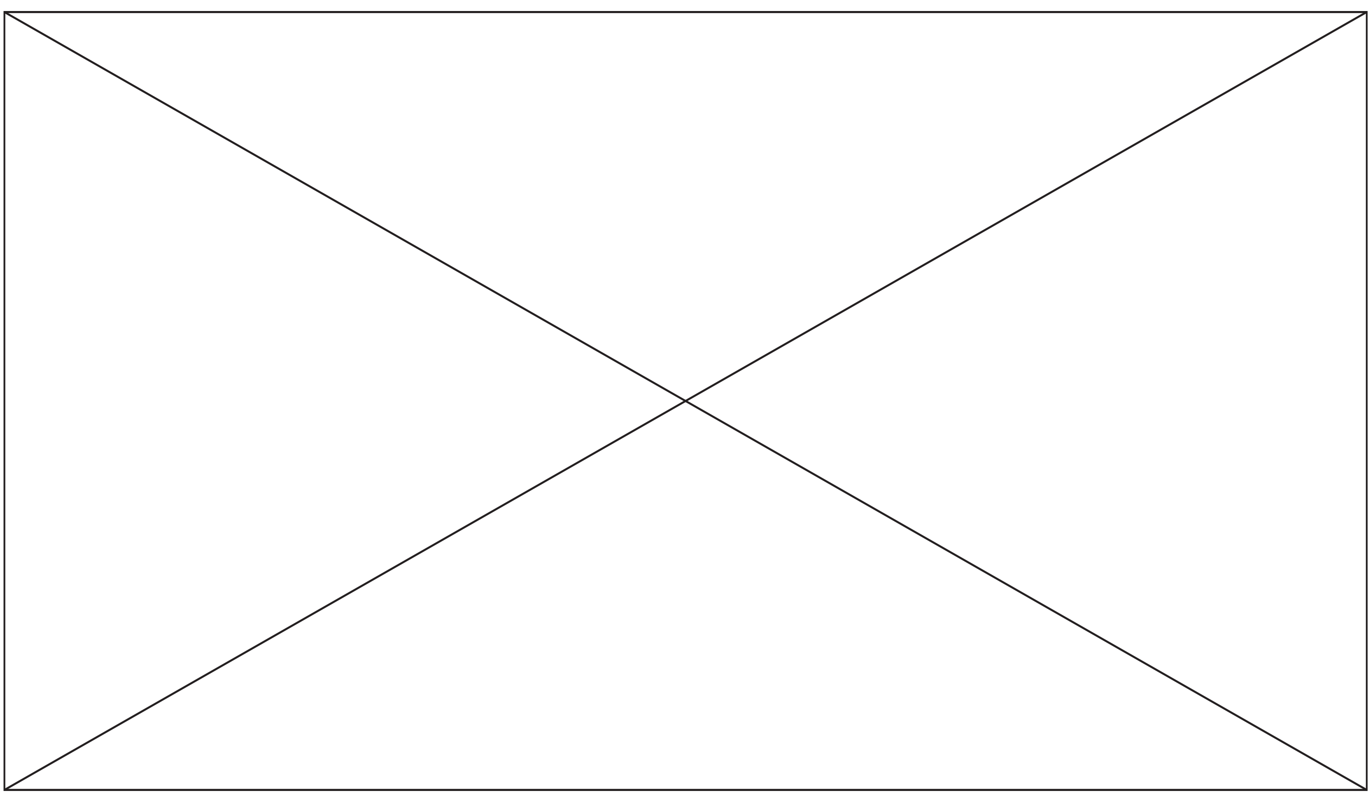
Tasks	Solutions
To elaborate mechanism for turning lift	Servo of continuous rotation with worm gear

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.



3.2.4 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.

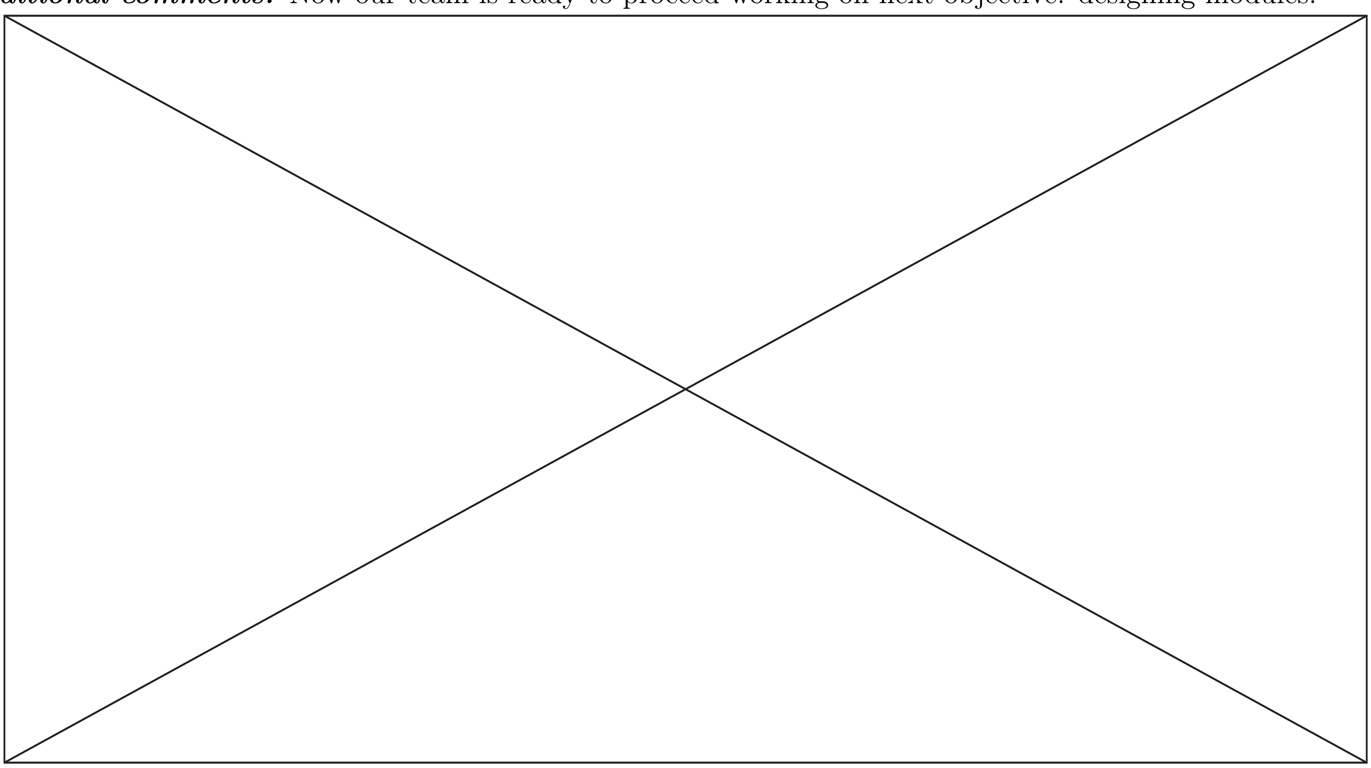
7. Mechanism for extracting lift and pulling

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.



3.3 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:

3.3.1 21.01.2016

Time frame: 16:30-22:00
The hooks were installed onto a mechanism for grasping the hurdle (figure 3, 4, 5).

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

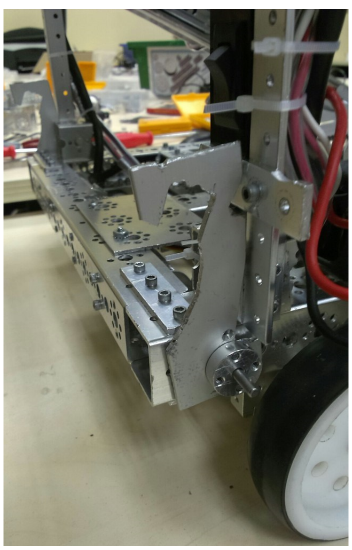


Figure 3: Hooks rised up

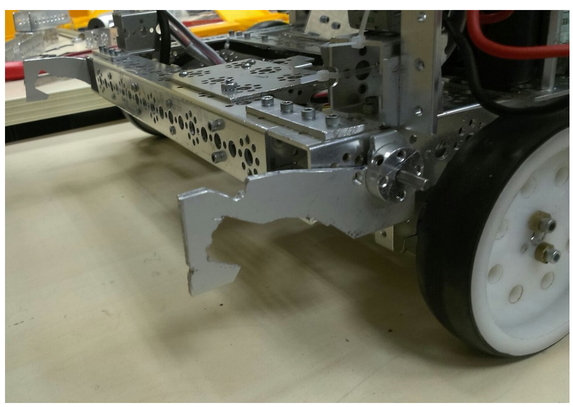


Figure 4: Hooks turned down

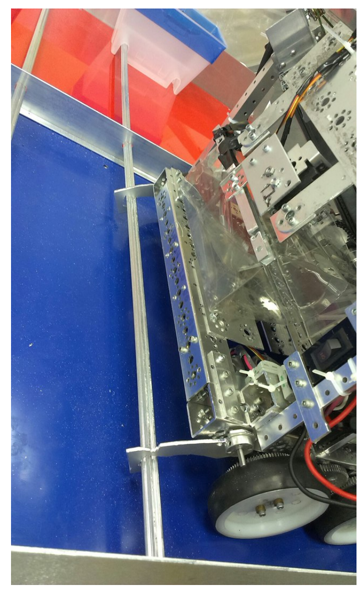


Figure 5: How does the module works

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 6).

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 7).

Figure 6: Drilled out holes

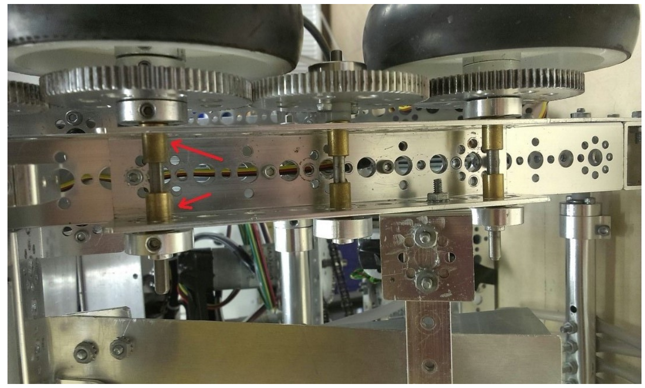


Figure 7: The bronze collars were installed

The bucket was installed onto the robot and it's servos were connected to the controller (figure 8).

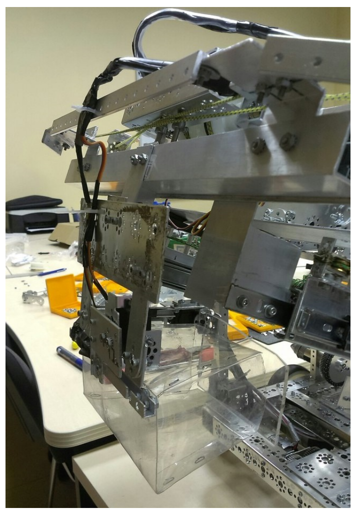


Figure 8: Winch installed onto the carriage

3.3.2 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.

3.3.3 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 3: 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

3.3.4 26.01.2016

Time frame: 17:00-21:00

The moving mounts for ribs on the elevator were recreated (figure 9, 10). 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.

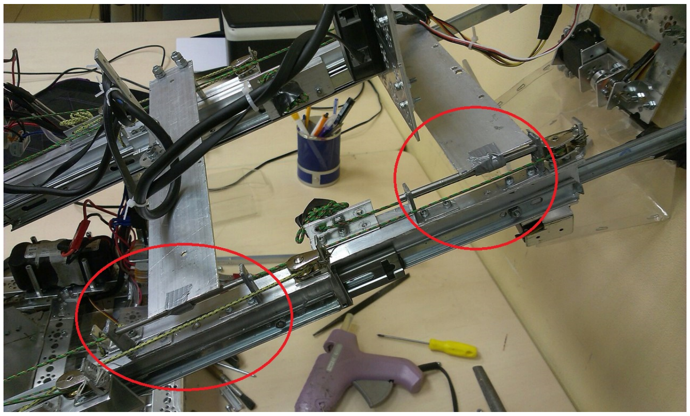


Figure 9: Convenient movable mounts of the ribs

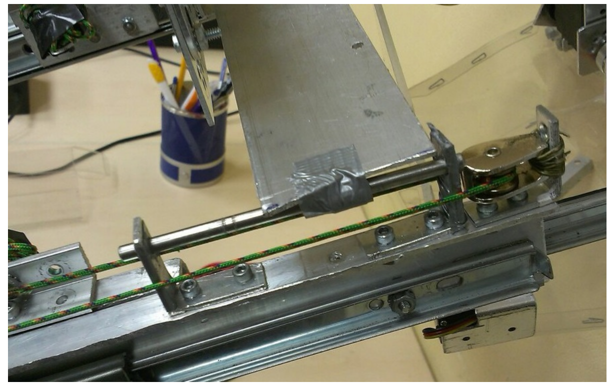


Figure 10: The mount of the rib

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 11).

The protection of the area under the bucket from debris was recreated with a layer of PET (figure 12).

Figure 11: Protection from debris 1

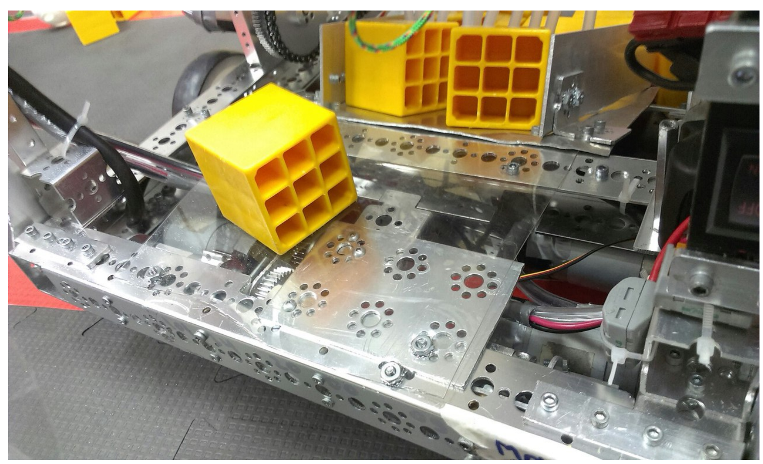


Figure 12: Protection from debris 2

3.3.5 27.01.2016

Time frame: 19:00-21:00

It was created a surface for pushing the button on the beacon (figure 13, 14).

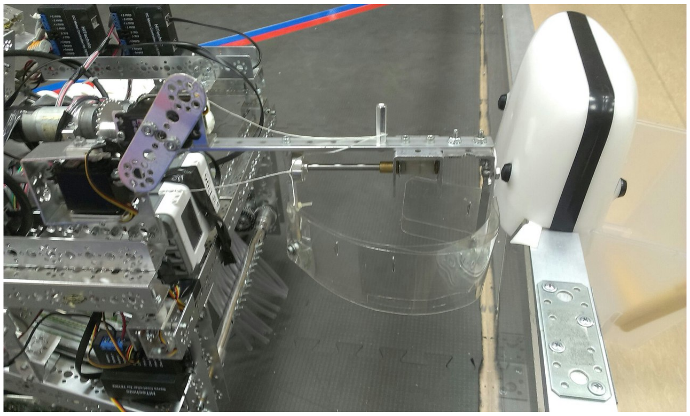


Figure 13: The surface for pushing the button

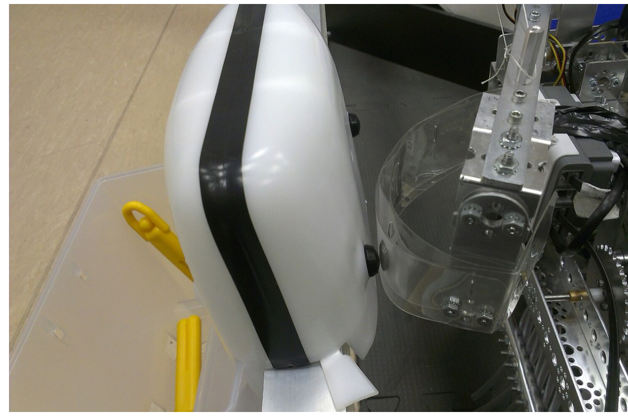


Figure 14: How does it works

3.3.6 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 15).

It was also created a protection from the engagement of the cable with the axis at the mechanism for shifting the bucket (figure 16).

