

*Center for robotics*  
*Physics-Mathematics Lyceum 30*



Engineering book of  
Competition First FTC

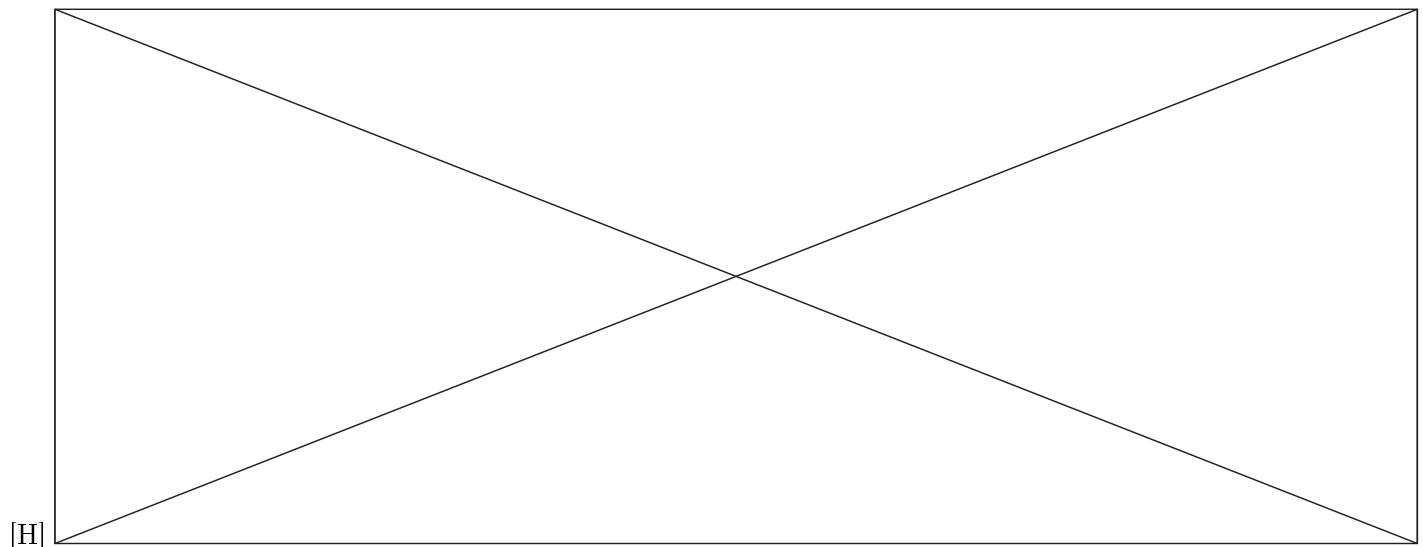
# Team PML30 -X



Saint-Petersburg, Russia  
2015-2016

# 1 Team PML 30 X

Team PML 30 X was assembled in September 2014 in the Russian city of St. Petersburg. Tasks and roles were distributed among the participants, and we established rules of safety. The team placed spreading principles of gracious professionalism to others on the first place of importance. All decisions were made collectively inside the team, with discussions to find the most optimal solutions. During the last year we took part in many events. We pursued and distributed the principles of gracious professionalism, and encouraged people to participate in the competition. By 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. Last season our team took part in the three qualifying competitions, in the regional finals, in European championship and in the World championship. In all of them we made new contacts, shared our experiences and provided mutual assistance to other teams. In the first qualifying rounds in Sochi we met Stuy Fission 310 from the USA, and we maintain contact with them to this day. On the regional finals, we met with a team from Romania, Auto Vortex, and we keep in touch with them through Facebook. 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 use the version control system GitHub, which allows the entire team to work simultaneously on a single projects without losing files, and provides an easy way to resolve problems. And for writing technical books we been used professional typesetting system LaTeX.



### 1.0.1 Coaches

:

Luzin Dmitry

*Head of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Main coach of FTC team.*

*Information: 26 years old, in robotics 6 years, in FTC 4 years.*



Luzina Ekaterina

*Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.*

*Information: 26 years old, in robotics 6 years, in FTC 4 years.*



Fedotov Anton

*Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.*

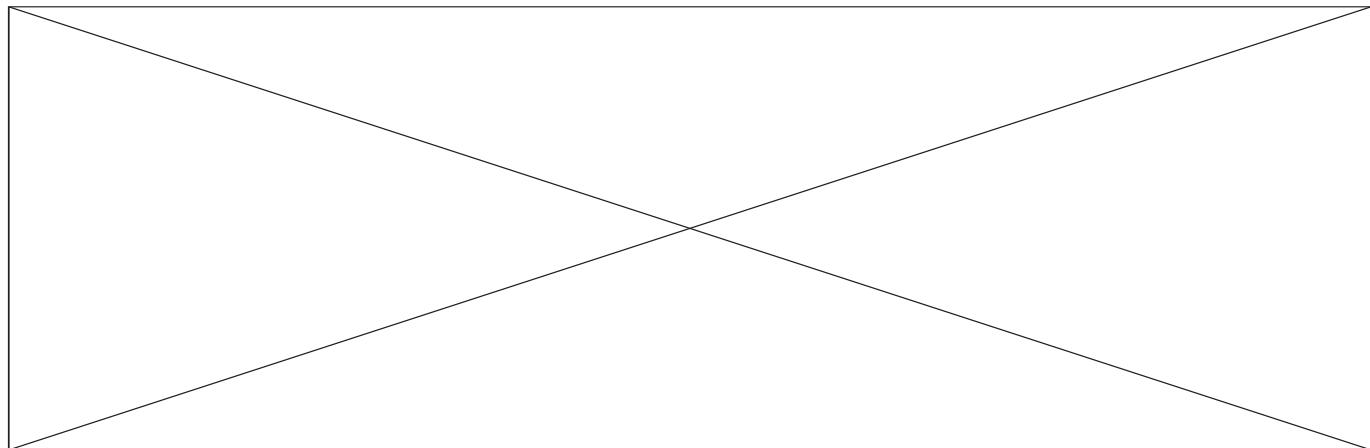
*Information: 23 years old, in robotics 5 years, in FTC 4 years.*



Krylov Georgii

*Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.*

*Information: 18 years old, in robotics 4 years, in FTC 4 years.*



### 1.0.2 Team members



Maksimychev Evgeny

*Role in team: captain, operator-2, responsible for the technic of safety, writing of engineering notebook, developer of lift and bucket for scoring elements.*

*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 close to real engineering problems."*

Timur Babadzhanov

*Role in team: operator-1, developer mechanism for scoring autonomous climbers*

*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."*



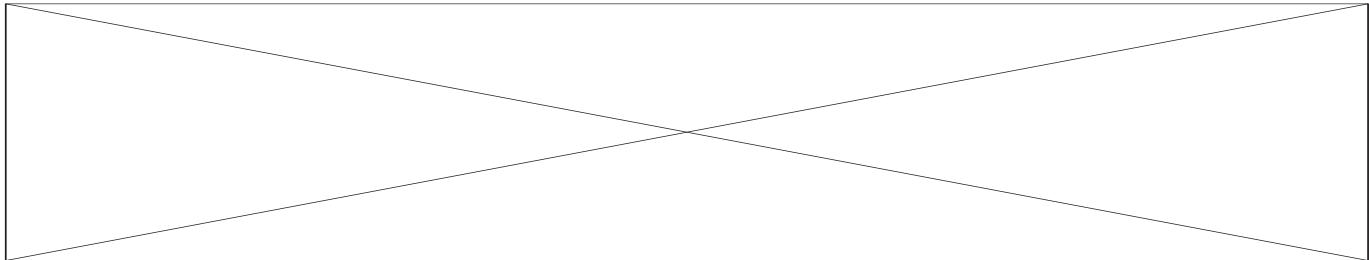


Victoria Loseva

*Role in team: developer of wheel base, programmer*

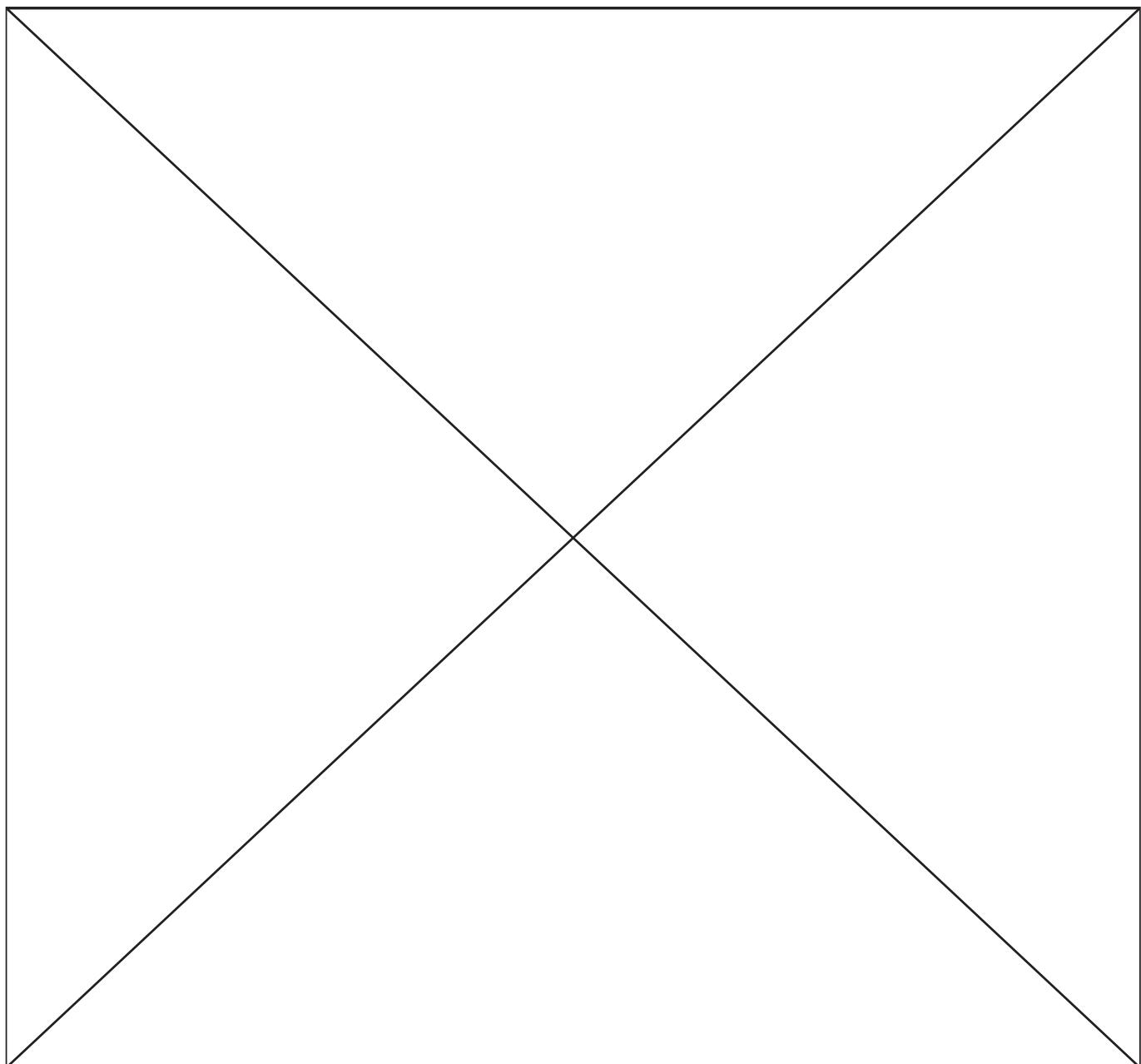
*Information: 17 years old, in robotics 2 years, in FTC 1 years.*

*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 FTC is about!"*



## 2 Annotation

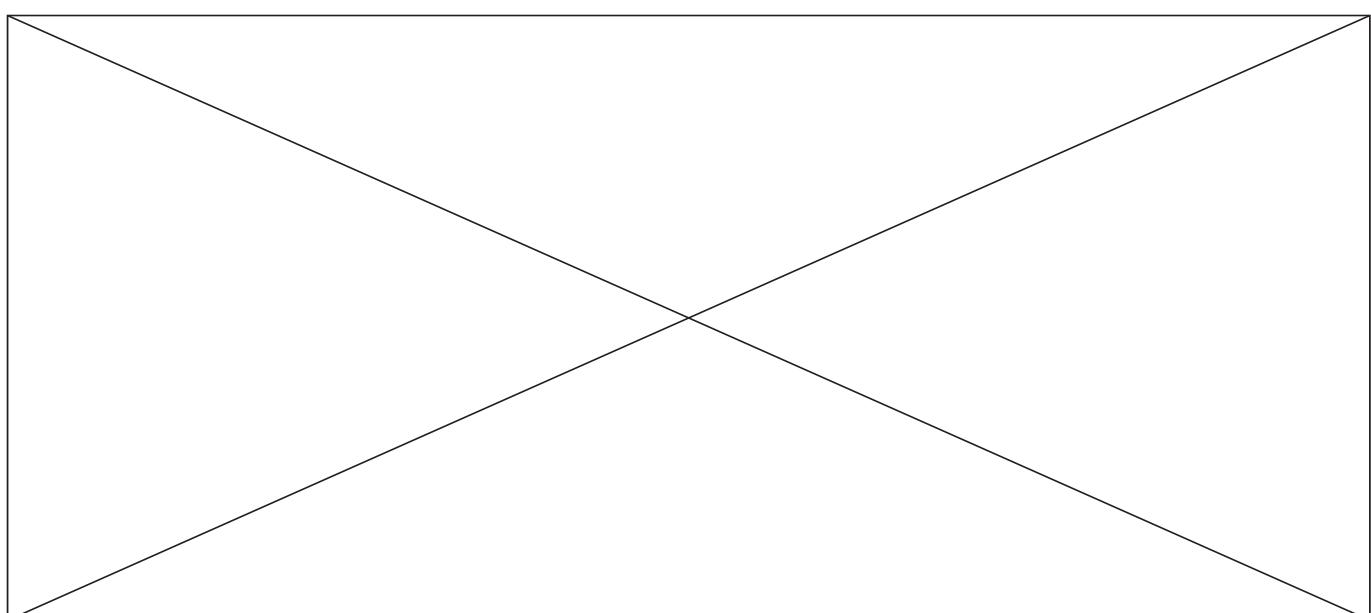
- Our engineering notebook consists of several sections. The main is "Engineering section". It consists of section "Brainstorming". Here is description of actions that robot should can do. Next section is "Strategy"and "Concept". After that there is a section "Elaborating robot". Here is description of designing each module, variants that were looked, how we choosed the best and describtion of all calculations. The next is "Team meetings and events". Here is wrote about process of assembling robot, problems that we found during it and how we solved them. Also in this section described team events such as competitions. Howeever we have "Business plan"where described resources that we had at the beginning of season and that we bought during this year. In addition there is sections "Team"and "Thanks and prospects"
- Firstly you should read "Strategy"and "Concept"then "Elaborating robot"and after that start read "Team meetings and events".



## Содержание

<b>1 Team PML 30 X</b>	<b>2</b>
1.0.1 Coaches . . . . .	3
1.0.2 Team members . . . . .	5
<b>2 Annotation</b>	<b>7</b>
<b>3 Engineering section</b>	<b>10</b>
3.1 Brainstorming (21.09.2015) . . . . .	10
3.2 Strategy discussing (22.09.2015) . . . . .	14
3.3 Concept discussing (24.09.2015 - 03.10.2015) . . . . .	15
3.3.1 24.09.2015 . . . . .	15
3.3.2 26.09.2015 . . . . .	17
3.3.3 28.09.2015 . . . . .	18
3.3.4 01.10.2015 . . . . .	19
3.3.5 03.10.2015 . . . . .	20
3.4 Elaborating robot . . . . .	22
3.4.1 Wheel base . . . . .	22
3.4.2 Lift . . . . .	26
3.4.3 Bucket . . . . .	30
3.4.4 Gripper for debris . . . . .	36
3.4.5 Mechanism for scoring autonomous climbers and pushing button . . . . .	39
3.5 Team meetings and events . . . . .	41
3.5.1 16.11.2015 . . . . .	41
3.5.2 19.11.2015 . . . . .	41
3.5.3 21.11.2015 . . . . .	42
3.5.4 23.11.2015 . . . . .	42
3.5.5 24.11.2015 . . . . .	43
3.5.6 25.11.2015 . . . . .	44
3.5.7 26.11.2015 . . . . .	45
3.5.8 27.11.2015 . . . . .	45
3.5.9 28.11.2015 . . . . .	45
3.5.10 30.11.2015 . . . . .	45
3.5.11 01.12.2015 . . . . .	45
3.5.12 02.12.2015 . . . . .	45
3.5.13 "Robofest-South"(5-6 of December) . . . . .	48
3.5.14 8.12.15 . . . . .	50
3.5.15 9.12.15 . . . . .	50
3.5.16 10.12.15 . . . . .	51
3.5.17 12.12.15 . . . . .	51
3.5.18 14.12.15 . . . . .	51
3.5.19 15.12.15 . . . . .	52
3.5.20 16.12.15 . . . . .	52
3.5.21 "Robofest-Ryazan"(19-20 of December) . . . . .	53
3.5.22 22.12.15 . . . . .	54
3.5.23 23.12.15 . . . . .	54
3.5.24 26.12.15 . . . . .	55
3.5.25 04.01.15 . . . . .	55
3.5.26 05.01.15 . . . . .	55

3.5.27	06.01.15	55
3.5.28	10.01.15	56
3.5.29	12.01.15	57
3.5.30	13.01.15	57
3.5.31	14.01.15	59
3.5.32	16.01.15	59
3.5.33	18.01.15	59
3.5.34	20.01.15	60
3.5.35	21.01.15	60
3.5.36	PML30 Scrimage (23.01.16)	61
3.5.37	25.01.16	63
3.5.38	26.01.16	63
3.5.39	27.01.16	64
3.5.40	28.01.16	65
3.5.41	30.01.16	65
3.5.42	01.02.16	65
3.5.43	03.02.16	65
3.5.44	04.02.16	65
3.5.45	08.02.16	65
3.5.46	9.02.16	65
3.5.47	11.02.16	65
3.5.48	12.02.16	66
3.5.49	13.02.16	66
3.5.50	14.02.16	67
3.5.51	15.02.16	67
3.5.52	16.02.16	67
<b>4 Appendix</b>		<b>68</b>
4.1	Supplementary materials which were used in the robot's construction	68
<b>5 Business plan</b>		<b>69</b>
<b>6 Thanks and prospects</b>		<b>71</b>



### 3 Engineering section

#### 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 explanation:

- 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).

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).

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  $50^\circ$  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 manevrous, than carriages with omni and mechanium wheels. This way, the less robot will turn, the more effective it will compete.

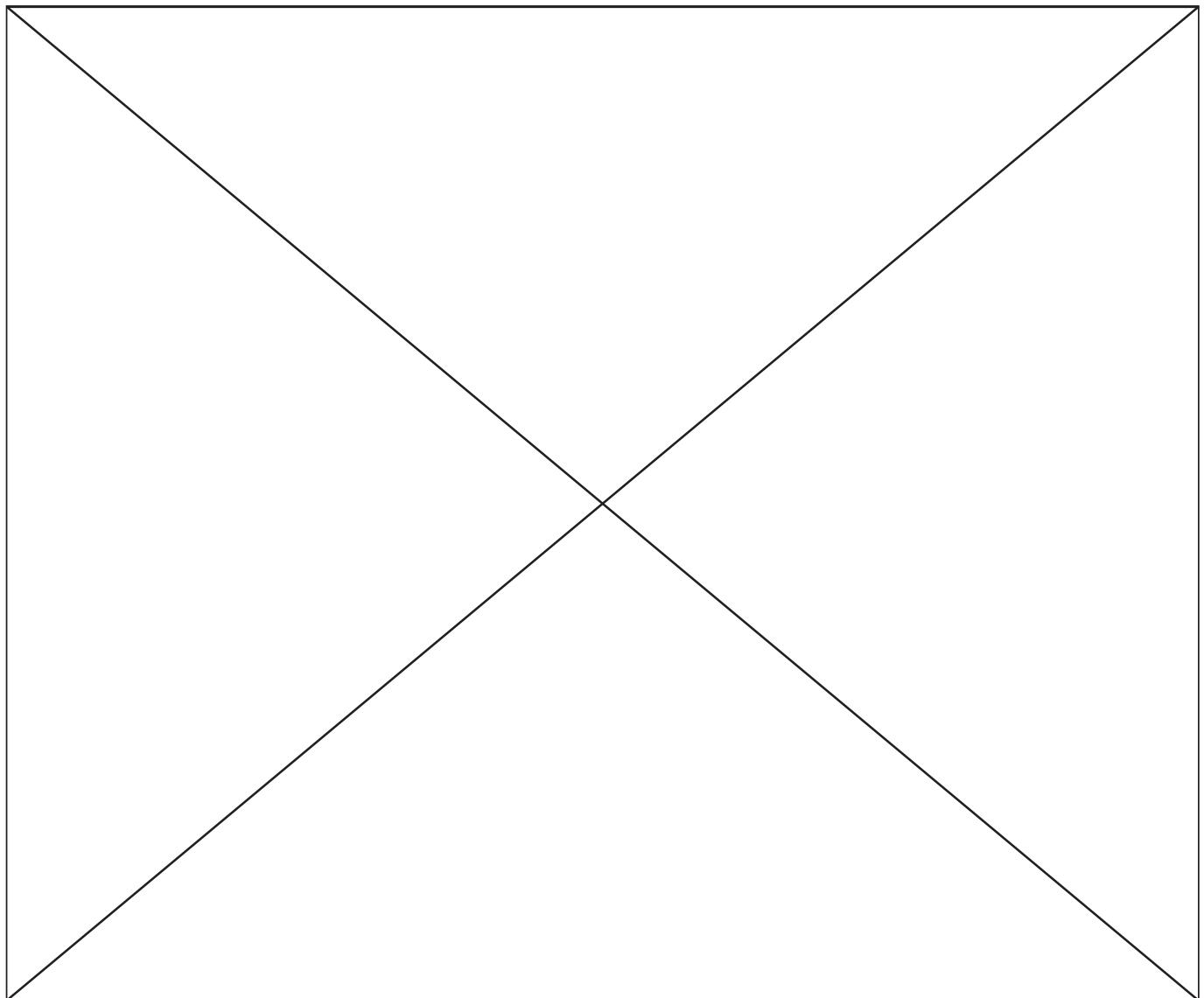
Accordind to this, it will be more convenient to realise construction that will allow robot to score debris without turning around. Robot can collect debris with gripper on it's front side while moving forward and then go backward to the ramp and score debris with the mechanism on it's back side.

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 two-sided as well.