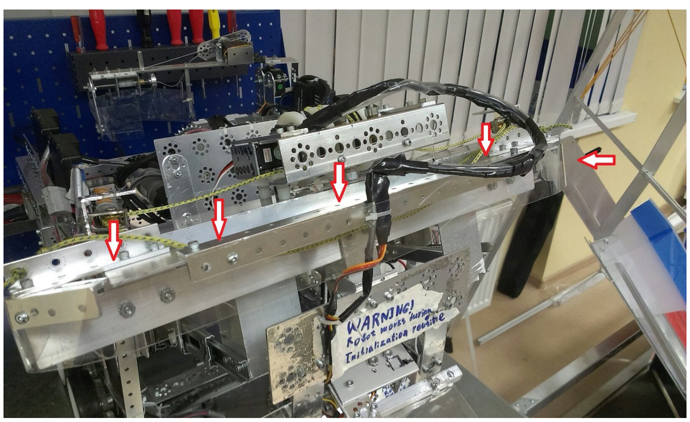


Figure 15: Protection for wire

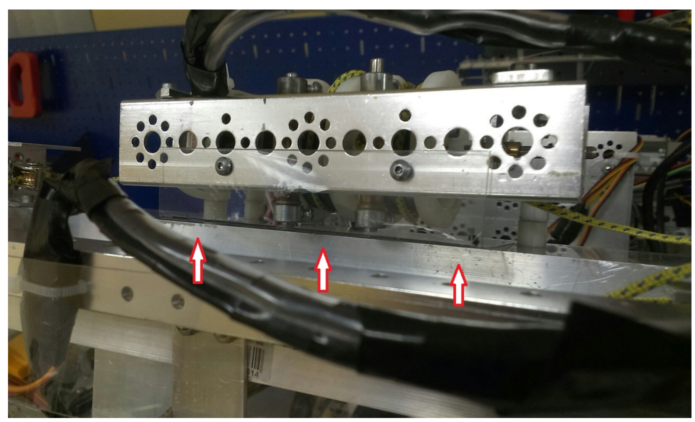


Figure 16: Protection for cables

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.

3.3.7 30.01.2016

Time frame: 16:00-21:30

The borders for debris were installed at both sides of the gripper (figure 17, 18). The extension of these borders was installed at both sides of the bucket (figure 19).

The moving mounts of the ribs were finished (figure 20).

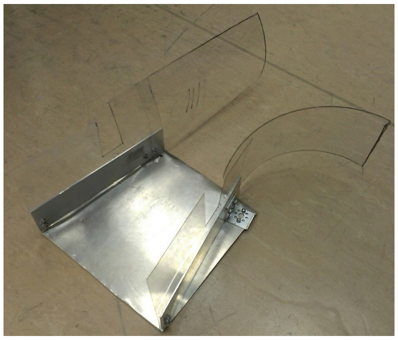


Figure 17: Borders for debris

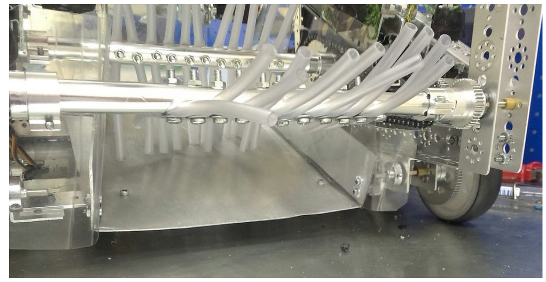


Figure 18: Borders for debris (front)

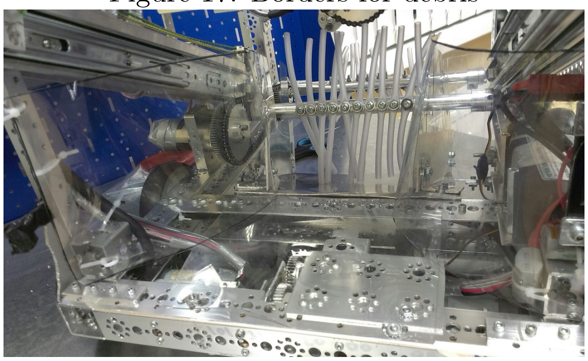


Figure 19: Borders for debris (back)

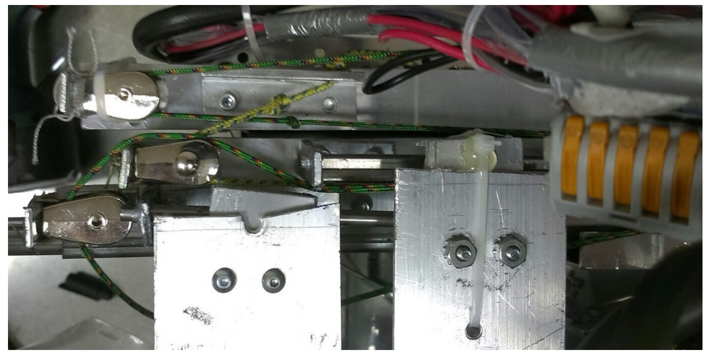


Figure 20: The moving mounts of the ribs

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 21, 22).

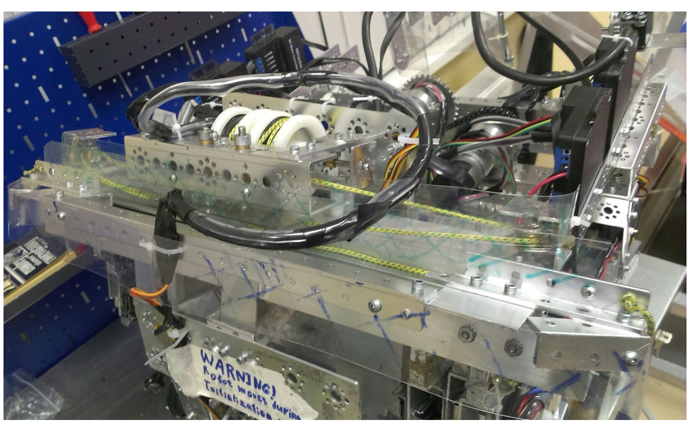


Figure 21: Protection for wire

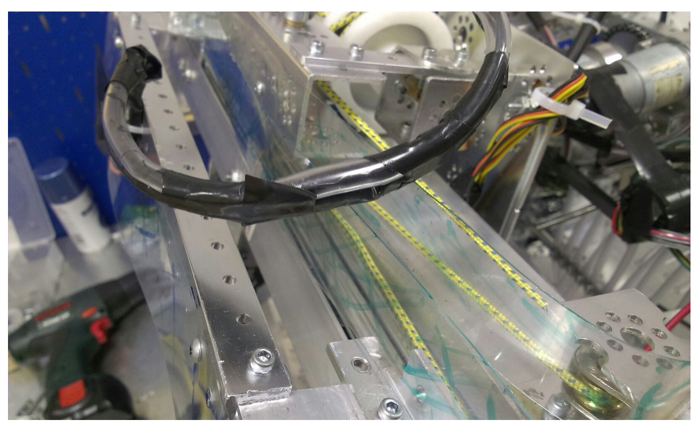


Figure 22: How does the protection works

It was created a new bucket for debris (figure 23, 24). It's shape allowed to collect 5 cubes at once, but was more convenient, than the previous.

Figure 23: Bucket 1

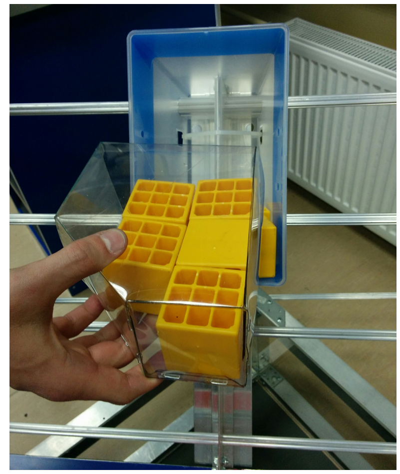


Figure 24: Bucket 2

3.3.8 03.02.2016

Time frame: 19:00-21:30

The mechanism for grasping the hurdle was improved so as to reduce the backlash of the hooks. There were put two pieces of foam rubber which kept hooks in central positions (figure 25). However, each hook still had some free space for movement (due to softness of foam rubber), which prevented the mechanism from brakes.

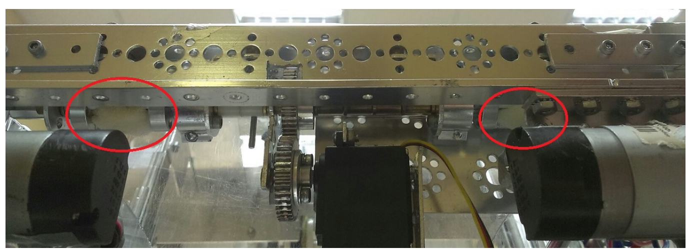


Figure 25: Foam rubber in mechanism for grasping the hurdle

It was recreated the mount for the bucket. It was made according to the new principle of mounting the bucket, which included fixing the servo on the bucket, not on the mount for bucket.

There was installed the cover for bucket (figure 26, 27).

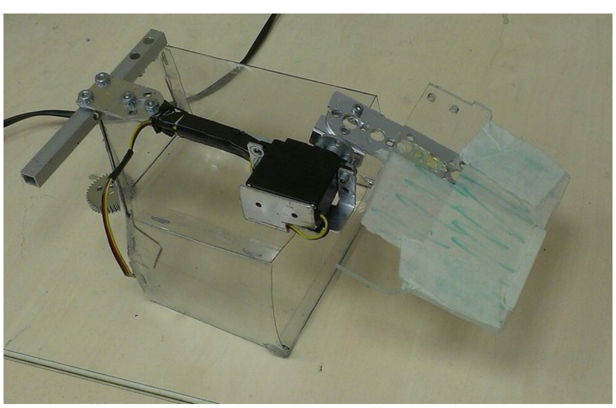


Figure 26: Cover for bucket (opened)

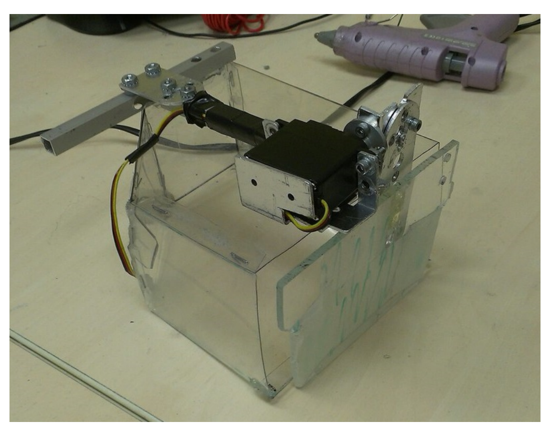


Figure 27: Cover for bucket (closed)

3.3.9 04.02.2016

Time frame: 10:00-18:00

The cover for bucket was tested and it was found out that the axis if rotation is placed too far from the bucket, so the trajectory of its movement is too wide. However, free space inside the robot was not as much as required, so it was decided to recreate the cover (figure 28, 29).

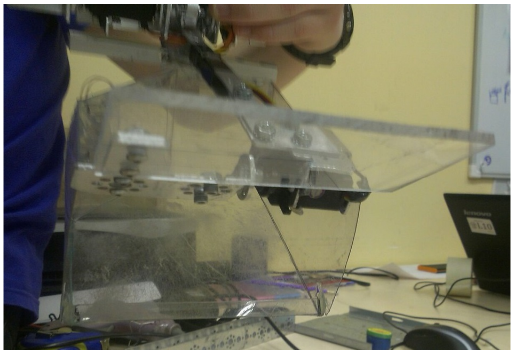


Figure 28: Cover for bucket (opened)

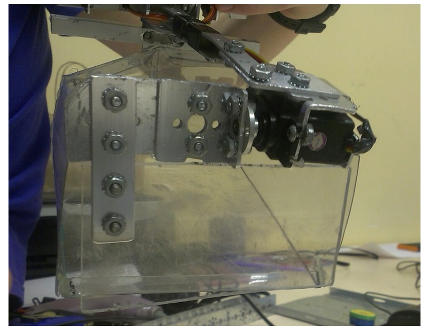


Figure 29: Cover for bucket (opened)

After the cover was improved, the bucket was installed onto the robot (figure 30).

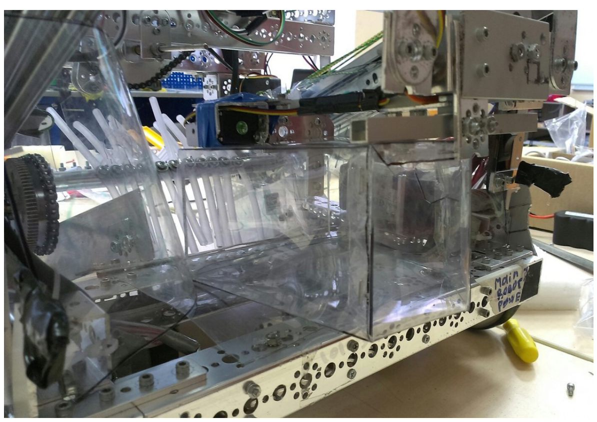


Figure 30: Bucket fixed on the robot

3.3.10 05.02.2016

Time frame: 12:00-21:00

This day we participated in a friendly match which took place in the Nizhny Novgorod. There was total of 3 teams in this meeting, so the matches were held 1 vs 1. Our team got the second place in this competition.

Figure 31: Match

Figure 32: Match

During the competition there were found some problems in the robot.

The first problem was that the protection around the bucket prevented the bucket from getting inside the robot. To avoid this, the protection was adjusted to the needed dimensions. Since then the bucket could get inside the robot without difficulties.

Figure 33: Protection around the bucket was adjusted

The second problem was that the mechanism for shifting the bucket was grasping the mount which prevented if from shifting. The cause of this grasping was detected and the protection was improved.

Another problem was that the servo that operated the bucket's cover worked very poor. The problem was that the contact on the signal wire was bad. We couldn't solve this problem because of no reserve servos. However, we decided to change the servo after returning home.

3.3.11 08.02.2016

Time frame: 17:30-21:00

There was installed a sheet of PET, which was used to prevent debris from getting out of the gripper (figure 34, 35).

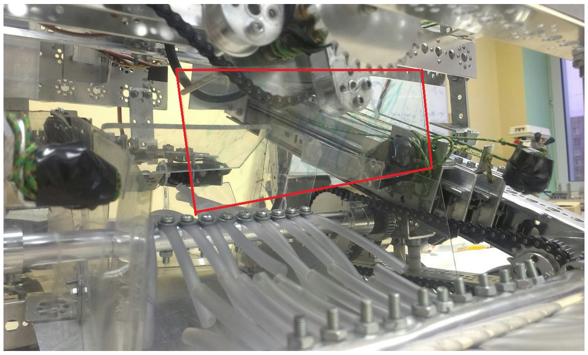


Figure 34: Sheet of PET (front)

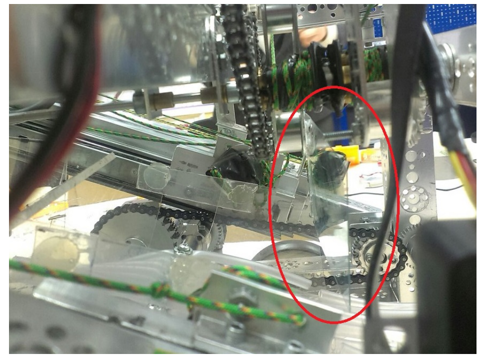


Figure 35: Sheet of PET (side)

3.3.12 09.02.2016

Time frame: 17:30-21:30

The servo on the cover for the bucket was changed. The new servo worked OK.

It was started the assembling of the mechanism for pushing the “All Clear” signal. Today it was installed the low section of this mechanism (figure 36, 37).

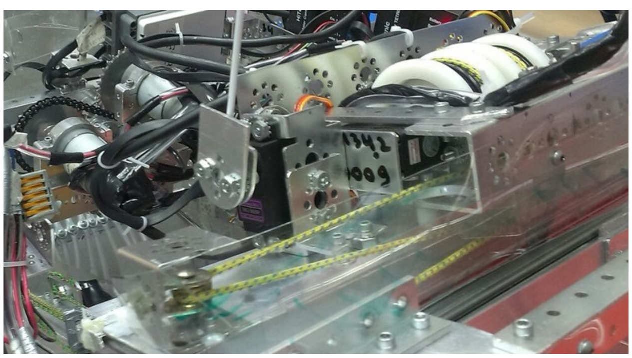


Figure 36: Servo that rotates the section

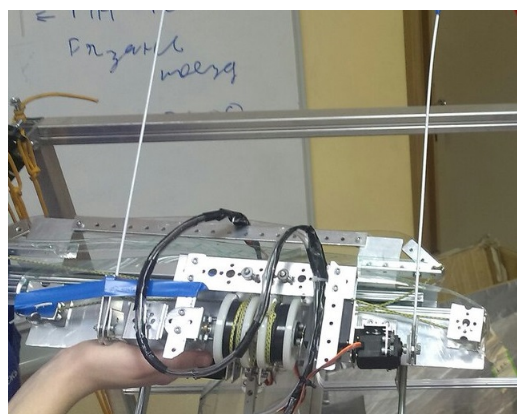


Figure 37: Construction

3.3.13 10.02.2016

Time frame: 19:00-21:00

Today it was installed the second section of the mechanism for pushing the “All Clear” signal. Then the mechanism was tested (figure 38, 39). The result of the test was positive.