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

1. which tasks our robot should be able to execute without loss of efficiency  
and
2. to set the priorities of performing tasks during the game.



### 3.2 Strategy discussing (22.09.2015)

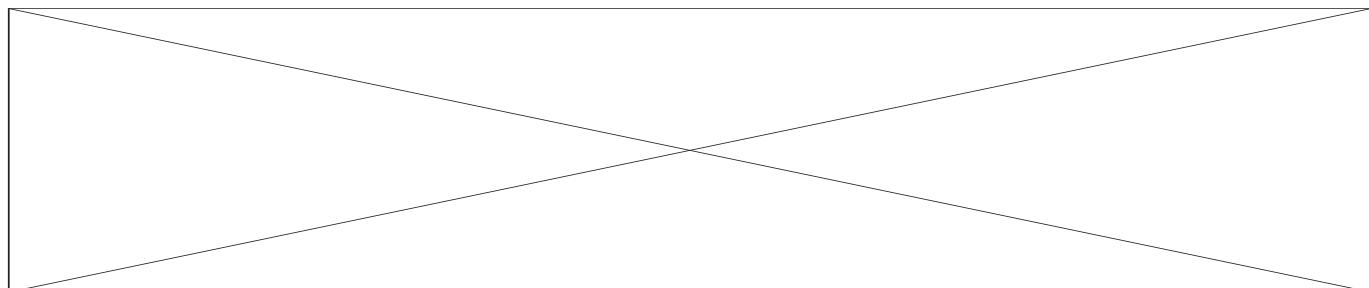
**Time frame:** 22.09.2015 17:00-21:00

**Preview:** Today we put the priorities during the building of the robot and performing tasks of the game.

**Detailed explanation:**

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

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



### 3.3 Concept discussing (24.09.2015 - 03.10.2015)

**TIME FRAME:** 24.09.2015 - 03.10.2015

**PREVIEW:** Objectives for current session are developing the concept of the robot and

#### CONCLUSIVE SOLUTIONS FOR MODULES:

The main idea that we held during elaboration robot that it should be simple and reliable. Also it was decided to concentrate on the scoring debris to boxes and complete this task as well as possible. So we refused from the completing the hardest task - pulling. If our robot will score debris very well we'll get lots of points even if we'll not be able to pull. **DAYS INSIDE SESSION:**

#### 3.3.1 24.09.2015

**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 work.

Module	Solution	Label
Wheel base	6 standard wheels with 6 DC motors. The center of gravity is between the second pair of wheels; the corner wheels are equidistant from the center of gravity.	chassis
Heaviness	Robot should be as light as possible to afford gear ratio for speed 2:1 on drive motors.	chassis
Elevator for debris	Crank elevator with one degree of freedom.	elevator
Bucket for debris	Bucket with turning cover which will close entry inside the bucket to prevent scoring elements from accidental falling out	bucket
Slopes for collecting debris	To increase collecting area on both sides of the bucket will be placed slopes	gripper
Separator for debris	Turnable beam before the bucket, which prevents balls from getting into the bucket in its lower position (5cm from floor).	gripper
Scoring autonomous climber and pushing button	F - shaped beam	climbers + button

#### Detailed explanation:

1. The wheel base includes 3 pairs of wheels. The middle pair of wheels provides better rotation, because their direction corresponds with the tangent of the circle of rotation.  
The center of gravity should be on the crossing of lines which link opposite wheels. wheels on one side should be placed on one line. In this construction each wheel will obtain  $\frac{1}{6}$  of robot's weight and moments on all wheels will be the same.
2. Both standard TETRIX and "NeveRest 1:40"motors have moments around 10 kg/cm. The diameter of standard wheels is 10 cm. So, the moment on wheels will be  $\frac{10\text{kg}\cdot\text{cm}}{5\text{cm}} \cdot n = 2n\text{kg}$  (n - number of motors). The moment required for climbing to the ramp is  $10\text{kg} \cdot \sin 30^\circ = 5\text{kg}$ . Consequently, 3 motors will be

enough for driving robot of 10kg to the 1 zone of the ramp. It's possible to use 6 motors with gear ratio 2:1.

3. The crank elevator is the most reliable construction. One rotating beam requires 1 DC motor.

The moment of DC motor should be enough for moving bucket with 5 scoring elements at a lever of about 40-50 cm. Moment of 5 cubes (250g) is  $0.25\text{kg} \cdot 50\text{cm} = 12.5\text{kg} \cdot \text{cm}$ . Moment of bucket will be about 10kg as well. So, it was decided to use gear ratio 1:3 (it will increase motor's moment to  $30\text{kg}\cdot\text{cm}$ ).

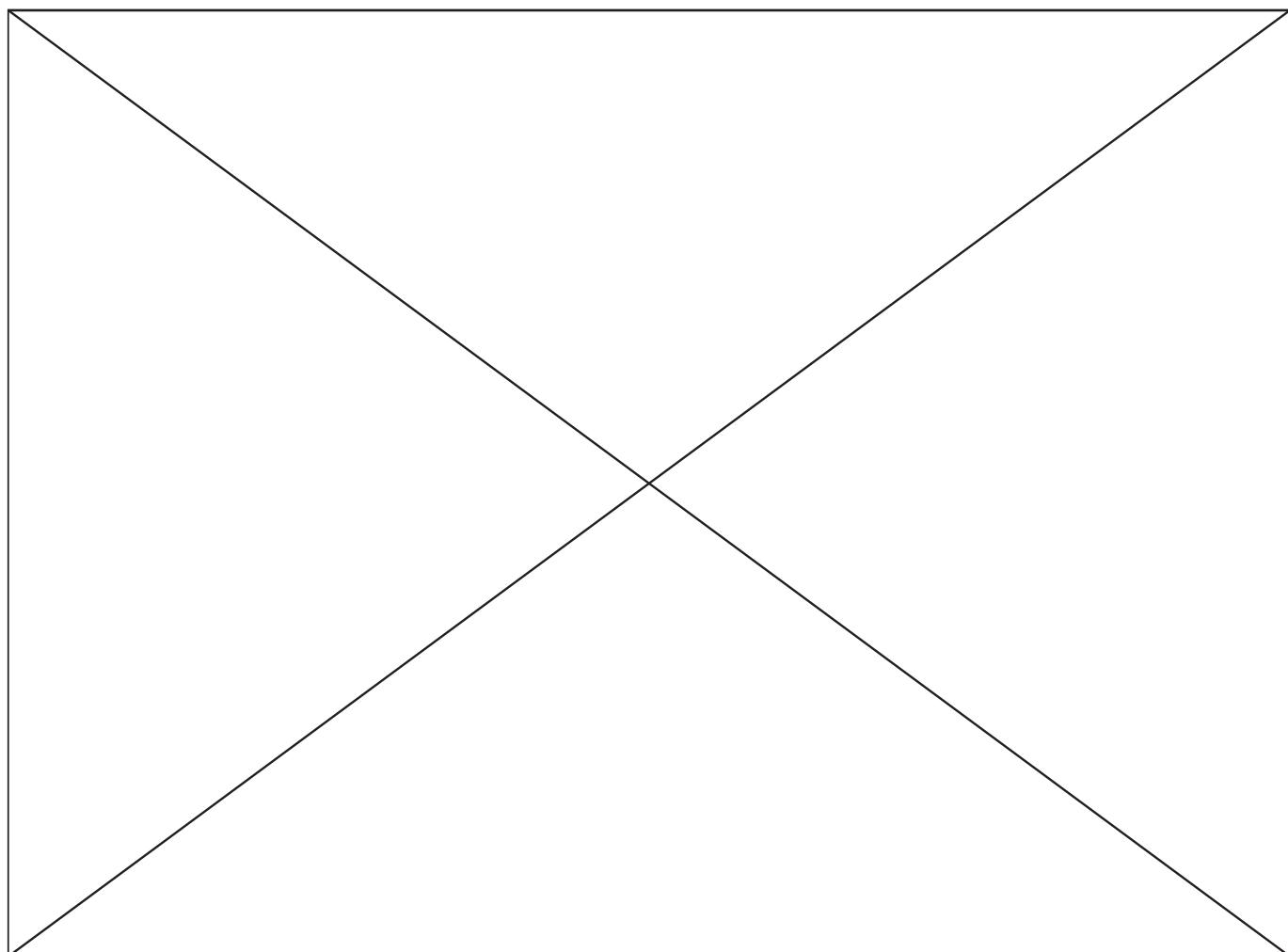
4. Bucket will be made of PET. PET is the best variant because of it's little weight (weight of  $100 \times 100 \times 0.5\text{mm}$  sheet is 7g) and flexibility. This plastic is transparent, so it will be possible to see how much debris inside it.

The bucket will have a special cover for retaining debris in the bucket during the turning of beam with bucket towards the goal.

5. The slopes will be mounted to the carriage. They will be placed on both sides of the bucket entrance and will lead debris from corners of capturing area to the center. Additionally, they will protect wheels from debris (wheels can get stuck on debris).

6. For scoring climbers and pushing button in autonomous period it was decided use F-shaped beam that turn by servo. When it turns climbers fall to goal from the bucket that fixed on the top beam and bottom beam push the button.

**Additional comments:** The next meeting we will continue developing concept.



### 3.3.2 26.09.2015

**Time frame:** 16:00-21:30

**Preview:** The purpose for this meeting was to develop ideas that were proposed last meeting.

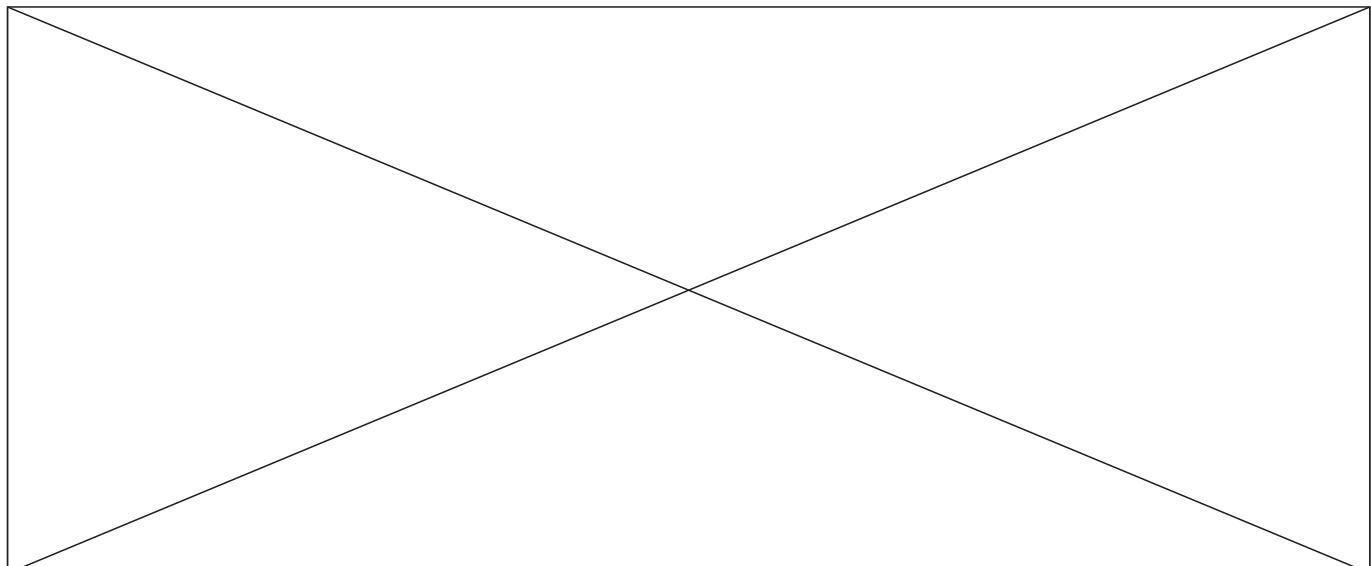
**Modules:**

Module	Solution	Label
Bucket for debris	The shape of bucket should form one stage.	bucket
Debris separator and lock for bucket	Flap above the enter.	bucket
Crank elevator	There were calculated basic parameters.	elevator
Gripper for debris	Axis with 2 rotating blades ahead of the bucket for grabbing debris.	gripper

**Detailed explanation:**

1. Today we researched how to score debris into boxes with maximal efficiency. Experiments revealed that scoring cubes one-by-one won't allow to score a lot of elements because they will settle down randomly. It was discovered that the best solution is to put 4 stages with 5 cubes in each one. Cubes in each stage should be placed as 2+2+1. According to this research, the shape of the bucket for debris should form one stage.
2. Today we came up with one possible construction of the debris separator. It consists of an axis with a flap above the bucket's enter, which can narrow its height as to prevent balls from scoring. It will also prevent debris from falling out of the bucket while it's overturned. This way, the mechanism will be a separator and a lock at one time.
3. Intake is made with a rotating brush for collecting debris. It will be used for faster debris collection and also for retaining it in bucket (without the gripper debris can freely escape the bucket when the robot moves backward). Gripper should be powered by 1 DC motor or 1-2 powerful servos to be fast and powerful enough. Using 2 blades at an angle of 180° is the most convenient solution as it's simple to realise and it requires less space than construction with 3 blades at an angle 120°.

**Additional comments:** The next meeting we need to revise all the aspects of concept and correct it.



### 3.3.3 28.09.2015

**Time frame:** 17:00-21:30

**Preview:** The purpose for current meeting was to revise all our previous ideas and discover weaknesses, then correct our concept.

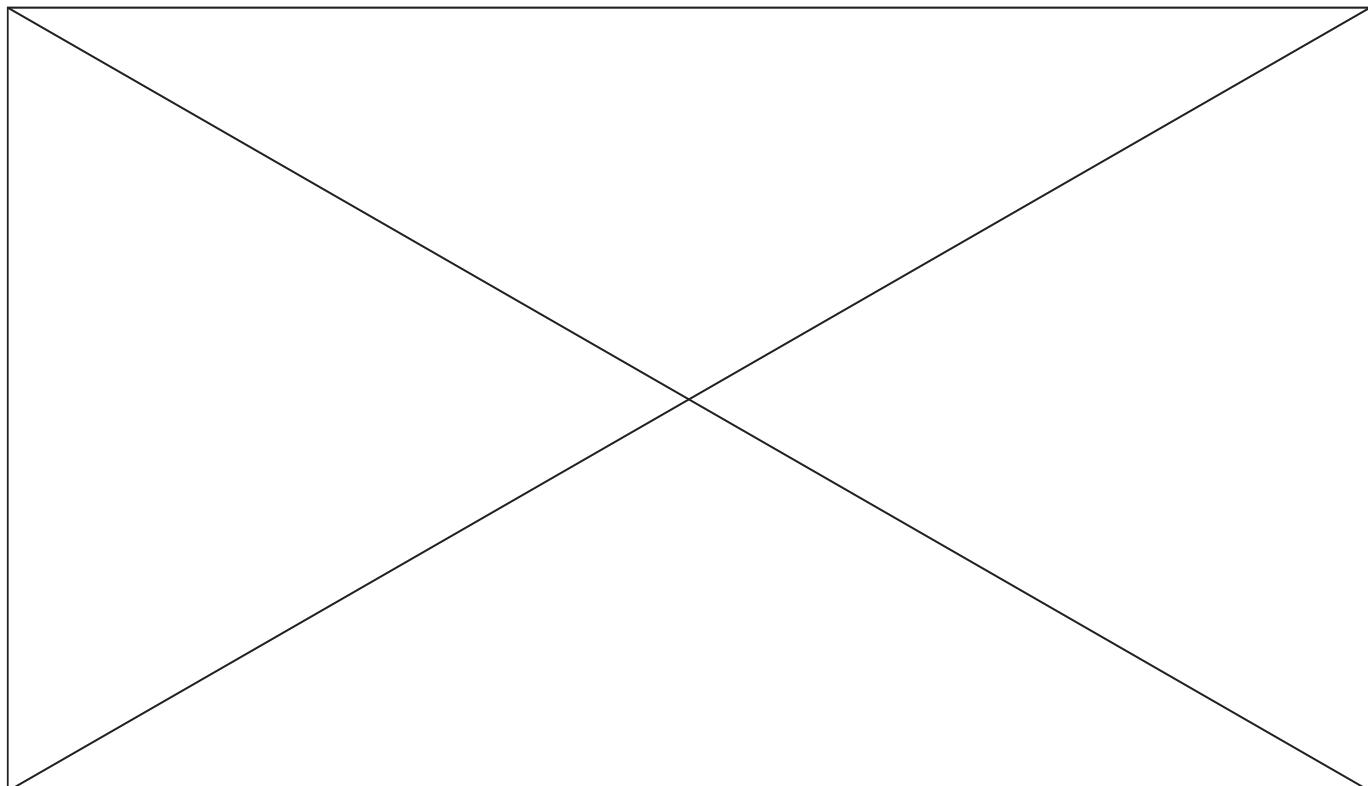
#### **Weak points**

Weak point	Solution	Label
The Gear ratio 2:1 on wheels can be not enough for climbing	It will be installed gear ratio 1:1 at first. If tests of the 2:1 gear will be successful, it will be installed on the robot.	chassis
Shape of the bucket		bucket

#### **Detailed explanation:**

1. It's difficult to predict if the gear ratio 2:1 will provide the robot with enough power for climbing to the second zone of the mountain before a test drive. That's why at first wheel base should be realised with gear ratio 1:1. A test model with gear ratio 2:1 should be assembled and tested independently. In the case the testing of 2:1 model will be successful, this gear ratio will be installed onto the main robot.
2. If the bucket would be a size of 5 cubes, it could keep no more 2 balls at once. That's not good enough as when cubes run out our robot becomes ineffective. So, the bucket's capacity should be improved. The possible solution is to improve the length with keeping the prior width. For example, bucket with parameters  $13 \times 21$  cm is enough to hold 5 balls.

**Additional comments:** The next meeting we will structure ideas into a system.



### 3.3.4 01.10.2015

**Time frame:** 17:00-21:30

**Preview:** The purpose for this meeting was creating structural layout of the robot in CAD Creo Parametric 3.0.

#### **Detailed explanation:**

1. We made a structural model of the robot. The whole construction was divided into particular modules. They are:
  - 1.1. Chassis - carrying base and wheels mounted on it.
  - 1.2. Bucket - container for debris.
  - 1.3. Elevator - mechanism for lifting bucket.
  - 1.4. Gripper - mechanism for collecting debris.
  - 1.5. MSA - mechanism for scoring autonomus alpinists.

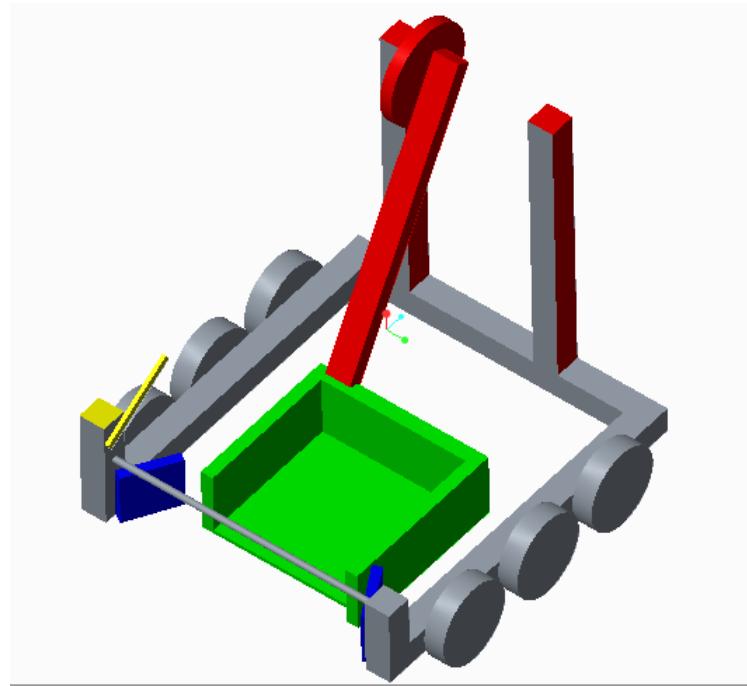
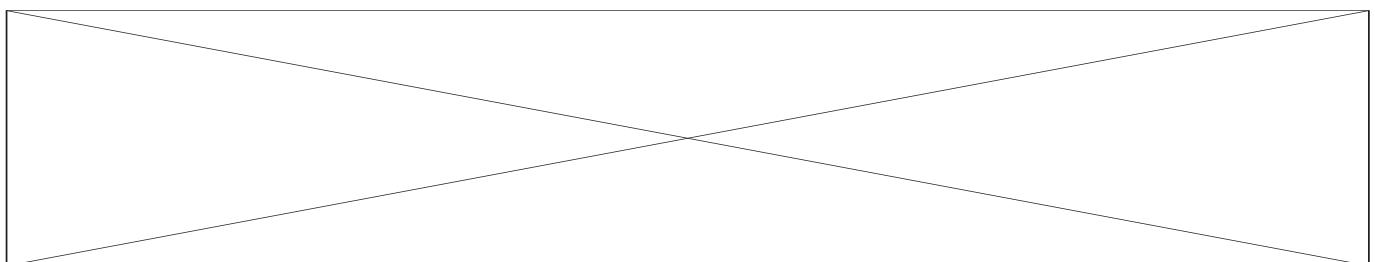


Рис. 1: Schematic model of the robot

**Additional comments:** The task for the next meeting is to summarize our ideas for each module.



### 3.3.5 03.10.2015

**Time frame:** 16:00-21:30

**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 technical specification for each group of modules to help collaborators follow the requirements.