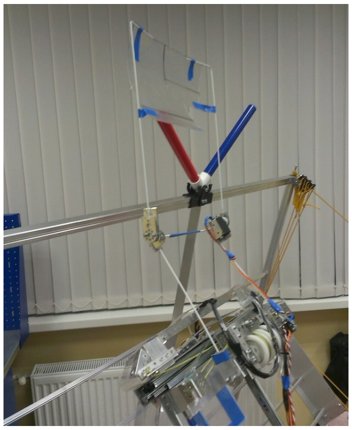


Figure 38: How the mechanism works 1

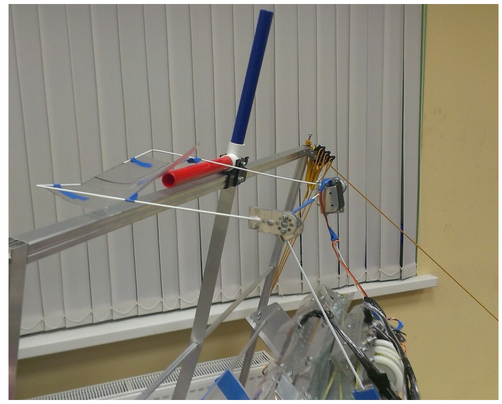


Figure 39: How the mechanism works 2

3.3.14 12.02.2016

Time frame: 17:00-22:00

Today there were held only trainings for operators.

During the trainings the robot accidentally overturned and the bucket was broken (figure 40). However, it was quickly repaired and the trainings continued (figure 41).

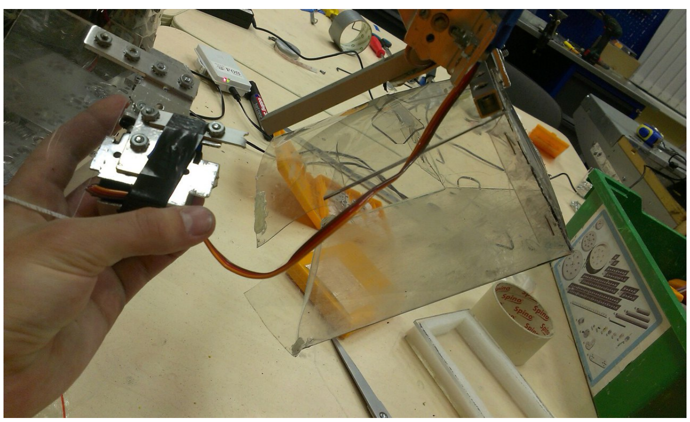


Figure 40: Broken bucket

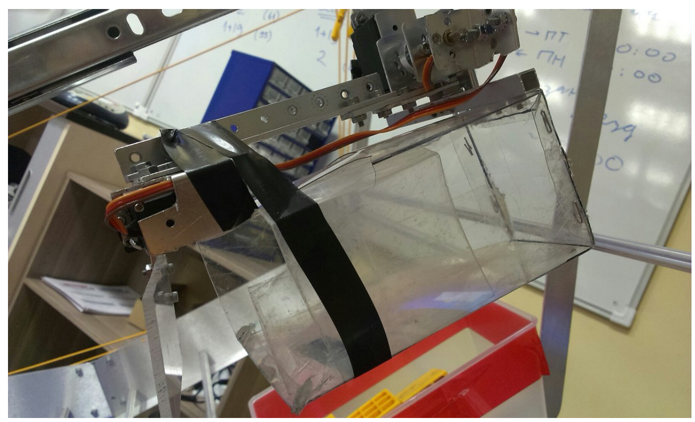


Figure 41: Repaired bucket

3.3.15 13.02.2016

Time frame: 16:00-21:30

The axis on the winch was changed on a shorter one, which wouldn't interfere with the cover of the bucket.

The chain gears on the winch were moved closer to the motors in order to make the mechanism more reliable.

There were added new segments to the front brush in order to enlarge the collecting area.

It was also installed the protection which would prevent debris from getting under the wheels (figure 42).

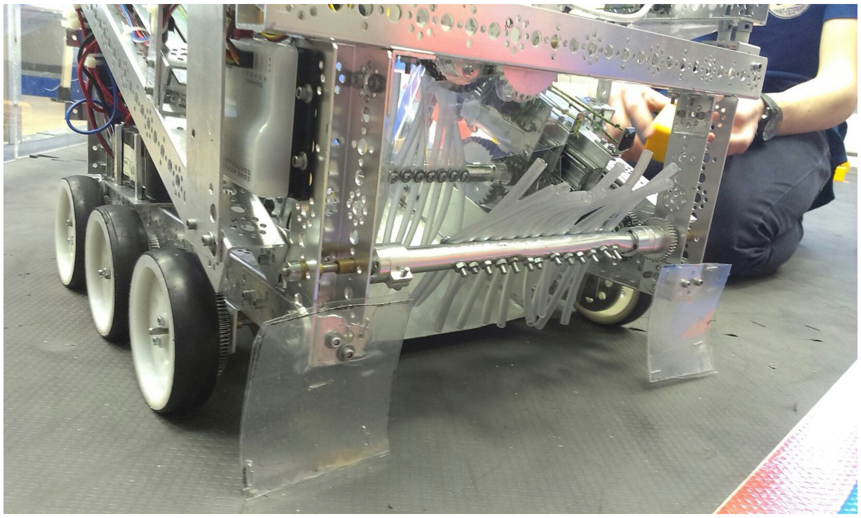


Figure 42: Protection for wheels

3.3.16 15.02.2016

Time frame: 17:30-21:00

The NXT brick was replaced with the new system (figure 43). Then, the program was tested. The operating of motors worked without problems. However, the operating of servos was not provided.

It was installed the protection for controllers (figure 44).

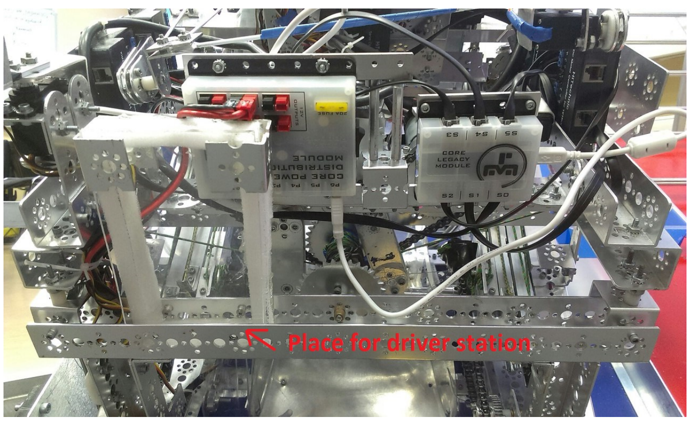


Figure 43: New system was installed

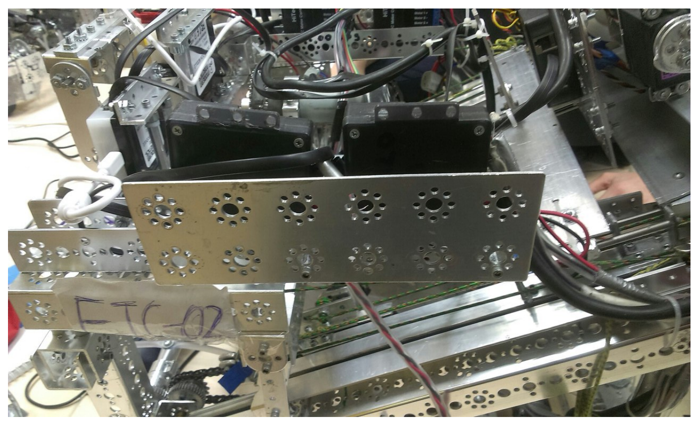


Figure 44: Protection for controllers

3.3.17 16.02.2016

Time frame: 17:00-21:30

The program was improved so that it became possible to control both motors and servos.

After that, it was held a training for operators. At the conclusion of the training it was investigated that the program at the new system of control worked as well as the program at the NXT brick. It was also revealed that the connection between control system and the robot controlled by the "Motorola" became more stable than when the robot was controlled by the NXT.

3.3.18 17.02.2016

Time frame: 17:30-21:50

Today there were cut out pieces of plexiglass which would be installed at both sides of the robot for the protection of electronics from collisions.

It was created the decor for robot. There were printed stickers for plexiglass protection and it was decorated the mechanism for pushing the "All Clear" signal (figure 45).

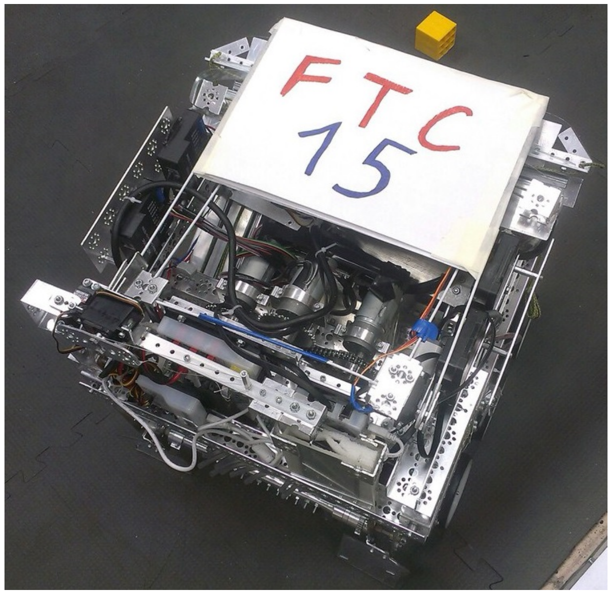


Figure 45: Decorated mechanism for pushing the baton

3.3.19 19.02.2016

Time frame: 12:00-23:00

It was the first day of the competition . . . . There were no matches, so we had time to prepare the robot.

Firstly, the plexiglass protection was mounted to the robot and the sticker was glued on it (figure 46, 47).

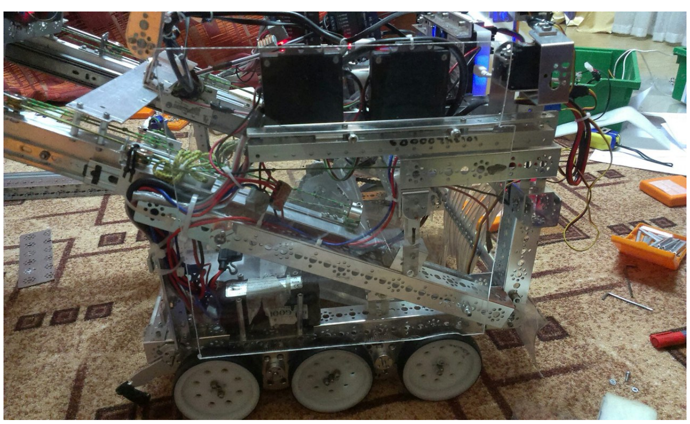


Figure 46: Plexiglass protection

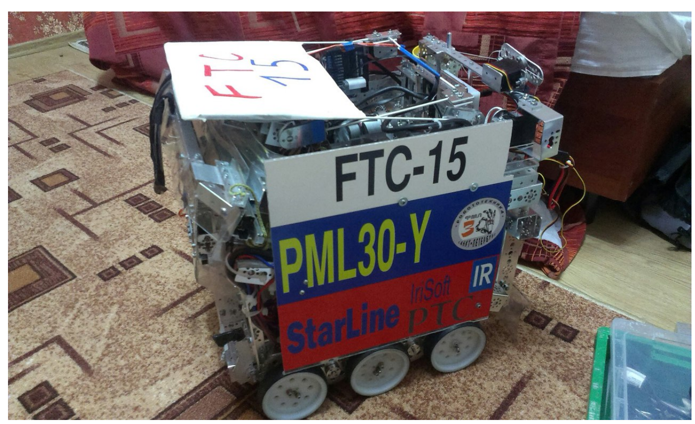


Figure 47: Sticker on the plexiglass protection

Secondly, it was created the protection which prevented wires from the elevator from getting into the winch (figure 48).

Thirdly, it was created the protection which prevented wires from the core power module from getting into the winch (figure 49).

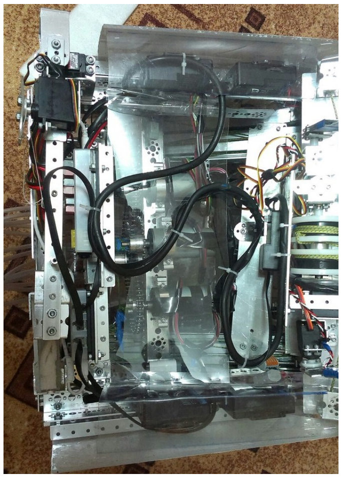


Figure 48: Protection above the winch

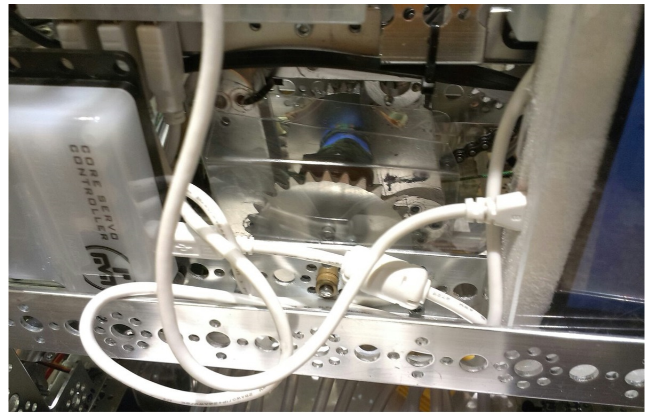


Figure 49: Protection for wires

Lastly, it was created a device for the prevention of the engagement between the mount of the bucket and the slats (figure 50).

It was revealed that protection for wheels scratches the field when the robot attempts to climb on the mountain and this prevents robot from climbing. Furthermore, the protection touches the field while the robot is on the mountain which means that the robot in not fully supported by the ramp (figure 51). So, it was decided to remove the protection.

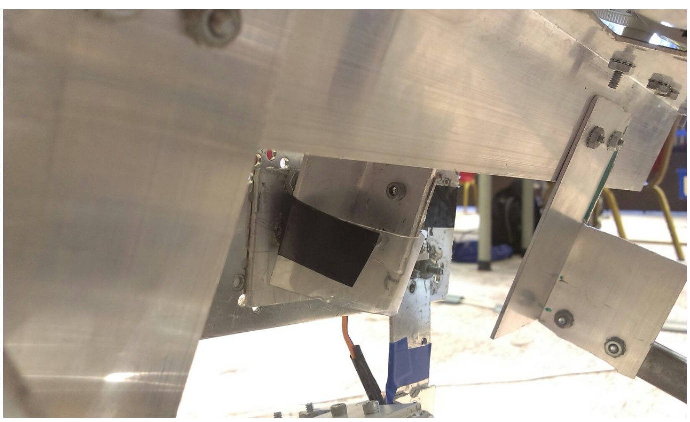


Figure 50: Protection from the engagement

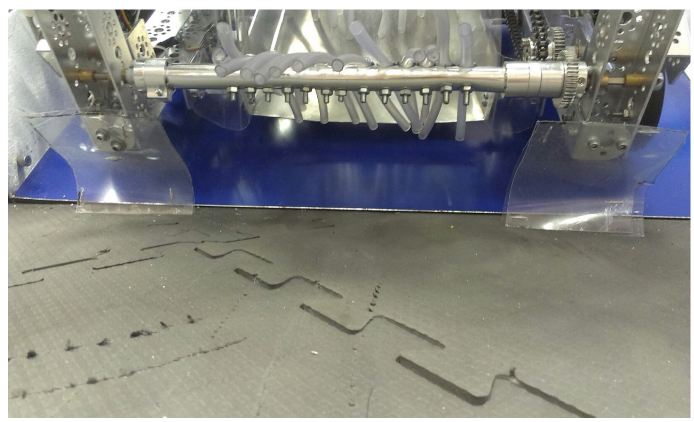


Figure 51: The problem of the protection for wheels

3.3.20 20.02.2016

Time frame: 10:00-21:00

It was the second day of the competition. Today were held only qualification matches. Our team participated in 4 matches and we managed to win in all of them.