**Technical specifications for modules:**

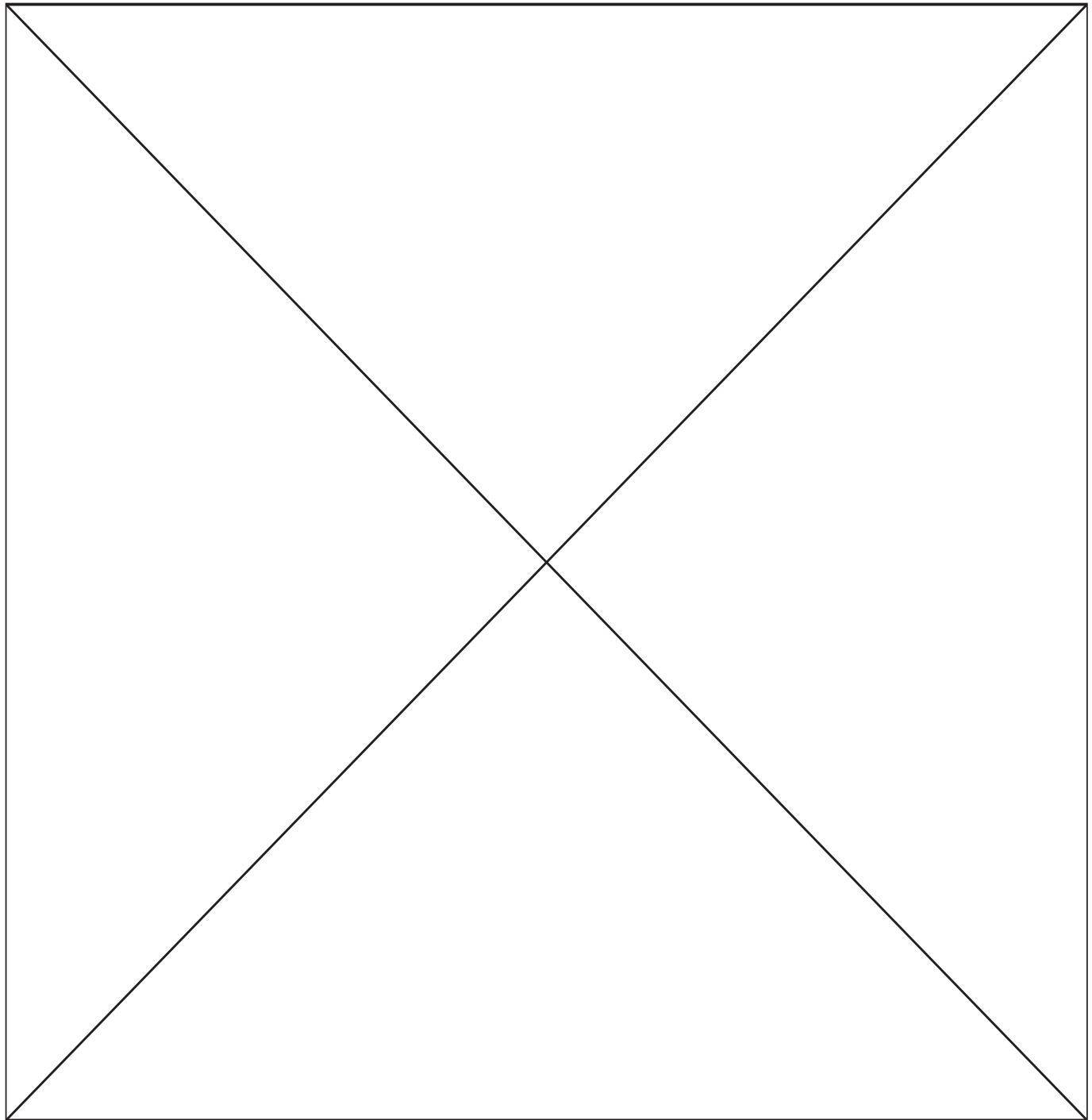
1. Chassis
  - 1.1. Carriage consists of two lengthwise beams 41.5cm connected at the back side. All other modules will be mounted to this base.
  - 1.2. Wheel base consists of 3 pairs of standard wheels. All wheels at one side are linked to each other and move together.
  - 1.3. Wheel base is powered by 6 dc motors (3 at one side).
  - 1.4. Motors should not interfere with bucket which will be placed in the forward half of the robot.
  - 1.5. There should be no construction elements except wheels that can touch the surface while climbing the ramp.
2. Elevator
  - 2.1. Elevator consists of 2 static beams fixed on the base and one pivoting with bucket on it.
  - 2.2. Turnable beam rotates around the axis on top of the static beams. It's rotation powered by 1 dc motor with gear ratio 1:3.
  - 2.3. Length of the elevator should be enough for scoring debris into all boxes without climbing to the 3-rd zone.
3. Bucket
  - 3.1. Bucket should be fixed to the turning beam of elevator.
  - 3.2. Free space inside the bucket should be 10-14cm at width, 15-17cm in length and 7cm in height. It should be capacious enough for containing 5 cubes of 3 balls.
  - 3.3. The back side of the bucket can be narrower to prevent collecting more than 5 cubes at once (cubes will settle as 2 + 2 + 1).
  - 3.4. Bucket's movement should not interfere with gripper for debris.
  - 3.5. Entrance hole of the bucket should have the same height and width, as the internal space.
  - 3.6. Bucket should have a turning flap above the entrance which can prevent balls from scoring on demand. Additionally, the flap will stop debris from falling out of the bucket when it will be overturned.
4. Gripper
  - 4.1. Gripper consists of 2 rotating blades, mounted to axis at an angle 180° to each other.
  - 4.2. Gripper is powered by 1 or 2 continuous rotating servos or DC motor.
  - 4.3. Gripper is placed ahead the bucket. Width of blades should match with the entrance of the bucket.
  - 4.4. Space between axis and field enough for unhindered passage of balls.
  - 4.5. Gripper should not make any obstacles for bucket's moving.
  - 4.6. At both sides of the blade's working area placed slopes, which are tapering to the bucket.
5. Scoring autonomous climbers + pushing button
  - 5.1. 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.
  - 5.2. Mechanism consists of F-shaped beam powered by standard servo.
  - 5.3. At the end of top beam is a bucket for 2 alpinists. The bottom beam pushes the button.

5.4. Module should not interfere with gameplay after the autonomous period ends.

***Responsibilities for each module:***

- 5.1. Carriage and wheel base - Victoria Loseva
- 5.2. Bucket and elevator - Evgeniy Maksimychev
- 5.3. Gripper with slopes - Ivan Afanasiev
- 5.4. Mechanism for scoring alpinists - Timur Babadzhanov

***Additional comments:*** Now our team is ready to proceed to the next objective: designing modules.



### 3.4 Elaborating robot

**PREVIEW:** The following section is about elaborating of each module of the robot. Here it is wrote about all decisions that were looked during designing, what advantages and disadvantages are in the each variant and how was choosed the best.

#### 3.4.1 Wheel base

- Since the robot is only supposed to do one task well, the structure of all the elements had to be optimized for the completion of that one task: collecting debris and placing it in the bins.
- The decision not to pursue completion of other tasks means that we could use some additional motors to boost driving speed as well as improve climbing the ramp, bringing their number up from the usual four to six.
- It was decided to use six standard wheels. It allows high traction so we can climb the ramp well. The central wheel should be located near the COG of the robot. It allows fast and accurate turning.
- The U-contour was chosen as the shape of the wheelbase due to its proven durability and the ease with which other elements may be attached to it.
- The use of a chain to connect the motors and wheels allows for more mobility in changing the position of the wheel, especially since the length of the chain can be changed freely.
- The important moment is that chain should touch a half of circle of the gear. Otherwise it can slip during working. So it was decided to locate gears as in the picture

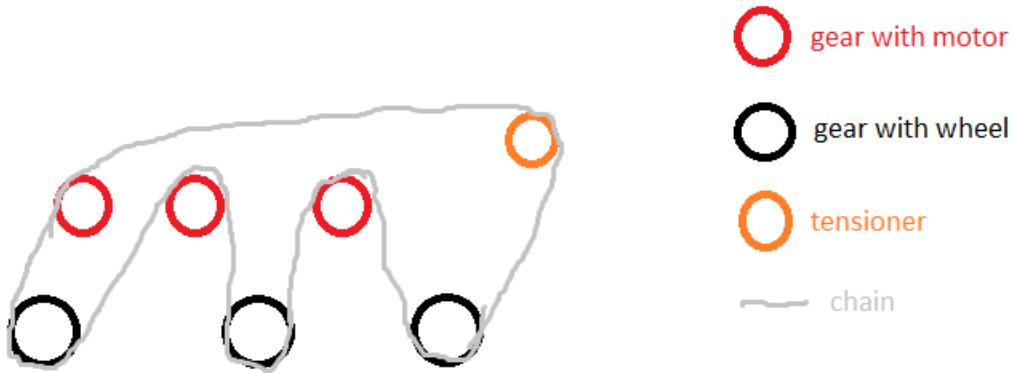


Рис. 2: Location of gears for chain

- The first step in creating the wheelbase was making a model in Creo Parametric. Though in subsequent assembly the original design was deviated from, creating this model allowed us to establish a conceptual foundation that we were not to steer away from - usually doing so wastes time and effort.

- To assemble the wheelbase, we needed to shorten a bar and create a chain of the exact length that was needed. In addition, the chain would slack on its highest segment, and required careful adjustment to ensure that it would not slip while operating.
- During tests and first competition we identified several problems:
  1. Robot can't climb to ramp due to an overextension that prevented the robot from achieving the needed angle. And even if the robot was manually placed on the ramp on the needed position, it couldn't climb on top of the first churro due to low clearance. In order to fix this problem the front wheels were moved slightly forward, so that the distance between the wheel axis and the end of the beam would not exceed a certain value that is easily calculated through the angle of the ramp. After this was done, the robot could easily ride up the mountain. In order to fix the churro problem, we attached treads to the back wheels of the robot. This worked, but doing the same to all six wheels of the robot improved performance even further, and we could easily climb over the first churro in tests. However, when attempting to climb over the second churro, we found that our wheels were placed too close together: the middle wheels pushed into the first churro and prevented the back ones from reaching the second one, and the robot would be unable to advance any further.
  2. Another problem we faced in first competition was the fact that our chain was not protected, and our robot could be disabled very easily just by driving into it and pulling the chain off. We added a metal sheet in front of the most exposed section of chain to protect it.

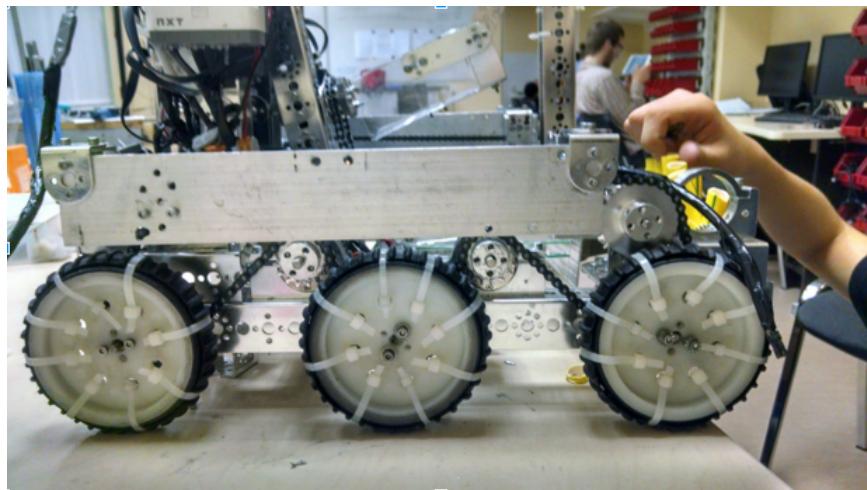


Рис. 3: Wheels with caterpillars and protection for chains

- However, the treads on the wheels turned out to tear easily, and we decided to scrap that development. Instead, we added a pair of “carrier wheels” at the back of the robot that would ease going over the churros by taking on some of the weight of the robot. We also cut off some of several millimeters off of the bottom beams of the chassis to compensate for the lost height boost from the removal of the treads.