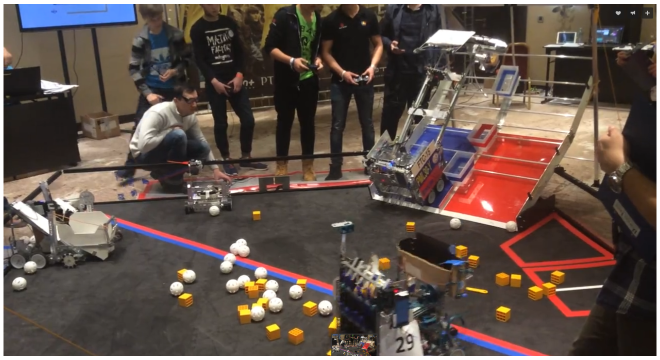


Figure 52: Match in progress. Our robot is scoring debris into the top goal

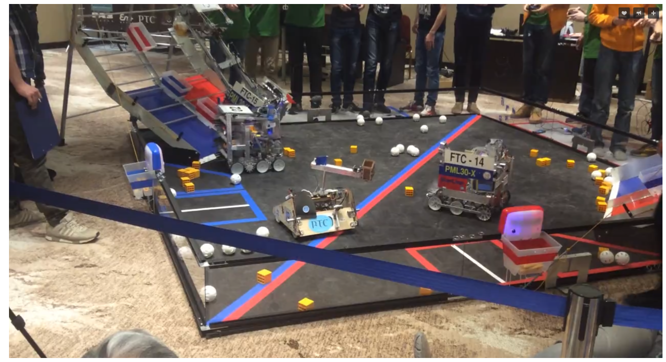


Figure 53: Another match

During the matches it was found out that the "All Clear" signal fixed tighter that we expected and it required strong force to turn it. Our mechanism for pushing the baton was not strong enough to turn the baton on the official field. Due to this fact, it was decided to remove the mechanism for pushing the "All Clear" signal from the robot.

3.3.21 21.02.2016

Time frame: 10:00-17:00

It was the third day of the competition. We got 2nd place at the conclusion of qualification matches, so our team was a head of a final alliance.

We won semi-final and lost final match, so we won the “Alliance-Finalist” award. We won the “Inspire Award”, so we got a quotation for the FTC World Championship.

Figure 54: Team photo with awards

3.3.22 25.02.2016

Time frame: 17:00-21:00

This day was day of discussing FTC Russia Open competitions. Problems of robot and way of their solving were discussed.

Table 4: Results of discussion of FTC Russia Open competitions

Problem type	Problem	Solution
Breakdowns (fatal)	Elevator's slats break	New construction of elevator
	Rope on the elevator tears	Correct stucking of rope inside slats. Study ropes
	Turning over because of high center of mass	Problem can stay
Breakdowns (can be fixed in match)	Balls stays inside the bucket	Make bucket's height more than 10cm
	Elevator pulls out because of fast movement	2nd rope for folding in
Low speed	Low speed of elevator pulling out and bucket shifting	The same speed of shifting. Bigger cylinder or plastic gears
	Cover is inside the scoring bucket	Bucket is upper in new construction
	Bucket shifts only with fully pulled out elevator	Bucket is above the elevator in new construction
	Hard to move cubes away from mountain	New module
	Cubes are throwed out by gripper	Use chquered and overlapped tubes. Find the best phase shifting of gripper's axises
	Impossible to get 5th cube without taking 6th	Problem can stay
Construction impossibility	No all clear signal turning mechanism	No solution
	Alpinists throwing is impossible in autonomous	No solution
	No pulling up	No solution

These problems seemed to be hard to solve and improve other mechanisms because of many details in construction of robot and very little space inside the robot, also it had some problems that couldn't be solved without huge changes in construction of robot.

That's why it was decided to create the robot with new construction which would be built with response to our experience received in this season. The first thing in development of new robot was creating models of all the modules. New models development tasks were spread between team members.

Table 5: Results of discussion of FTC Russia Open competitions

Name	Module	Tasks	Time, h
Gordey	Hooks	Model	1
		Assemble	2
		Mount	1
		Cut new (additional)	*3*
	Wheelbase	Model	4,5
		Assemble	2,5
	Module for moving debris away	Model (Additional)	*3*
		Assemble (Additional)	*2*
		Total	11 *+8*
Alexandr	Bucket	Model with cover	2,5
		Assemble	6
	Bucket shifting	Slats' mounting (design)	3
		Servo with coiling drum (design)	9
		Assemble	4
		Total	24,5
Viktoria	Hook for pulling up (additional)	Model	*5*
		Assemble	*2*
	All clear turning mechanism (additional)	Model	*3*
		Assemble	*2*
		Total	*12*
Nikita	Elevator	Study ropes and slats	4 + 2
		Model	4
		Assemble	4
		Mount	2
	Winch	Model	2
		Assemble	2
		Mount	1
		Total	21
Andrey	Gripper	Model	6
		Assemble	4
		Tests	2
	Controllers (additional)	Model	4
		Assemble	4
		Total	20
Timur	Autonomous button (additional)	Model	*2*
		Assemble	*2*
		Total	*4*
Evgeny	Mechanism for alpinists	Model	2
		Assemble	2
		Total	4

3.3.23 27.02.2016

Time frame: 16:30-21:00

It was created a prototype of a twoside full-extracting furniture slat (figure 55). The reason was to replace the construction with 2 furniture slats used in the mechanism for shifting the bucket with 1 rail which can move in both directions.

The ordinary 30 cm furniture slat was improved so that it could be extracted to its full length in both directions. The result of the experiment was successful (figure 56, 57).

Figure 55: Twoside full-extracting slat (prototype)

Figure 56: Extracted in right side

Figure 57: Extracted in opposite side

3.3.24 29.02.2016

Time frame: 17:30-20:30

After the prototype was successfully tested, it was created the twoside full-extracting slat (40 cm, thin) which will be used in the mechanism for shifting the bucket.

3.3.25 01.03.2016

Time frame: 17:30-21:30

It was held the investigation on the most convenient way of constructing the lifting mechanism. The aim was to find the construction, which would be able to withstand twisting force caused by the shifted to the side bucket with debris.

There was tested a number of constructions and it was investigated that construction with two rails at the angle of 90° provides the best resistance to the twist. Unfortunately, only to the one side (figure 60, 61).

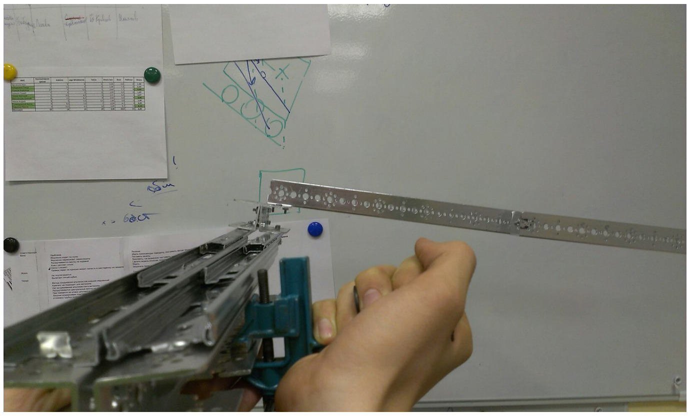


Figure 58: Two parallel rails

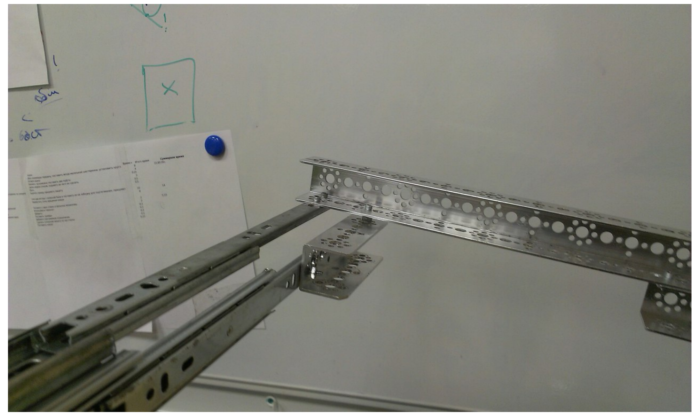


Figure 59: One rail turned on 90°

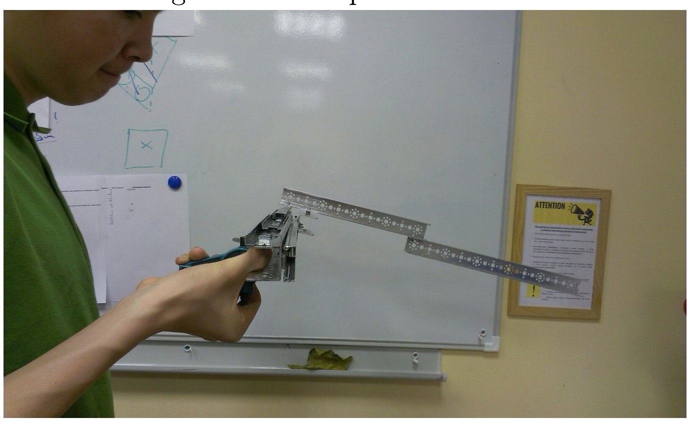


Figure 60: One rail turned on 90° (testing right bend)

Figure 61: One rail turned on 90° (testing left bend)

3.3.26 02.03.2016

Time frame: 19:00-21:00

Today it was found the optimal principle of building the lifting mechanism (figure 62). It was found out that if two slats are placed at the angle of 90°, they form the most firm construction with a good resistance against bend.

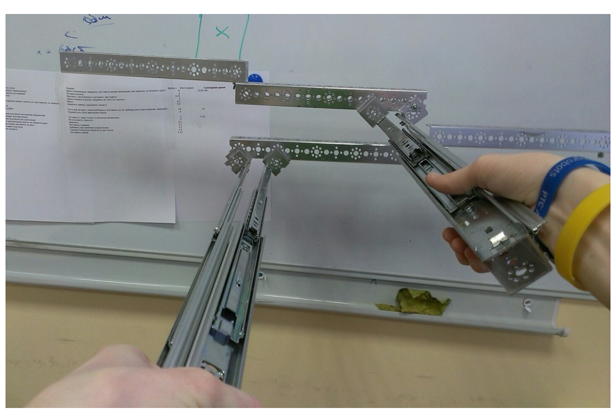


Figure 62: Optimal construction

3.3.27 03.03.2016

Time frame: 17:00-21:30

It was assembled the prototype of the axis with coils (figure 63). This prototype was used to find the best way of connecting parts to each other with screws. It was quite difficult to calculate this in Creo Parametric.

It was also assembled a case of the winch (figure 64).

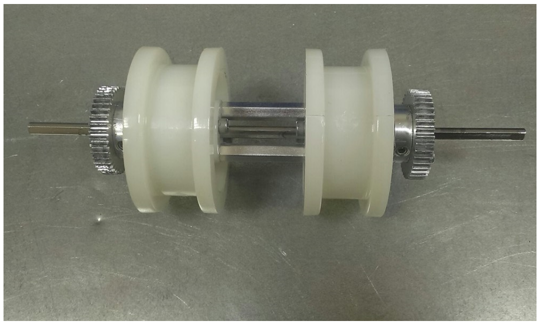


Figure 63: The prototype of the axis with coils

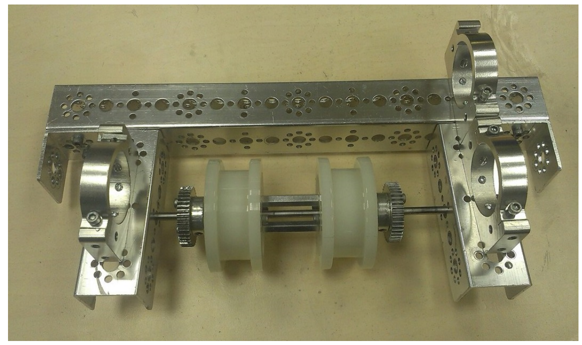


Figure 64: Case of the winch

3.3.28 04.03.2016

Time frame: 17:00-21:00

Today it was created the cascade of furniture slats for lifting mechanism (figure 65< 66). It consisted of three pairs of 35 cm slats placed at the angle of $90^{c}irc$. The construction was created using thin slats (150 g), so the whole assembly weighed only 1,5 kg instead of 3 kg in previous lifting mechanism.

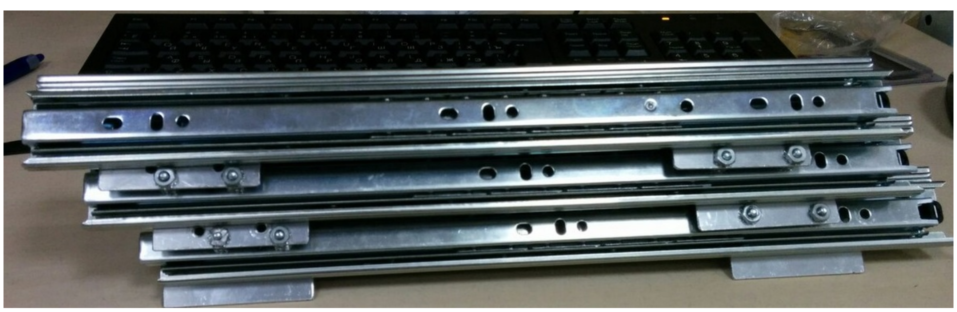


Figure 65: Cascade of slats (side)

Figure 66: Cascade of slats (top)

3.3.29 08.03.2016

Time frame: 12:00-21:00

The model of the gripper was finished, so it was begun the assembling of this module.

3.3.30 10.03.2016

Time frame: 17:00-21:30

Today it was held the discussion of models. Models were approved and it was started the assembling of the whole robot.

The assembling of the winch was continued (figure 67).

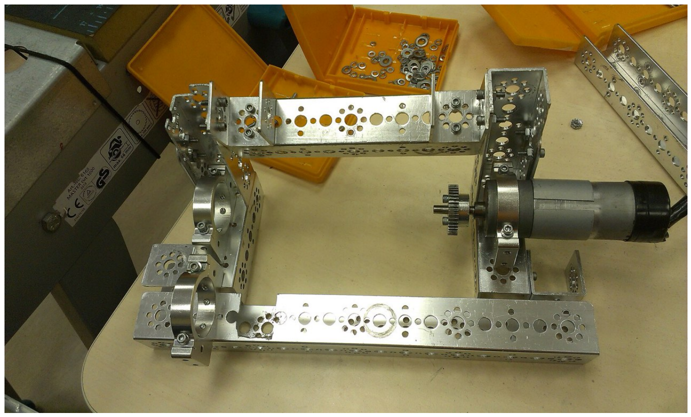


Figure 67: Winch

3.3.31 14.03.2016

Time frame: 17:30-21:30

The parts of gripper were assembled. The gripper was prepared for installation onto the wheel base.

3.3.32 16.03.2016

Time frame: 17:30-21:30

The assembling of the winch continued. Today there were installed coils and motors (figure 68). It was also created one mount for the lifting mechanism.

After that, the 41,5 cm beams were connected to the module of the winch.

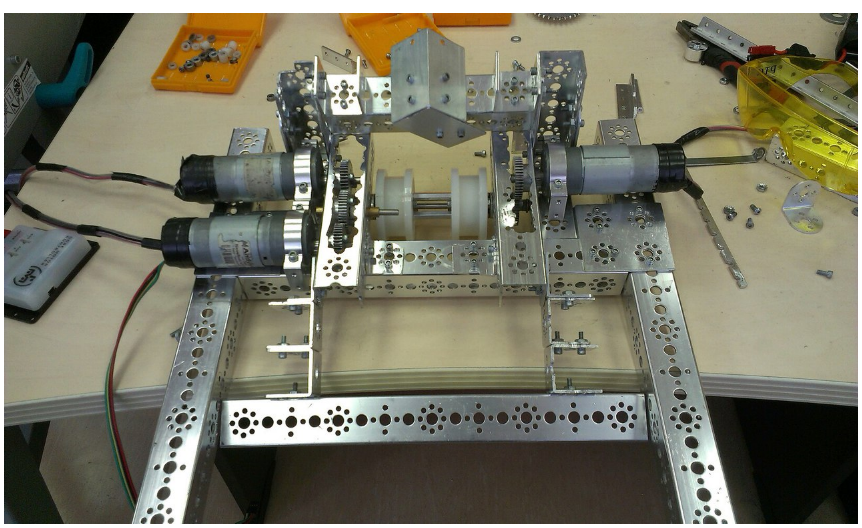


Figure 68: Motors were installed onto the winch

3.3.33 19.03.2016

Time frame: 13:00-22:00

The wheel base was assembled (figure 69). The chains were not held yet.

The gripper was connected to the 41,5 cm beams. The chains were not held yet.

It was created the second mount for the lifting mechanism (figure 70) and the mechanism was connected to the robot (figure 71, 72).