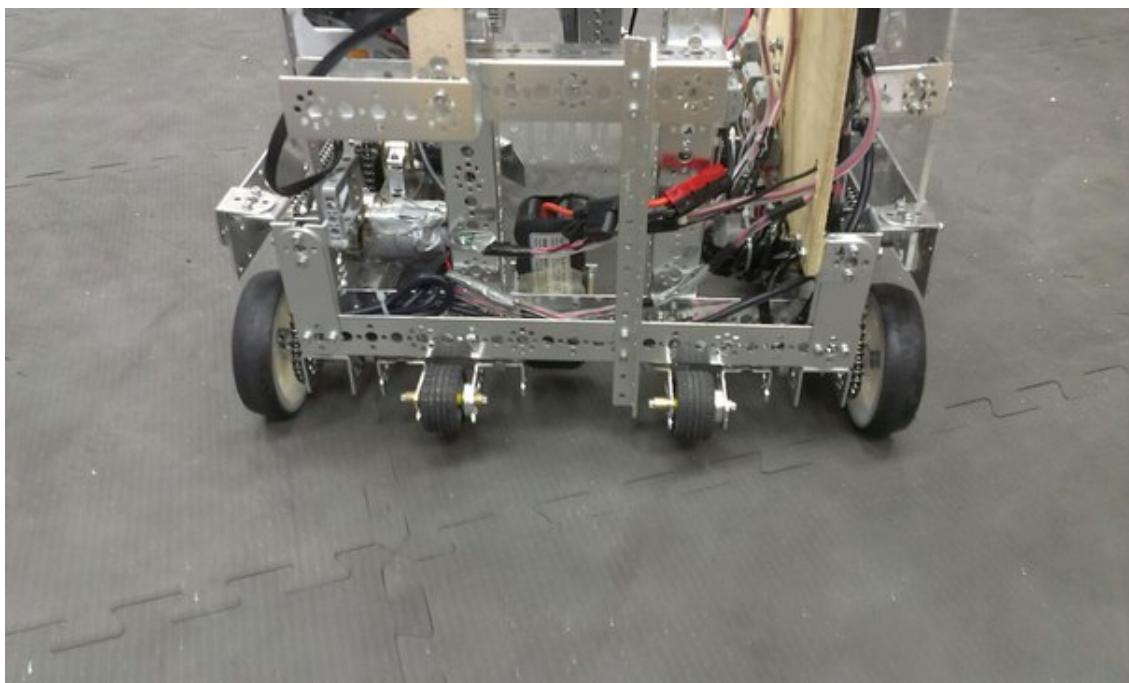
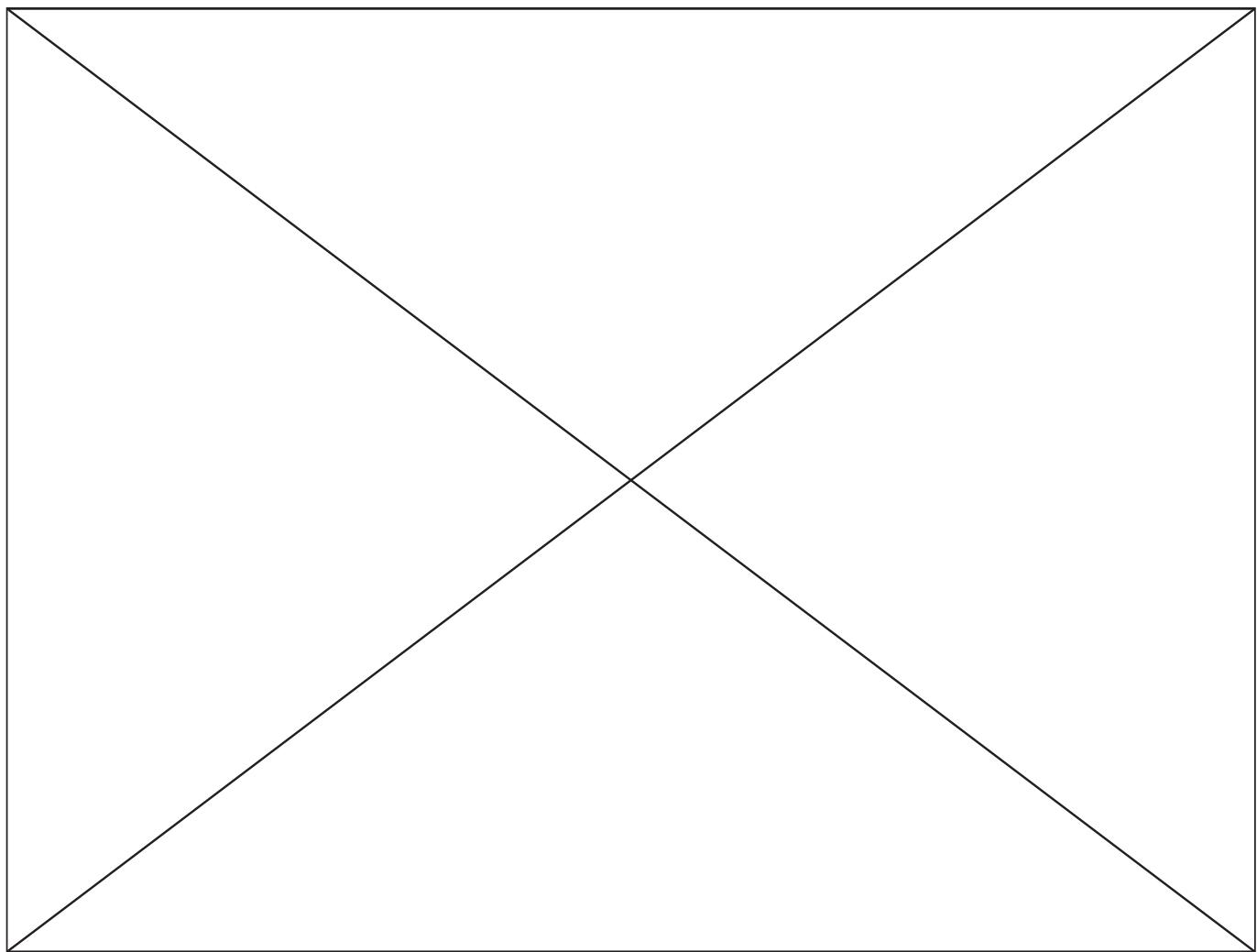


Рис. 4: "Carrier wheels"



### 3.4.2 Lift

- The lift consists of two beams. One beam is stationary and is fixed vertically on the back part of the robot. The second beam is turned by a DC motor that is mounted on the top of stationary beam. The lengths of beams must allow us to score debris into the high goal from the middle zone and into middle goal from low zone.
- To estimate optimal beams length we made a drawing in GeoGebra. The minimal length of the moving beam turned out to be 41cm.

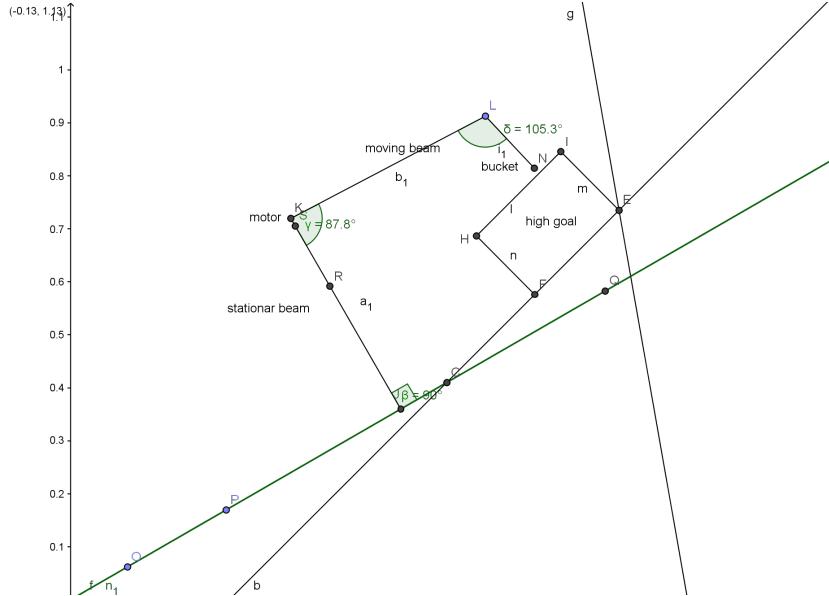


Рис. 5: Drawing of the lift

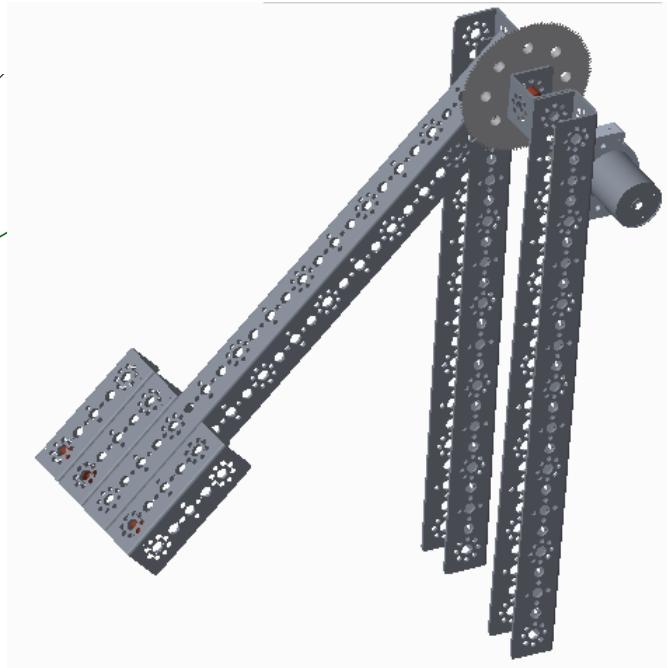


Рис. 6: Model of the lift

- Later it was found that reaching the middle zone of the mountain is not easy. So it was decided to design a moving beam that can increase its length. It was estimated (from the drawing in GeoGebra) that minimal moving beam length that would allow us to score into the high box is 70 cm.
- We decided to use two furniture slats to increase the length of turning beam. We fixed to two Tetrix beams together as shown in the picture. Also we looked variants with construction profile that is fixed on the side of beams. It is fixed rigidly to one beam and second beam slides on it. But in this case we need profile 50cm in length, and there is not enough space for it. In addition we thought about a lift made of retractable slats. But if slats are fixed to one side from the bucket, the slats will bend. If the slats are fixed from both sides from the bucket it will take up too much space.

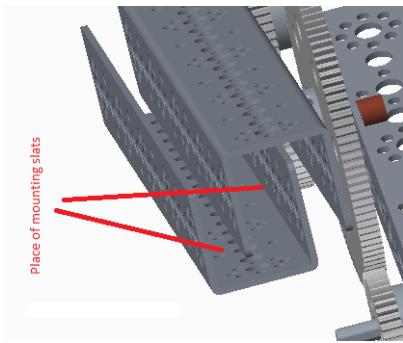


Рис. 7: Mount for slats

- For extracting slats we decided use the following mechanism. The servo fixed on the first Tetrix profile (which doesn't extract). It turn the beam that pivotally connected with the other beam that connected with slat (pivotally too). So when servo turns the point of connection the second beam with slat start move horizontally and slat extraxts.