It was created the mount for the mechanism for shifting the bucket.

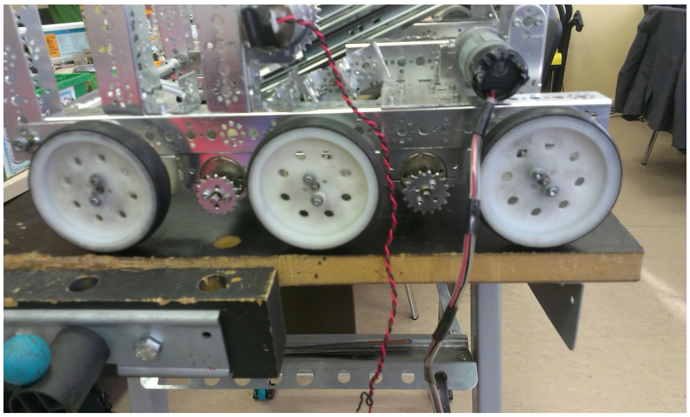


Figure 69: Wheelbase without chains

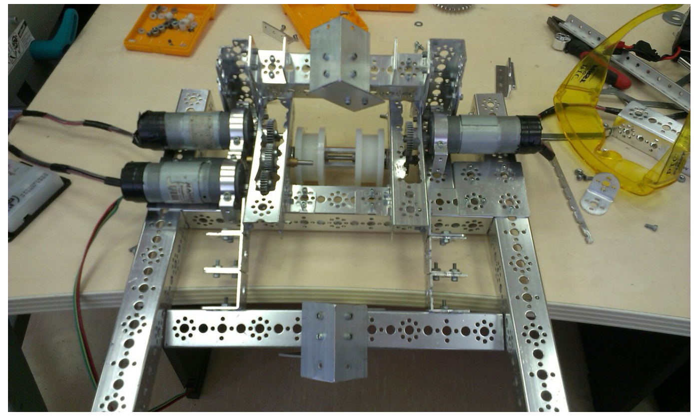


Figure 70: The second mount for the lifting mechanism

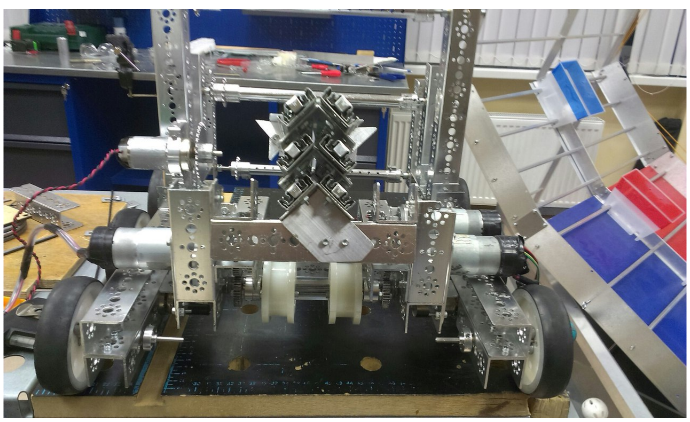


Figure 71: New robot (back)

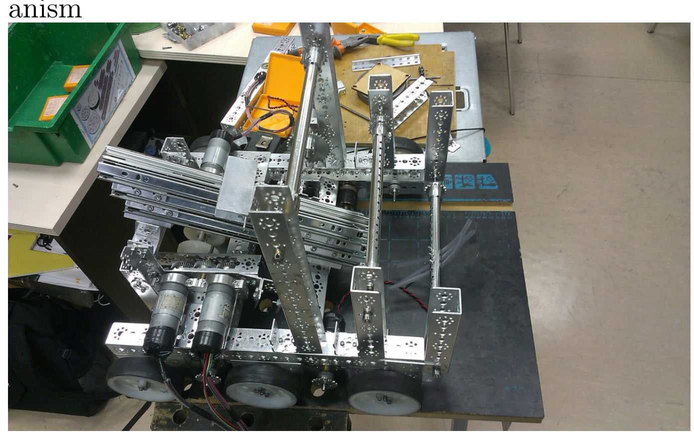


Figure 72: New robot (side)

3.3.34 22.03.2016

Time frame: 15:00-20:00

Today it was decided that because the new robot is not ready we will participate at the competition FTC Dutch Open with the old robot. Due to this decision, our team would stop working on the new robot before the competition finished.

The main aim for the following week before the FTC Dutch Open (1-2 April) is to solve all the problems in old robot and prepare it for the competition.

3.4 Specifications for modules

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

3.4.1 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.

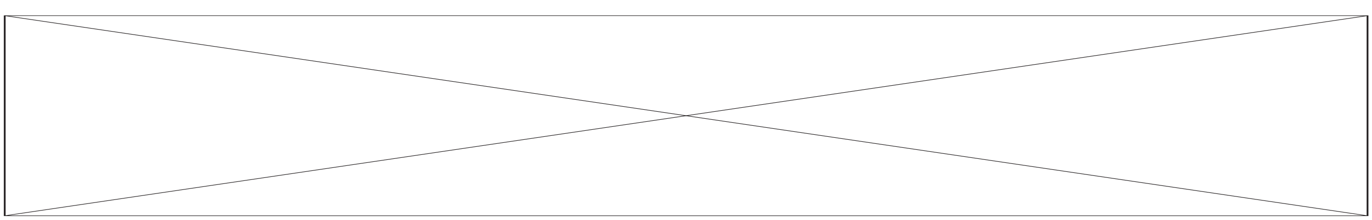
   On the October $12^t h$ it was assembled the first prototype of the chassis. It had 7 cm wheels and a gear ratio for speed (2:1). It's test drive showed that 7 cm wheels can't be applied.

   On the October $19^t h$ 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 $23^t h$, 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.



3.4.2 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 73).

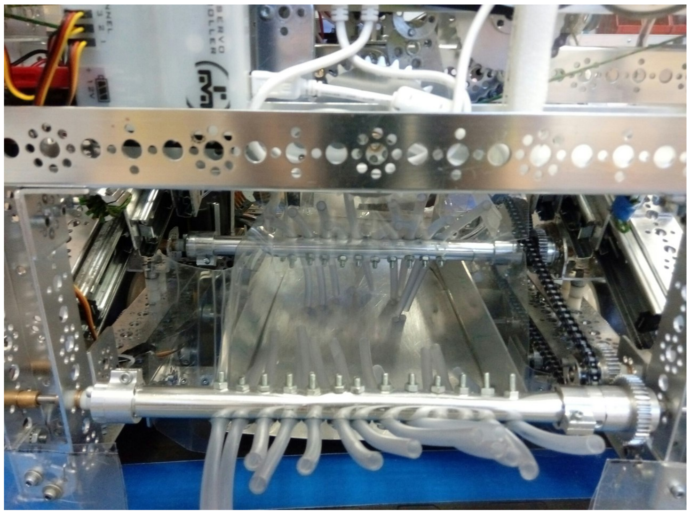


Figure 73: Gripper falities

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 74).

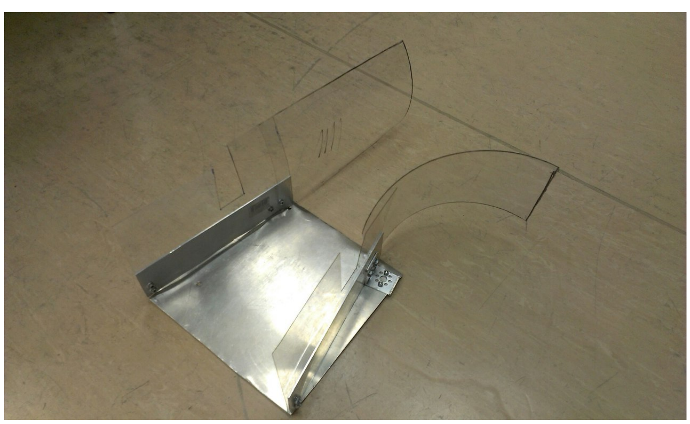


Figure 74: Blades on a axis

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 75).

Figure 75: 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 76).

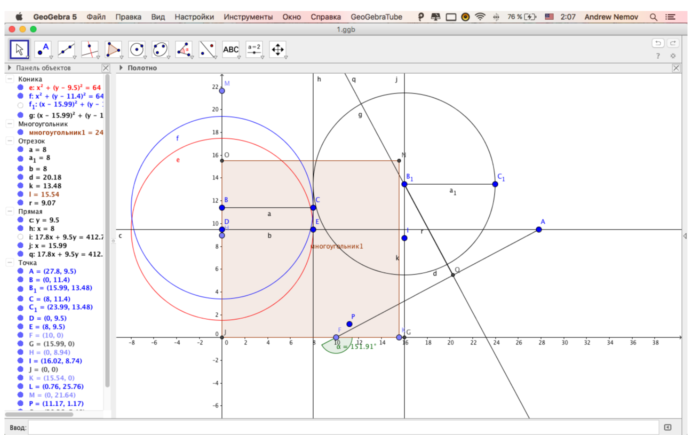
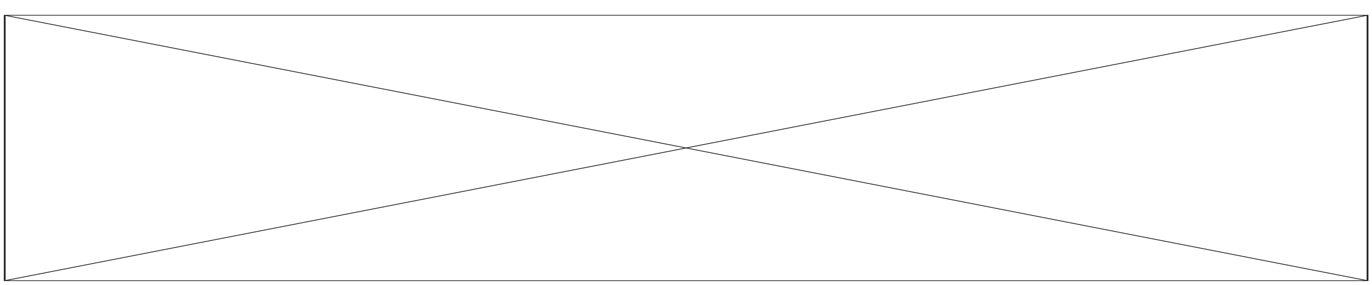


Figure 76: GeoGeabra workspace with open scheme f gripper

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



3.4.3 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 77, 78).

   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 79).
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 80).

Figure 77: Model of construction profiles connected by braces

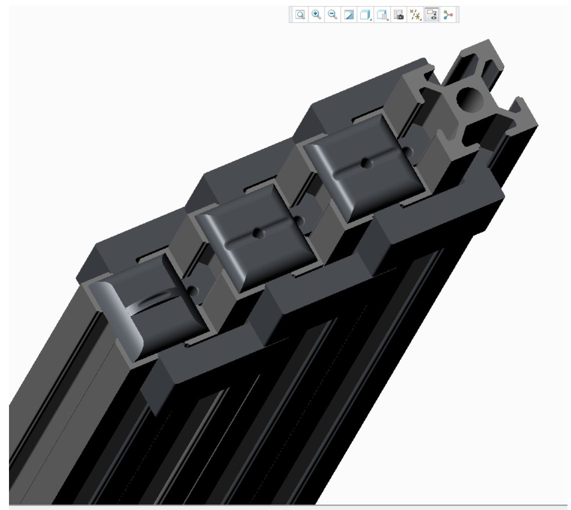


Figure 78: Braces

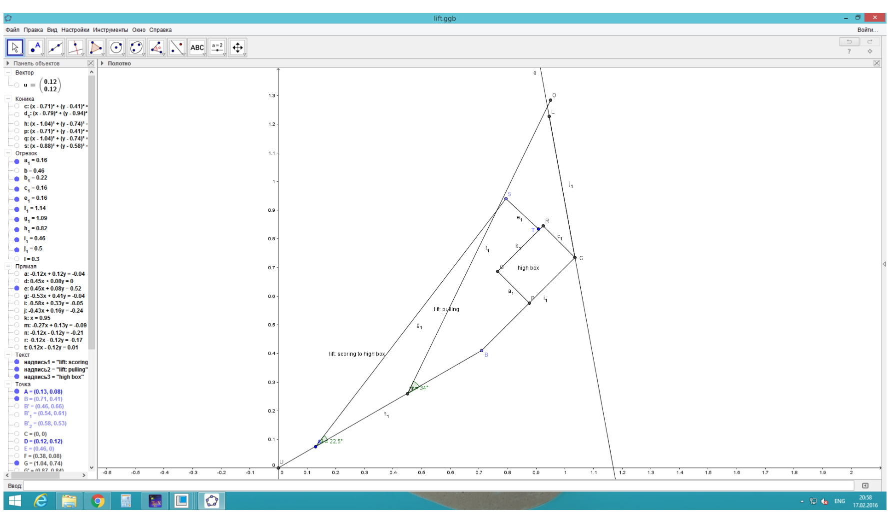


Figure 79: Drawing in GeoGebra

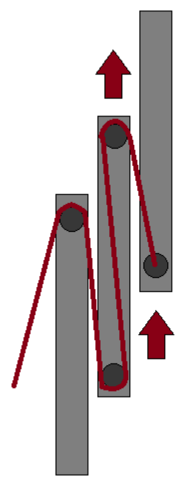


Figure 80: The principle of holding cables

3. At the 25$^{\text{th}}$ 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 81).

   Next, there was assembled a winch (figure 82). 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).

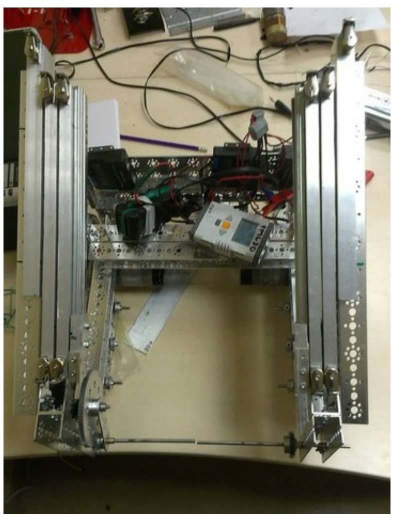


Figure 81: Elevator

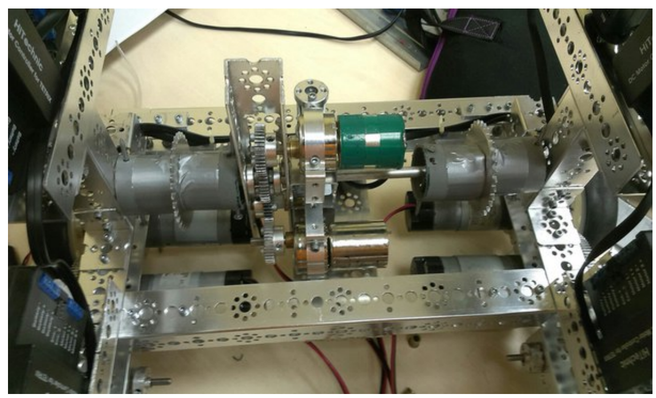


Figure 82: Winch

5. At the 8^{th} December there were discussed the results of the competition that took place on $4\text{-}5^{\text{th}}$ 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 83,

84).

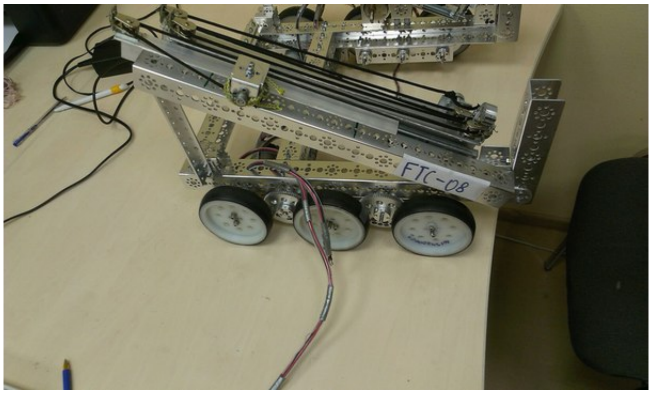


Figure 83: Elevator

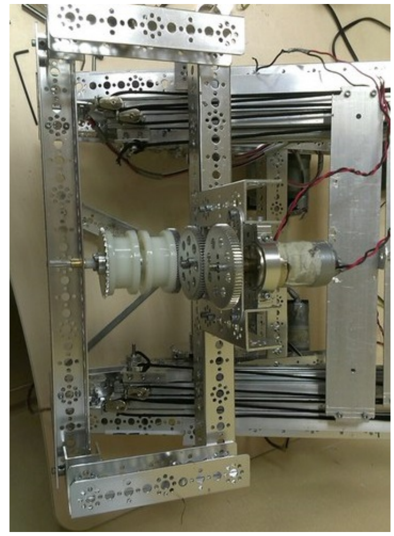


Figure 84: Winch

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 85).

Figure 85: 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 86). It increased torque 2 times (3 AndyMarks give torque of $3 \cdot 25 = 75 kg \cdot cm$, while 2 standard - only $2 \cdot 20 = 40 kg \cdot cm$).

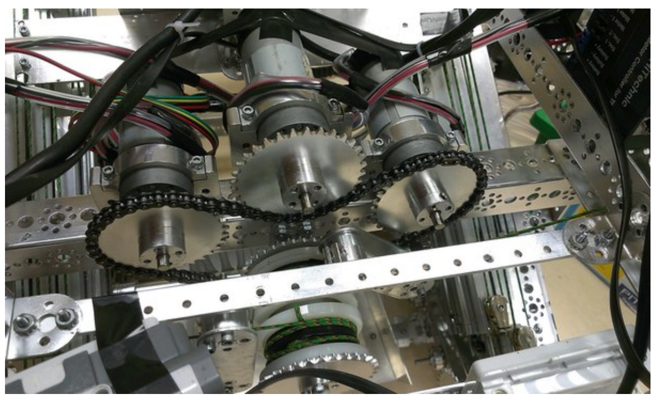


Figure 86: Winch with 3 motors

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 87).

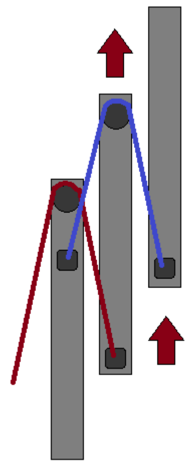


Figure 87: New way of holding cables

11. The system of blocks and cables at the lifting mechanism was changed (figure 88). The coils were also recreated (figure 89).

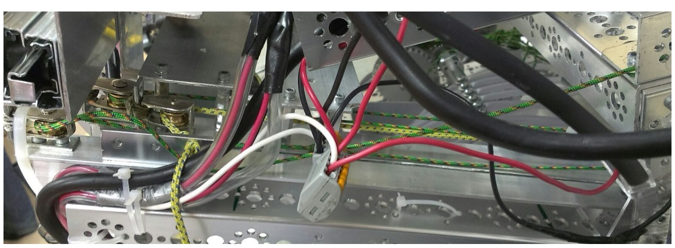


Figure 88: Elevator with new cables

Figure 89: 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 90, 91).

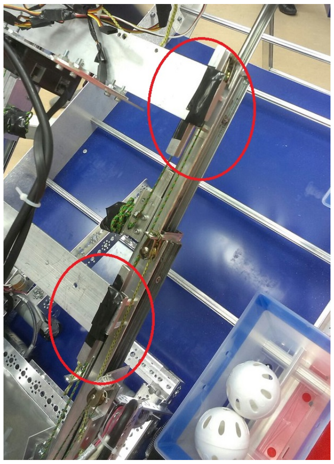


Figure 90: Flexible mounts (prototype)

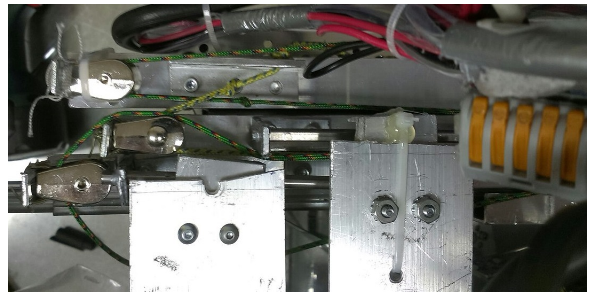
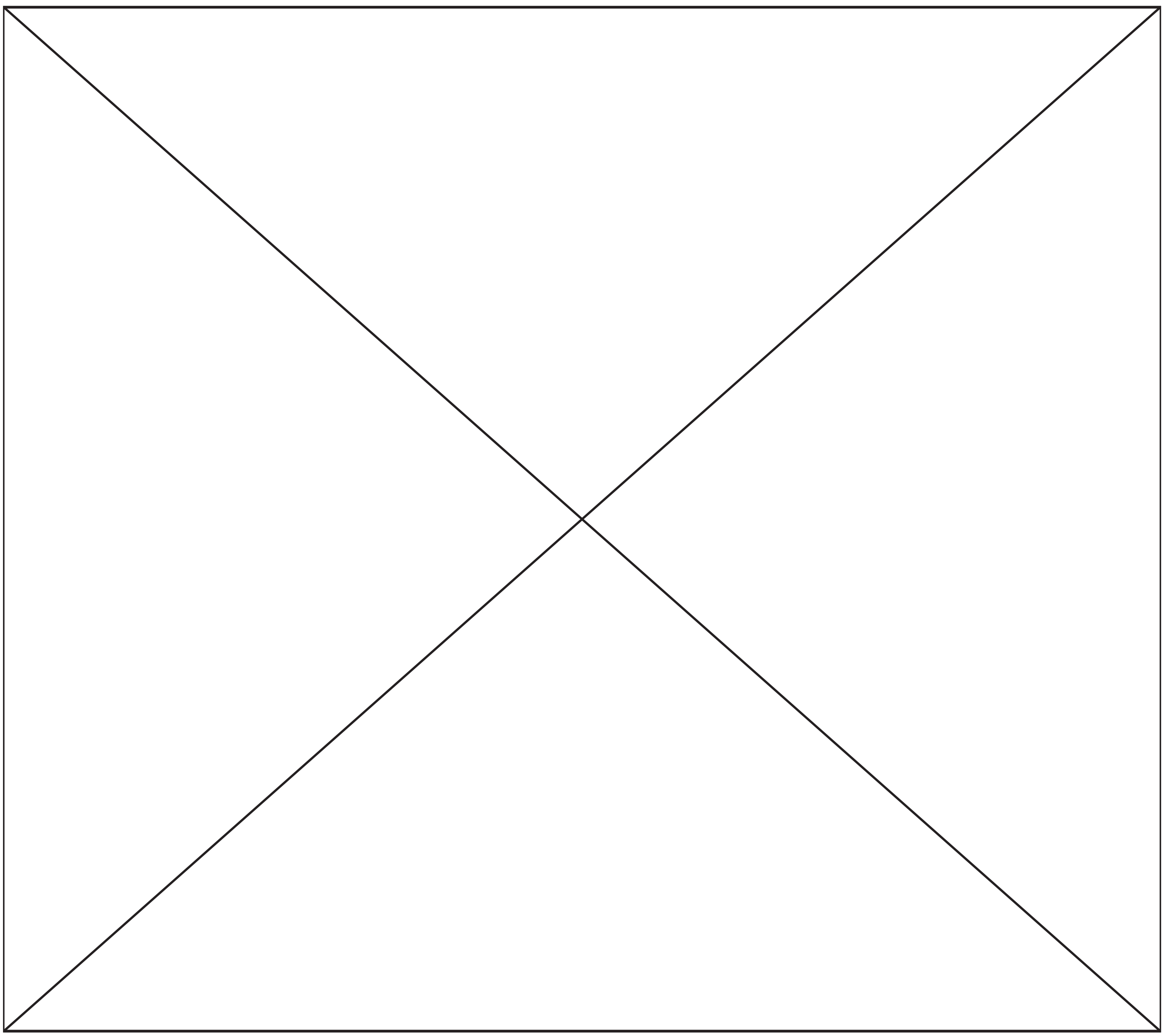


Figure 91: Flexible mounts



3.4.4 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:

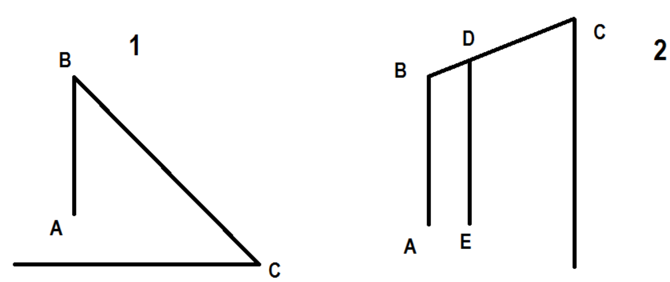


Figure 92: Side view of beams onto which the bucket is mounted

5. The bucket, mounted on the beams, which in 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:

6. 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

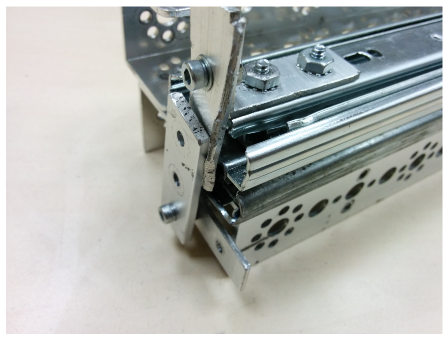


Figure 93: Structure of limiters

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

7. 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.

8. 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.

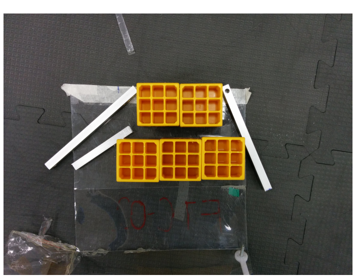


Figure 94: Structure of guides

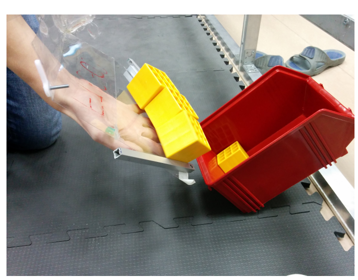


Figure 95: Process of guides testing

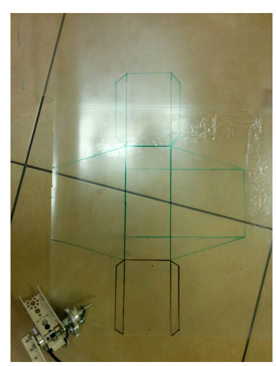


Figure 96: Marking of bucket

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.

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

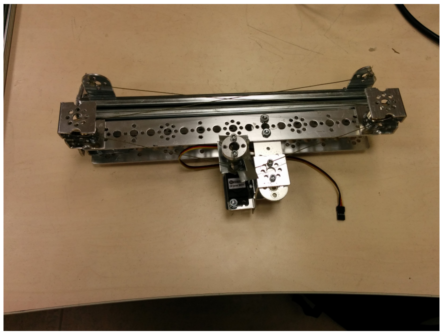


Figure 97: Construction of line and pulling it servo

Figure 98: Final construction of the slats

10. 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.

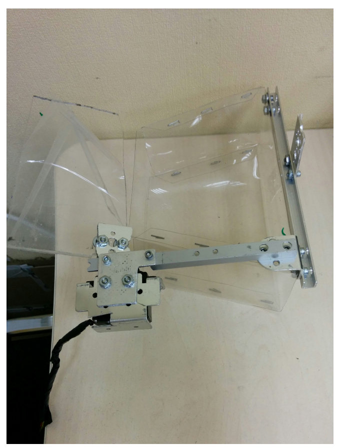


Figure 99: Final construction of the bucket with closing mechanism

11. 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.

12. 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.

13. 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.

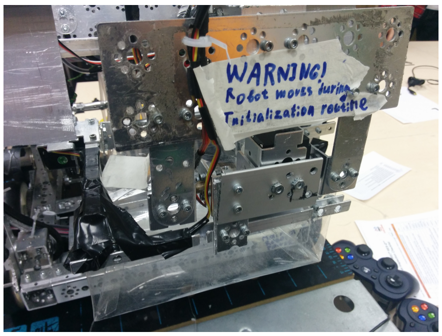


Figure 100: Construction of bucket

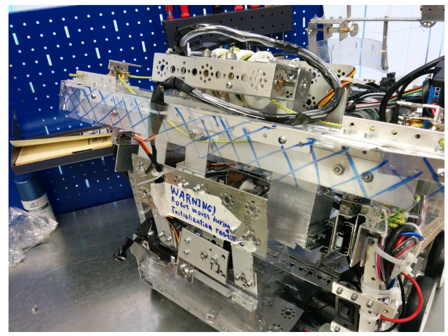


Figure 101: The bucket mounted on robot

14. 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.

15. After that the new shape was devised.

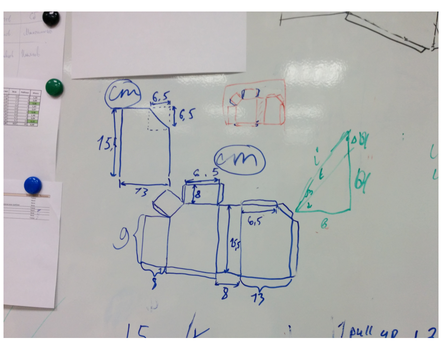


Figure 102: Shape and scan of the bucket

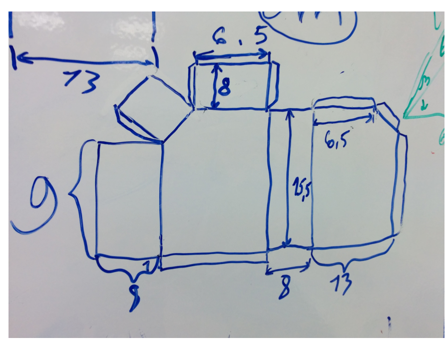


Figure 103: Closer view of the scan

This shape was chosen because:

- It was easier to fill by the gripper
- 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.

16. 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.

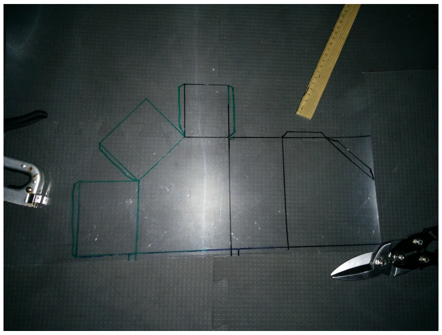


Figure 104: Marking of bucket on the plastic sheet

Figure 105: Fully assembled bucket with cubes inside

17. 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.

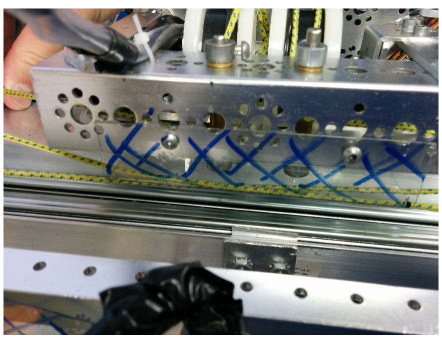


Figure 106: Protection of rope

Figure 107: Test of new bucket

18. Then competitions FTC Russia Open in Sochi started and no more upgrades were done but the cutting off part of cover of the bucket. It was made in order to make cover not be inside the scoring goal while dropping debris into it. This made process of scoring much more fast, safety and easy for operators.

19. After the competitions was made a decision on the creating new structure of robot and fully rebuilding it with making models of modules in CREO first. In new construction bucket wouldn't turn and had to have 2 holes: for debris entering on the top and for their falling on the bottom. It had to be spacious enough to let balls go throw it freely. New shifting mechanism had to be the same with some new features: two directions slat instead of two slats, lighter and easier mechanism of coiling the rope.

20. In the process of designing new shifting mechanism was decided to use wheel and rope from jalousie. It makes all mechanism much smaller and lighter. Servo had to be the same but with the gear to make shifting faster. it was decided to use lego gears because of their small weight and easy mounting.

21. The model of shifting mechanism with 1 slat was made in CREO.

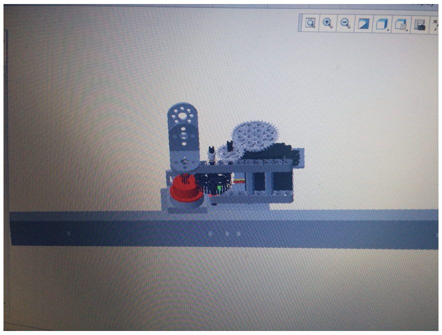


Figure 108: Shifting mechanism in CREO

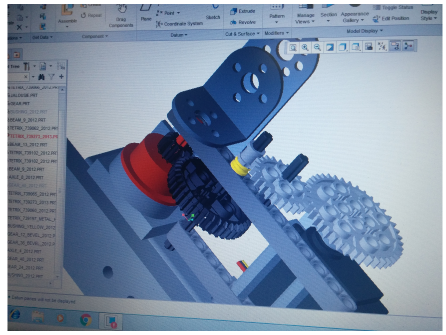


Figure 109: Shifting mechanism in CREO

22. It was decided to refuse from Lego gears because they take up much space and not reliable. It was created idea to make a wheel which move rope by ourselves. It was made model of this element and it was cut in a laser cut machine. This wheel mount on servo without gears. In addition it have a big diameter for increasing speed.