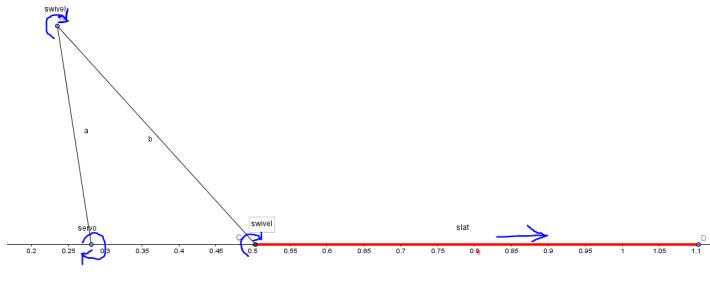


Рис. 8: Schematic drawing of the mechanism for extracting slat

- It was calculated moment of force of servo that extract lift. We calculated it as multiplication of weight of extracting part (bucket, debris, half of slats, Tetrix beam and servos that turn bucket) and length of beam that mounted to servo. We got the result  $14.25 \text{ kg} \cdot \text{cm}$  (weight of construction  $950\text{g}$  length of beam  $15\text{cm}$ ). So it was decided use servo with moment  $18.5 \text{ kg} \cdot \text{cm}$ . But this calculations are wrong because we didn't take in account that beam that fixed on the servo push the second beam at the something angle (that  $< 90$  degrees). So part of force is lost.
- It was decided to make mechanism for extracting lift with blocks and rope that mounted on the reel that rotate by servo of continuous rotation. It was decided to install two spools and two ropes so that one rope rise the lift and second - lower it. This mechanism provide holding of the lift position.

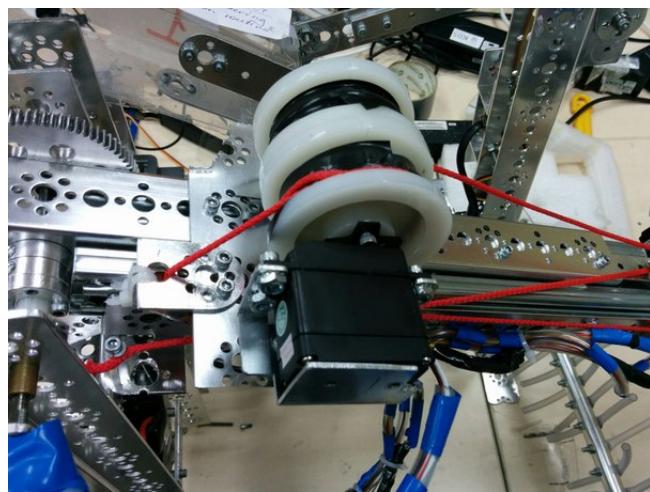
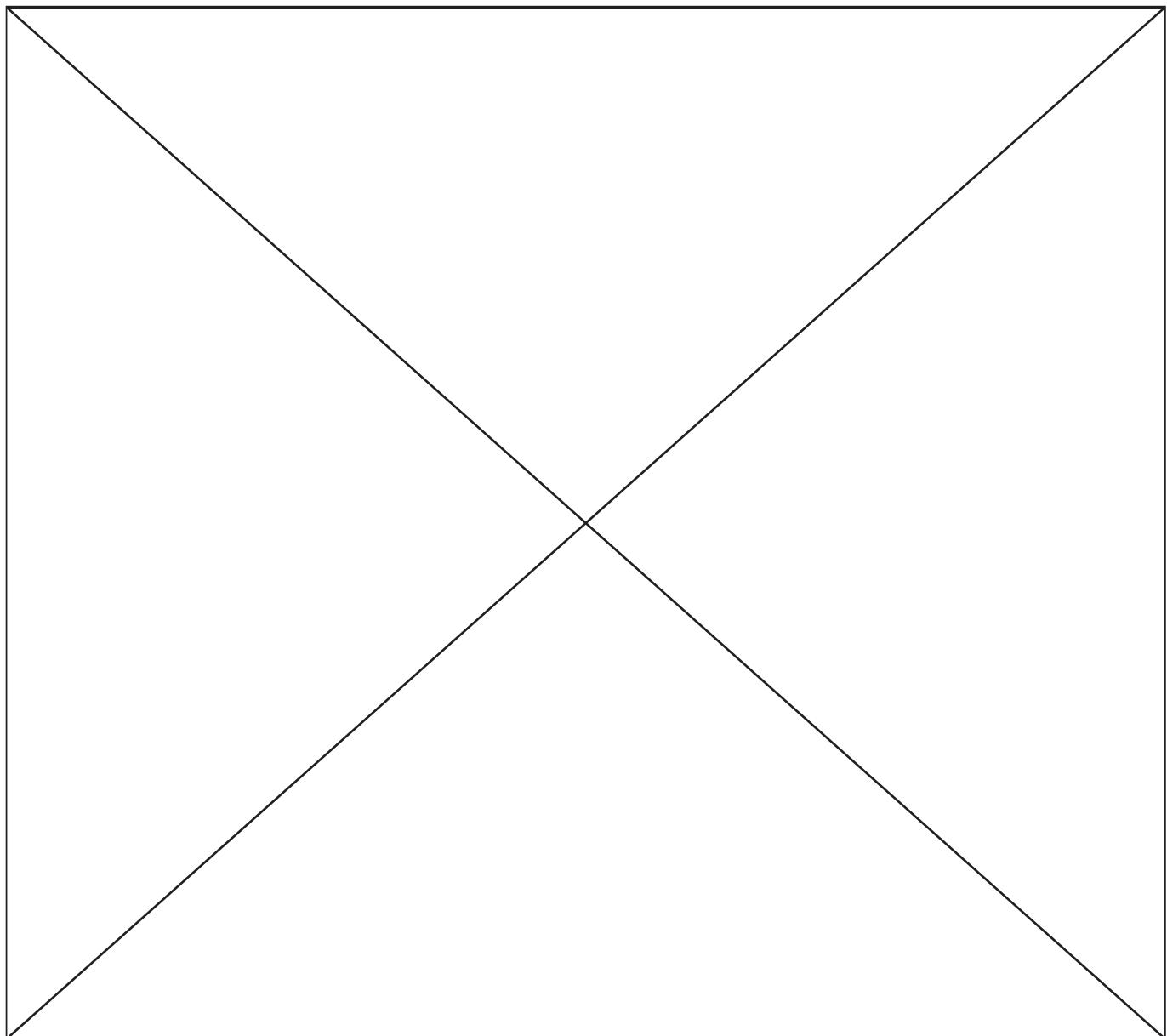


Рис. 9: New mechanism for extracting lift



### 3.4.3 Bucket

- The bucket's size allow to fit 3 cubes and 2 balls. So we can collect 5 cubes (because size of cube is smaller than size of ball) or 3-4 balls. It is enough for us because we want to concentrate on collecting cubes.
- For estimating optimal size and form it was made drawing in GeoGebra. During designing model of the bucket for all sizes were made dimention tolerances 2cm.

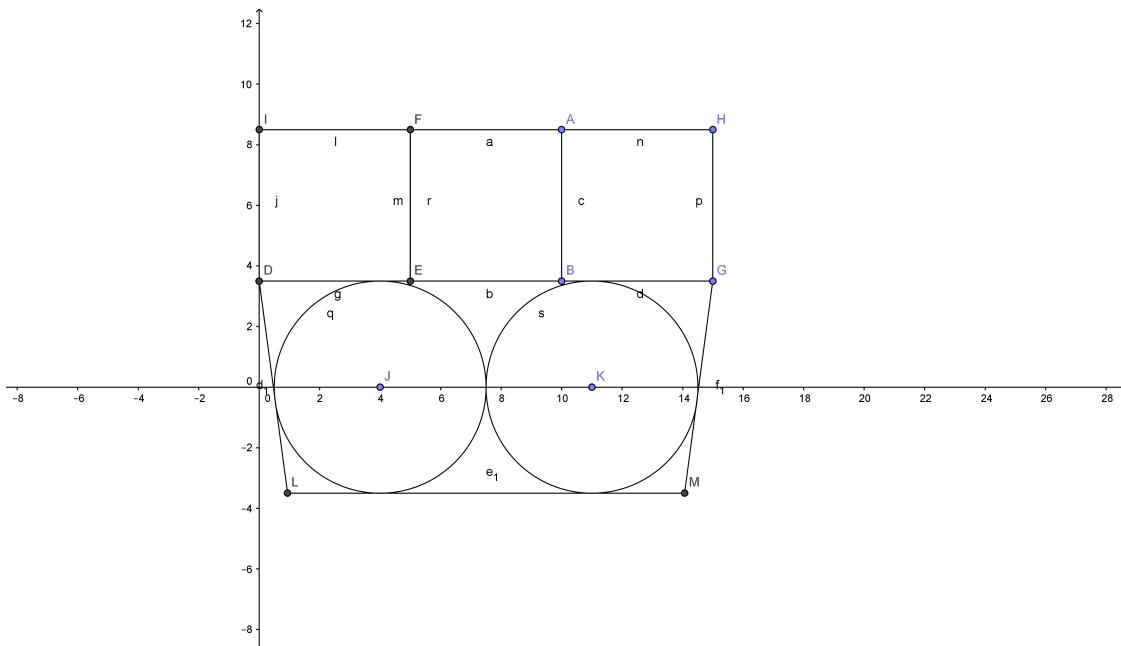


Рис. 10: Drawing of the bucket

- But after that it was decided to change size of the bucket. The width entrance hole and width of the scoring box should be the same (The width of the box for debris - 14.5cm. So it was decided to make the bucket's width 13.5 - 14cm). It ensure maximal accuracy of scoring debris. It was decided to make bucket that can fit 5 cubes or 3 balls.

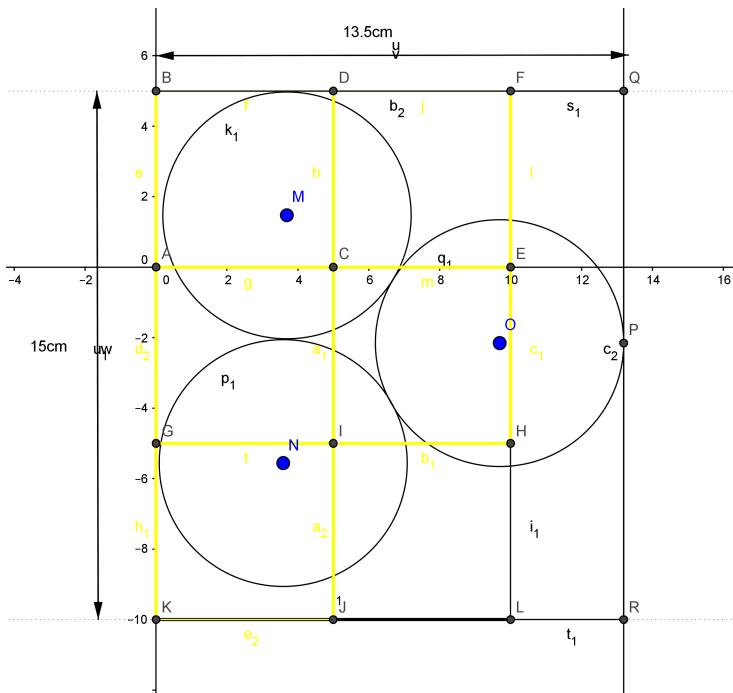


Рис. 11: Changed bucket

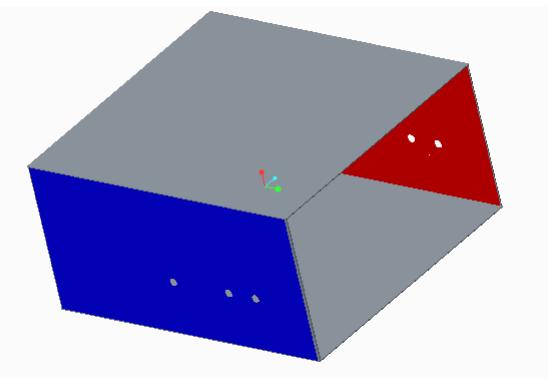


Рис. 12: Model of the bucket

- For building bucket it was decided use plastic PET 0.5mm. It is easy to cut it, it light, cheap and clear that allow us to see how much elements are incide the bucket.
- The bucket mounts to beam that turns by the servo which fixed on the lift. It need because else we have to make detail that fix bucket to the elevator on the defined angle. It require high accuracy. So it will be difficult to make this detail. In addition the mount with servo extend operational window of the lift.