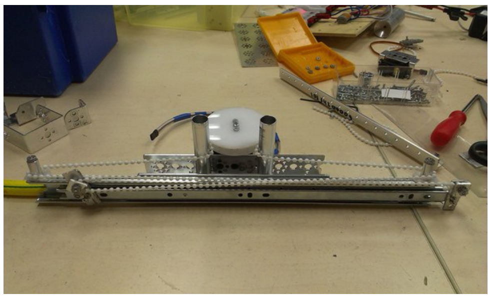


Figure 110: New shifting mechanism

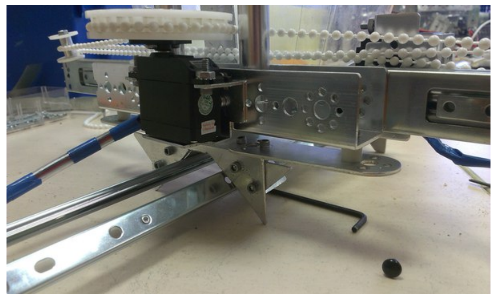


Figure 111: The gear for moving rope from jalousie

23. In process of designing new bucket it was found that old one (which was created in the beginning of season - look at the figure 99) have necessary dimensions. So it was decided to cut the back wall of it and use in new robot. In addition it was strengthened by Matrix element in order to make it rigidly.

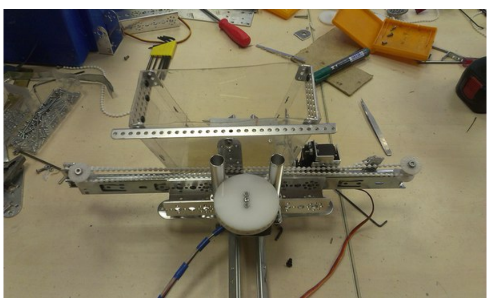


Figure 112: Bucket on the shifting mechanism

24. The cover for new bucket mounts on it with help of door hinge. The servo which open cover is mounted to side and turn rod mechanism that connected with cover. This construction is more compact than one that is on the old robot.

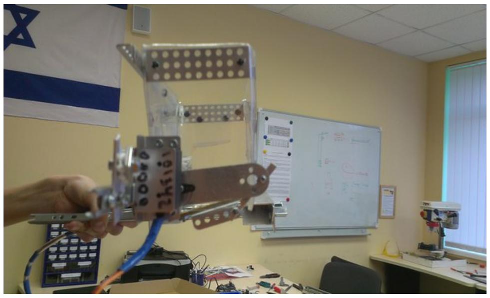


Figure 113: Cover (closed)

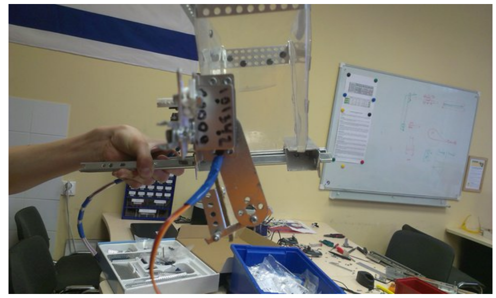
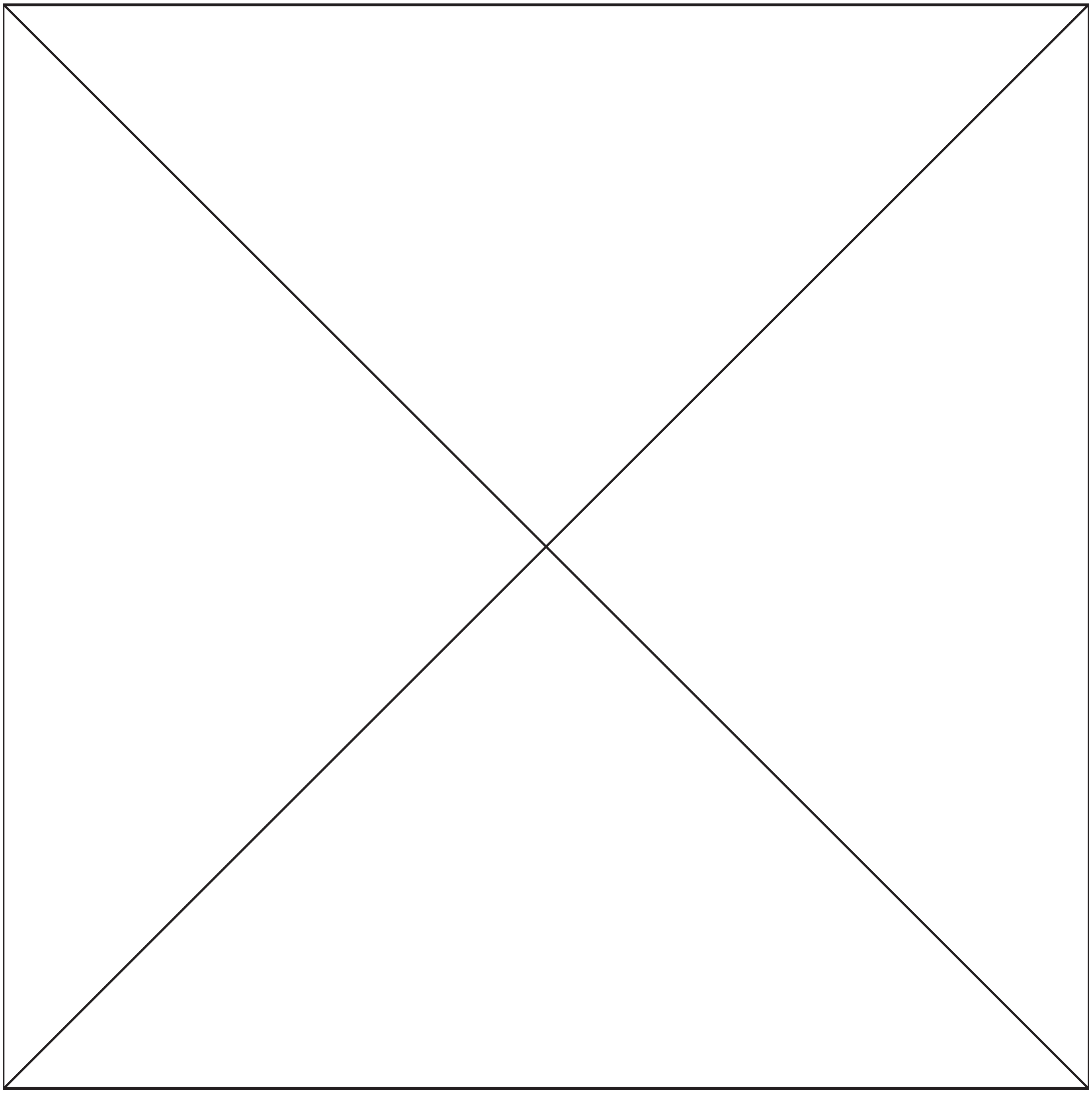


Figure 114: Cover (opened)



3.4.5 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.
6. It was decided to make next construction. There is a TETRIX aluminium tube that is turned by servo in vertical plane (so that when servo turn tube fall on the top of button). At the end of tube there is U-shaped profile. Through the tube and U shaped profile it is held the axis which hang climbers. The U-shaped profile dosen't allow climbers to fall during the robot's moving. Also there is a string fixed on the end of axis. The string is reeled by the second servo so the axis moves and climbers fall to the shelter.

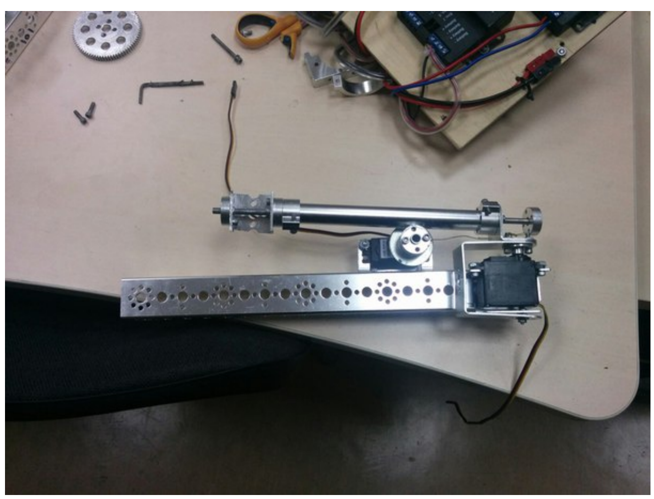


Figure 115: Mechanism for scoring climbers

7. In the new construction it was found a problem that when climbers scored mechanism can't to lower to the start position because the axis where hang climbers prevent to it's turning. So it was decided to make the mechanism that consists of the axis where hung climbers and one servo that turn it. When robot is near the beacon the servo turn. After that the robot ride back and clibers fall from axis to the shelter. This mechanism is more simple and it have an advantage that if we fail scoring climbers in

autonomous period we don't lose climbers and can score them in tele op.

3.4.6 Mechanism for pushing button

Plan of creating module:

1. Creating 3D model in Creo parametric.
2. Calculaition distances and angels.
3. Programming and debugging the mechanism

The module represents the servo, which turns the beam. The beam can push right and left button. Also the module includes Hi-Technic colour sensor, which can detect the colour of the button.

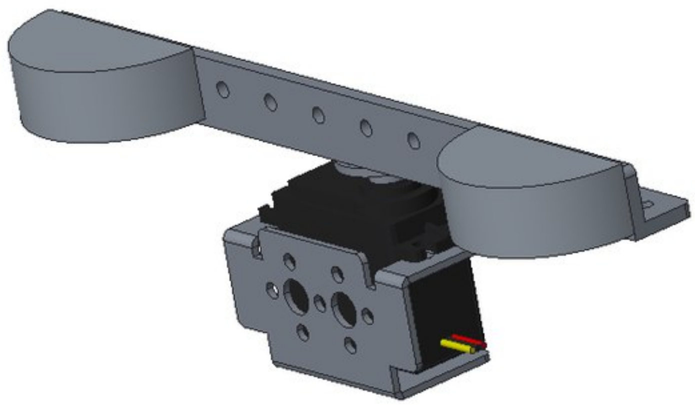


Figure 116: Creo model

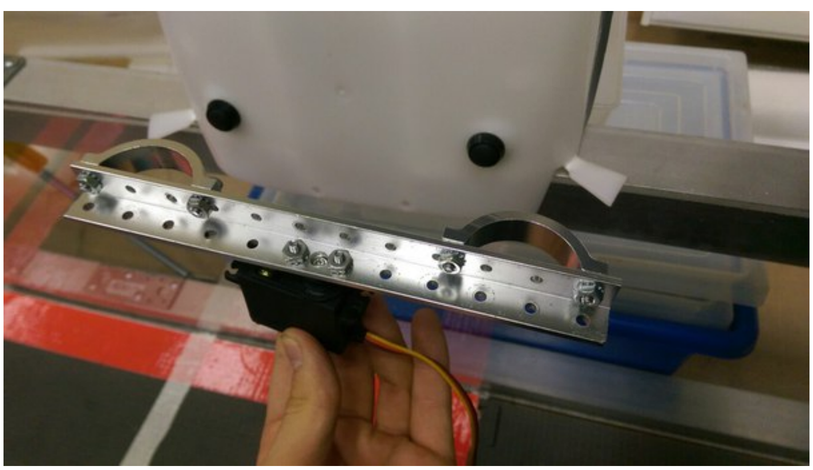


Figure 117: Real model

Algorithm

1. At first, the robot stops near the button. Then the sensor detects the colour of right button. If the colour is similar to our colour of alliance then the servo turns and the beam pushes the right button. In other case, servo turns in another direction and pushes the left button.

Programming To detect the colour of the button we use the algorithm of colour focus. Every colour has 3 parameters: red, green and blue. These three parameters can be represented as the basis of a 3-axis coordinate system. We need two vectors this coordinate system: one from calibration procedure and one measured during the game. Than we calculate the angle between them. If the angle value is below special limit, we can conclude that the measured colour is similar to calibrated one.

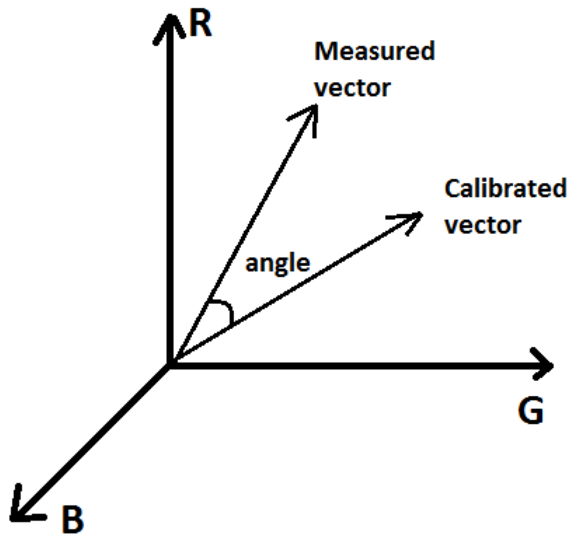
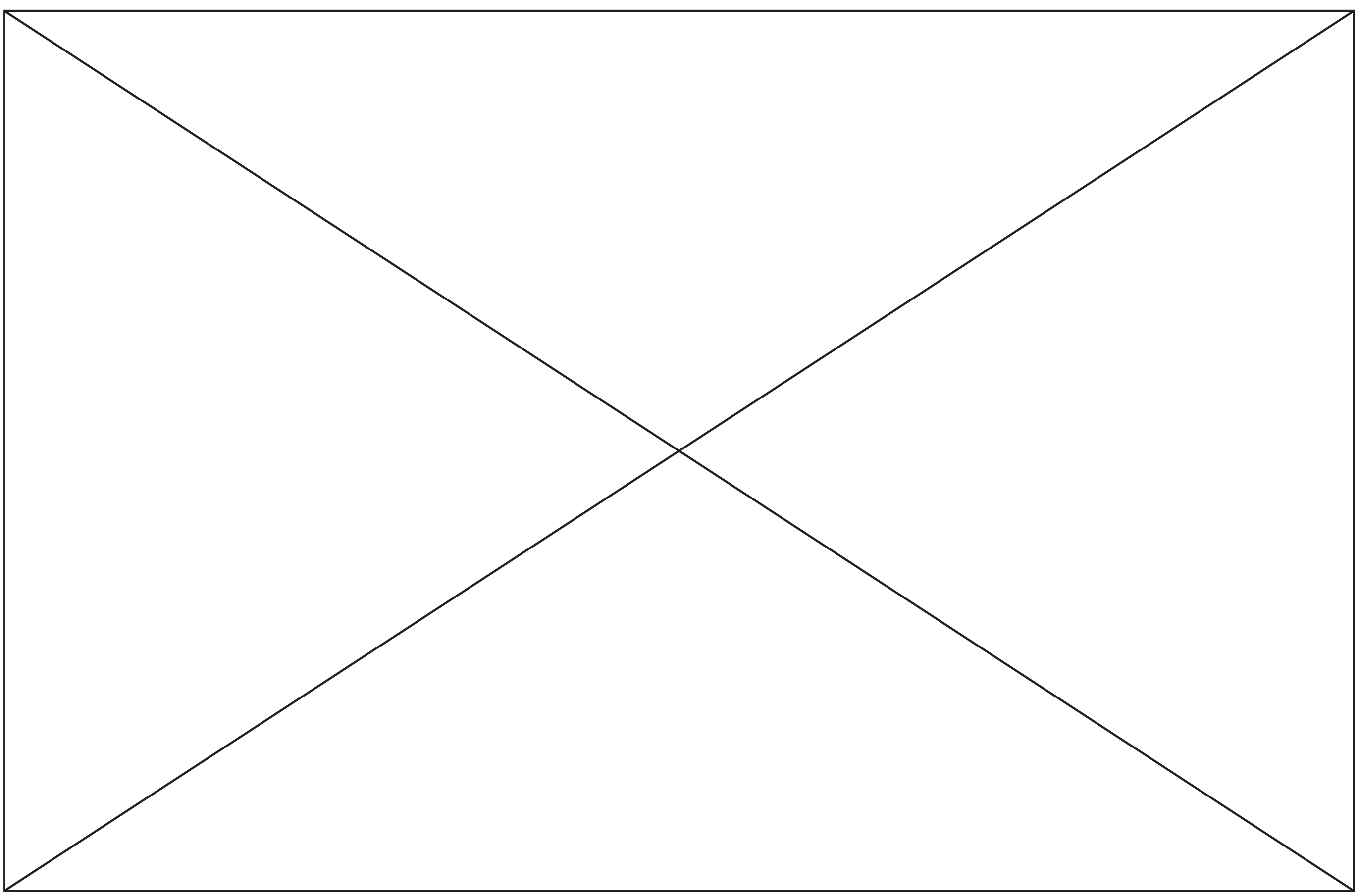


Figure 118: Colour focus



3.5 Specifications for programmes

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

3.5.1 Driver control program

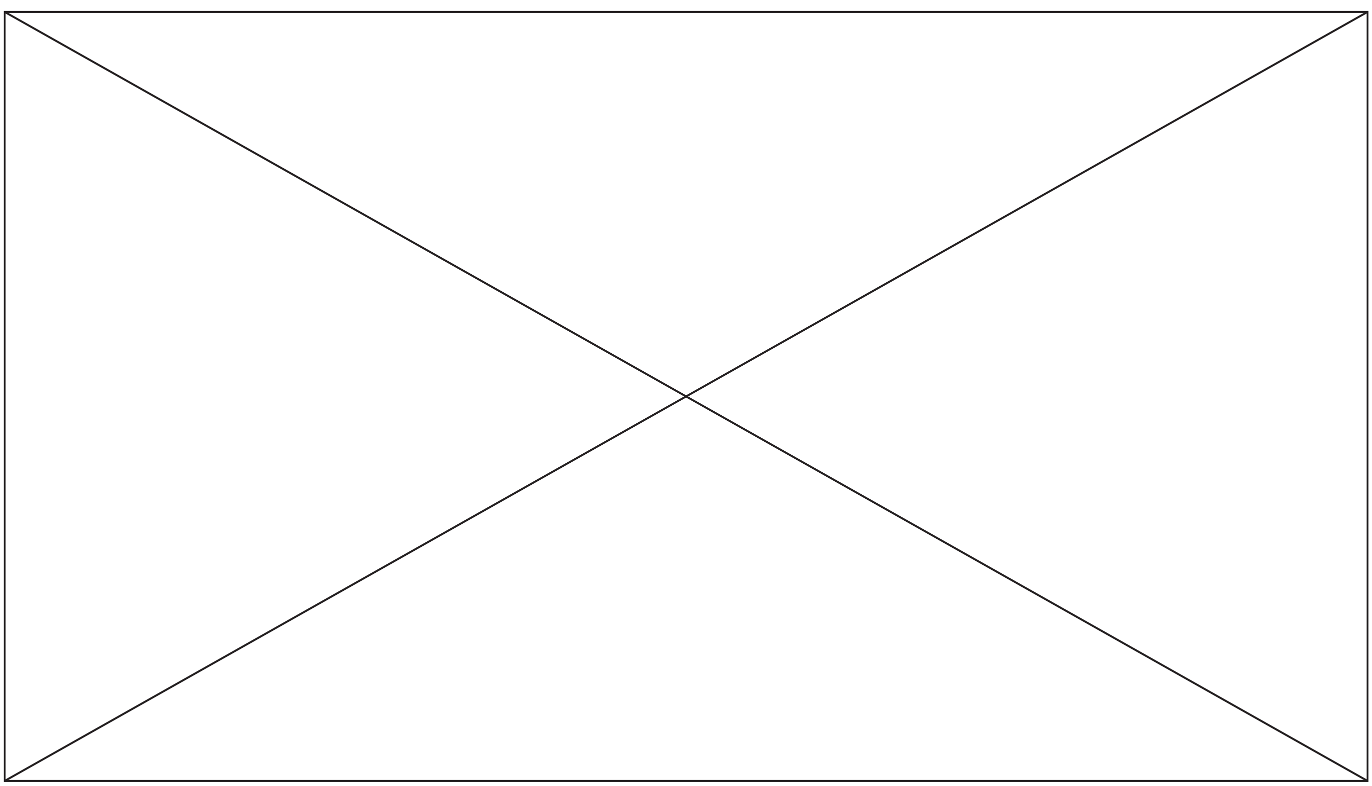
1. As soon as the first prototype of the wheel base was assembled on November $12^{\mathbf{th}}$, it was elaborated a program for test-drive. It included straight movement and turning around in 4 grades of speed. With this program, there were tested the abilities of the present wheel base.

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.

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 .

4. After the program for movement was finished, the controlling of the hooks and the debris collecting mechanism was placed to free buttons on driver-operator's joystick. Controlling of other modules was given to the second operator.

5. Before we replaced the NXT brick with the mobile phone the program was rewritten in Android Studio. So, when the new controlling system was installed (2 weeks before the competition in Sochi), we had the program adopted to it.



3.5.2 Autonomus program

1. Sensors used in the program:
   1.1. HiTechnic Gyro sensor for turns and movement stabilization.
   1.2. Andy's Mark encoder for range measurement.
   1.3. HiTechnic RGB sensor for beacon color detection.
2. Algorithm of the autonomous period:
   2.1. Parking in the beacon zone or parking zone.
   2.2. Drop autonomous climbers into beacon bucket.
   2.3. Push the button on the beacon.

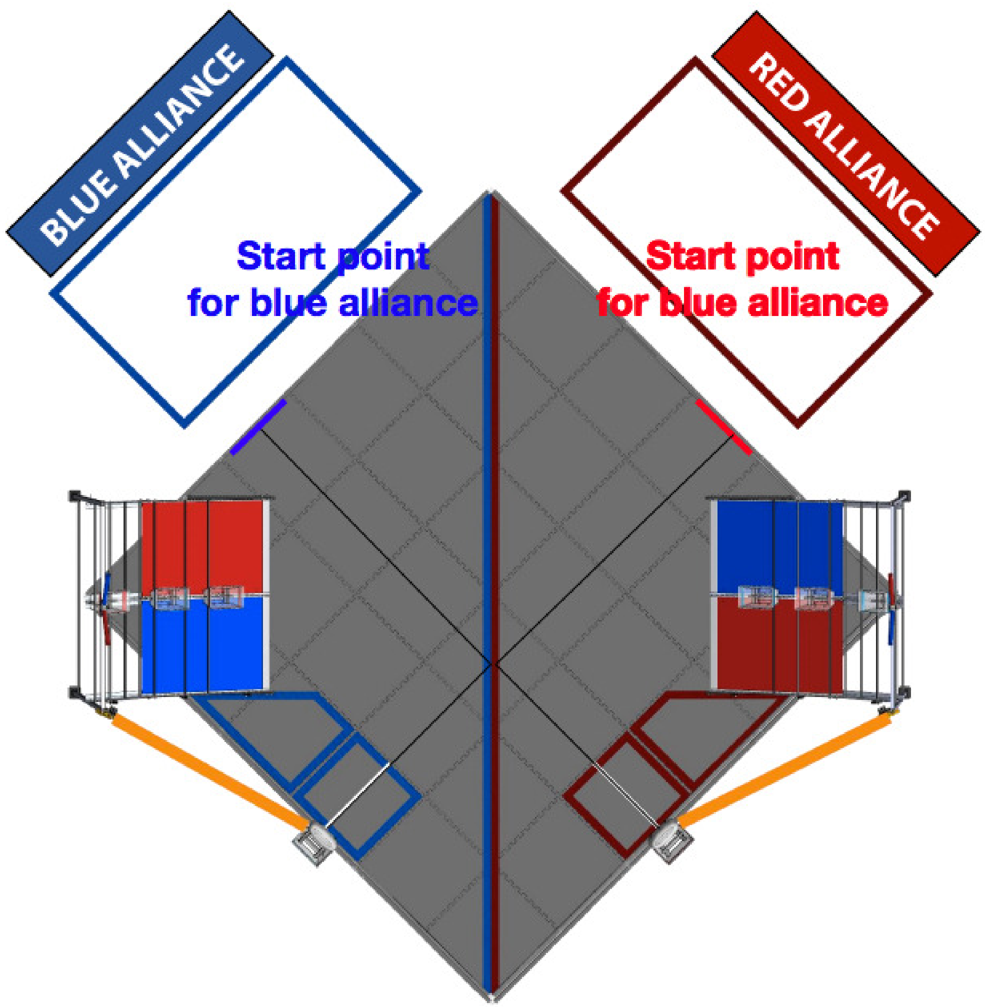


Figure 119: Autonomous movement trajectory

3.6 Key summary

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

Table 6: Tasks that the robot can perform according to its construction.

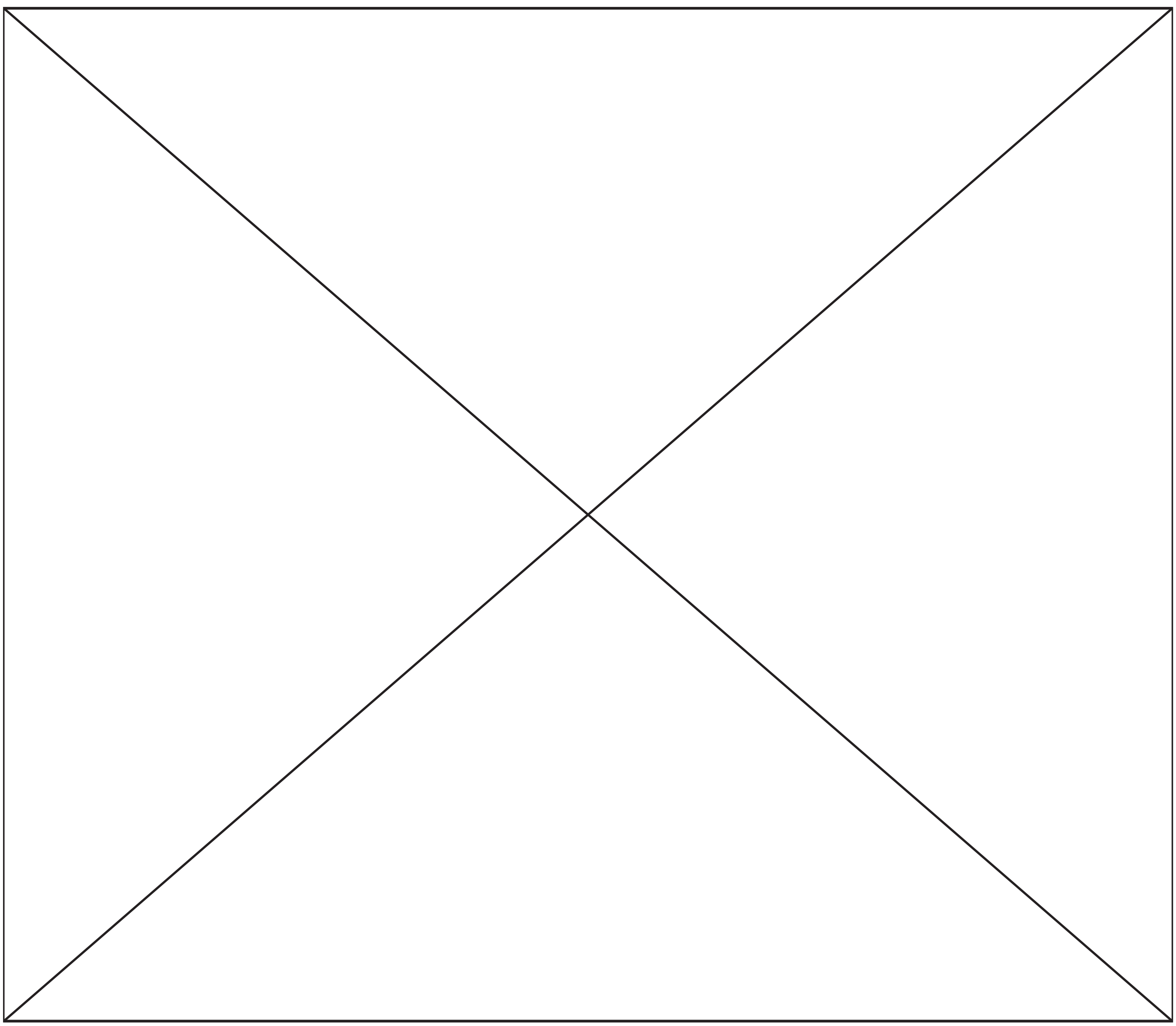
Tasks	Ability
Score climbers into shelter in autonomous period.	Yes.
Push the button on rescue beacon in autonomous period.	Yes.
Stay in beacon repair zone at the conclusion of autonomous period.	Yes.
Climb on mountain in autonomous period.	No.
Block the opponent's autonomous movement.	No. We consider 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.	No.

Table 7: Consequense of performing tasks in the match

Task	The time needed to perform (sec)	Points
Autonomous period		
Score climbers into shelter.	15	40
Push the button on rescue beacon.	10	20
Stay in beacon repair zone.	5	5
Autonomous total	30	*65*
Tele-op period		
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
Score low and second zip-line climbers (if we work on the mountain with the zip-line)	30	40
Stay in low zone at the conclusion of tele-op period.	—	10
Tele-op total	120	*150 (130)*
Game total	150	***215 (195)***

Table 8: Actions in extraordinary situations

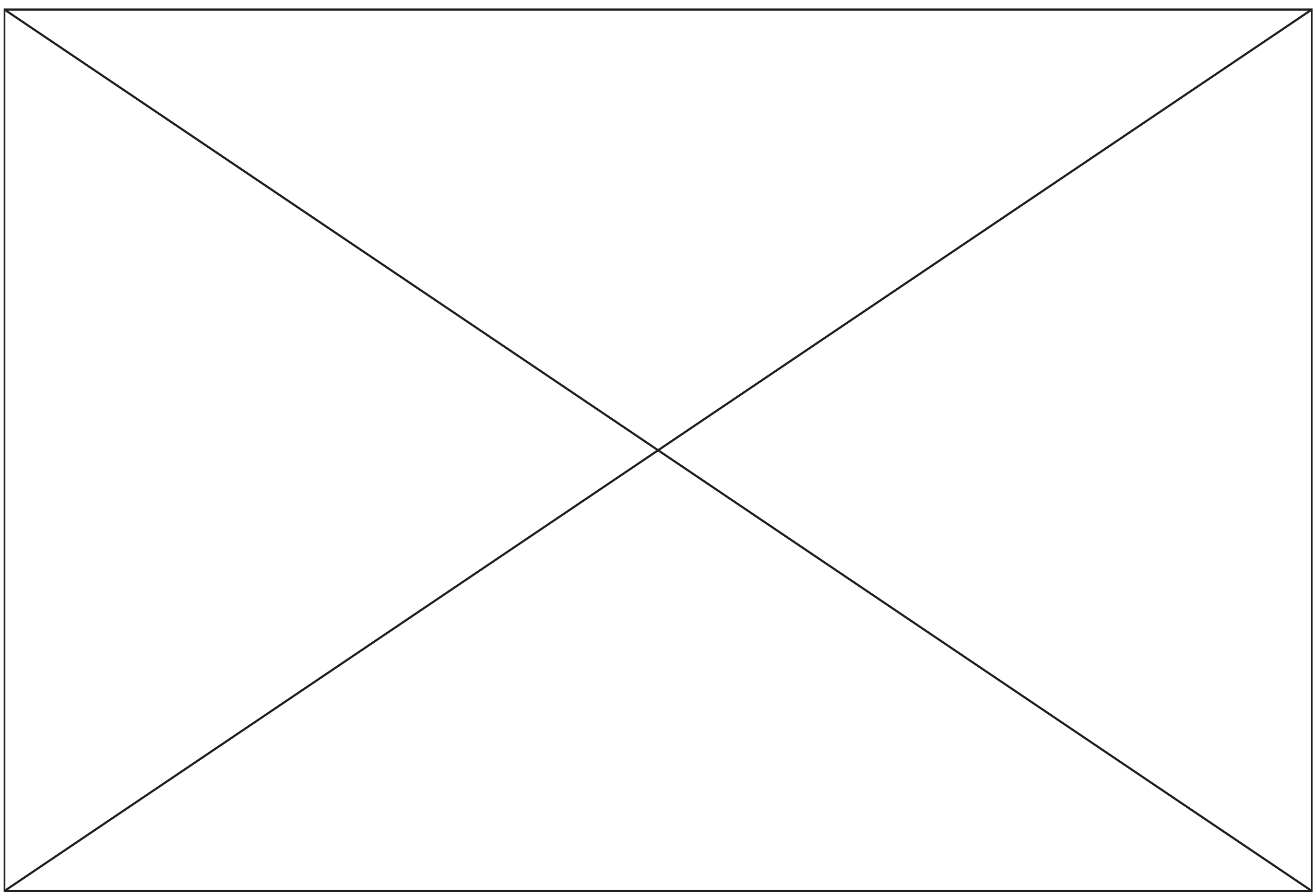
Situation	Action
The autonomus program didn't run.	Score climbers into shelter in tele-op period.
Scoring debris into mountain goals is impossible due to break.	Score debris into floor goal.
Our ally lost ability of scoring debris into mountain goals in case he was to score debris into the top goal.	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 (NL0067)

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 and about secondary modules.

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".