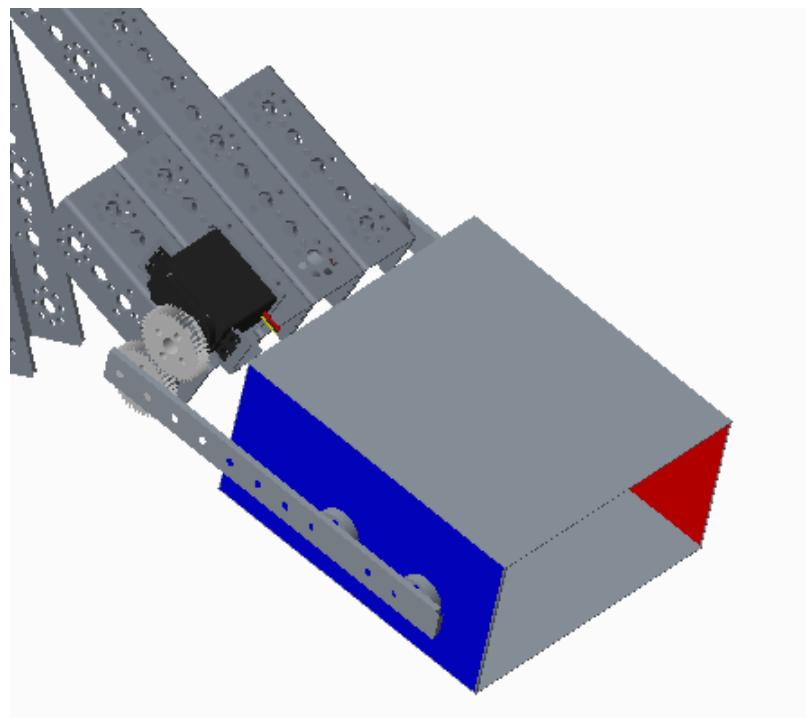


Рис. 13: Model of the mount for bucket

- Later the mount of bucket to servo was changed. It was decided to make it without gear because gears can slip and they have a big backlash.

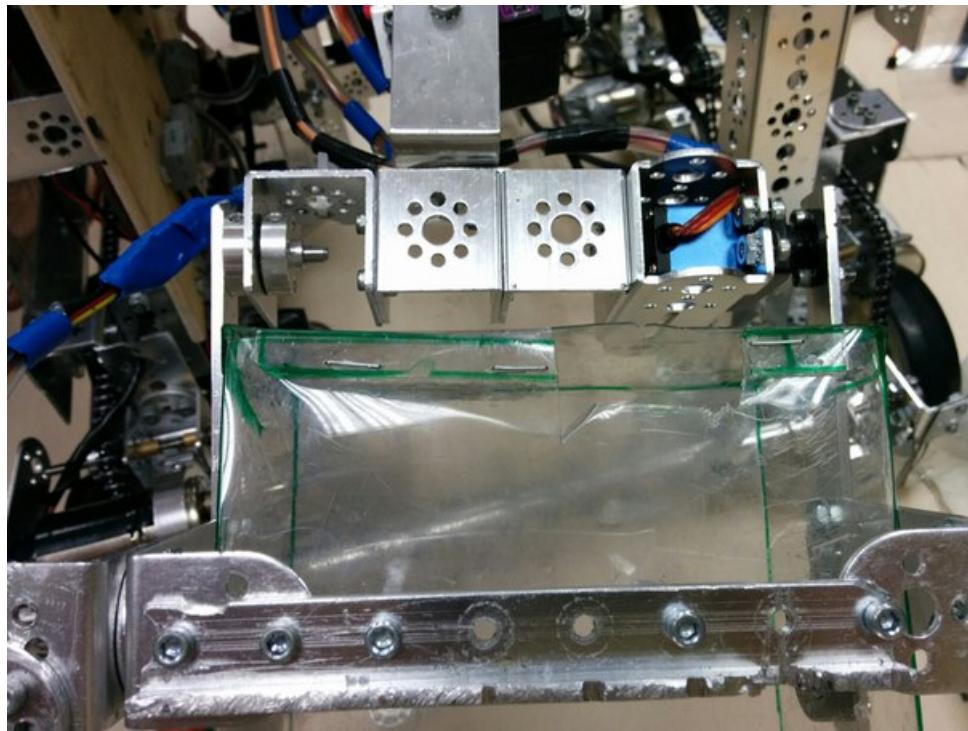


Рис. 14: Changed mount for bucket

- The bucket equipped by the cover that turns by the servo and close entrance hole of the bucket. It prevents

to falling debris out it during turning of the moving beam of lift. Also it can prevent balls get into the bucket when we collect only cubes. When it closed not fully (so that distance between bottom edge of cover and floor is about 6cm) the cube can get into the bucket but the ball is not. When we open cover the balls can get to the bucket.

- The cover fix on 14cm beam that turn by the servo. It was decided use so long beam as the most optimal variant when cover move vertically because otherwise it can prevent rotating gripper for debris. When it turn around the circle with big radius trajectory of cover's moving is close to vertical.

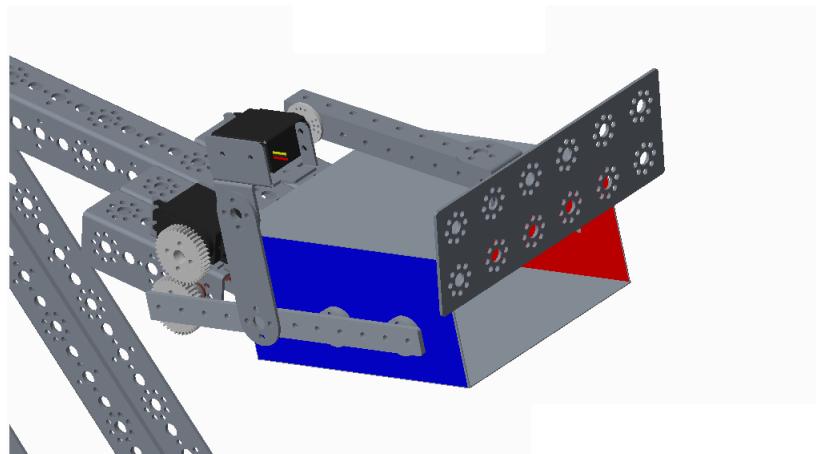


Рис. 15: The bucket with cover

- Later it was found that when cover close so that balls can't get to bucket cubes get to bucket very hard. But it doesn't problem because it very easy to collect only cubes without a special system. We can just don't come to balls too close without problems.
- During tests it was found that it will be difficult turn to box by the robot. So it was decided make mechanism that turn it to side.
- The mechanism for turning bucket to side is a beam that turn along the top plane of moving beam of the lift. The servo that turn it is fixed in the middle of moving beam of the lift. It connected with the chain gear (through the transmission in order to prevent failure of servo due to chain tension). The second chain gear is in the bottom of moving beam of the lift and it turn beam with bucket. It was decided make this system because servo take up much space and if it fixed near the bucket it will prevent it's turning.

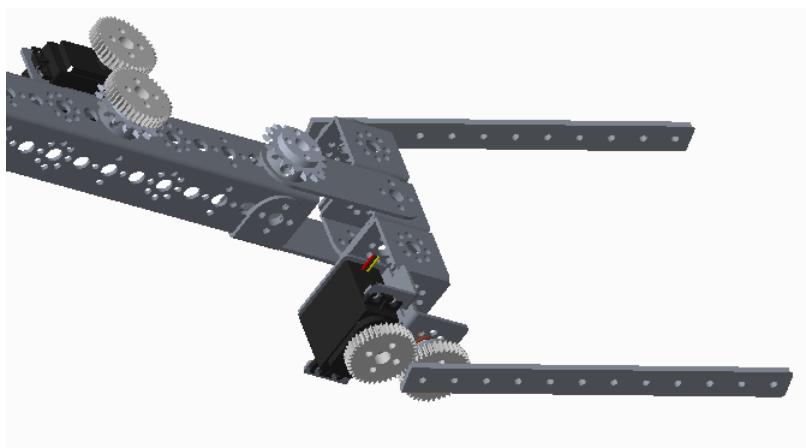


Рис. 16: Mechanism for turning bucket to side

- Later it was decided make this mechanism less complex. At the end of turning beam of the lift was fixed servo (at the center of it) and beam where fixed bucket connected with the servo without gear

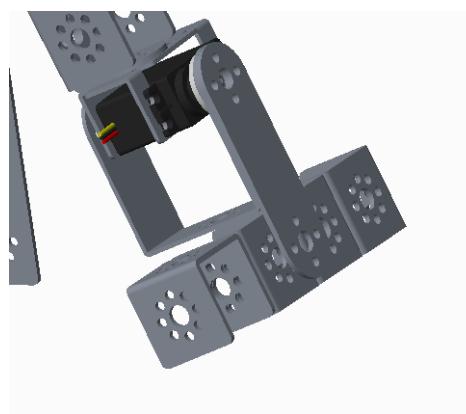


Рис. 17: Optimized mechnism for turning bucket to side

- During tests it was found that we still can't reach the box to side. So it was decided to remake cover. The servo that turn cover was moved as close as possible to it. So when cover open cubes slide on it and fall to box.

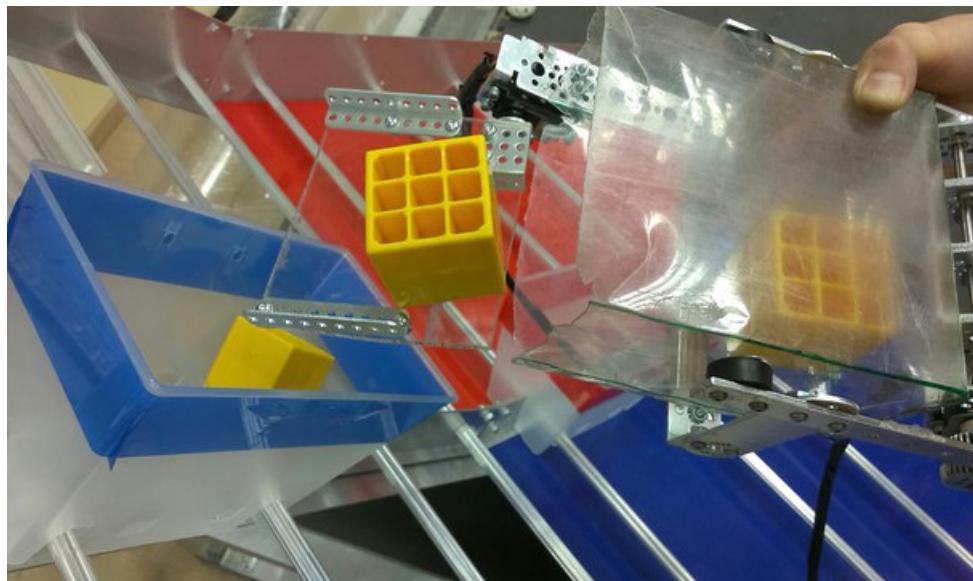


Рис. 18: Changed cover

- Also they were calculated moments of force that acts to servos. From this calculations they were choosed servo for turning bucket and cover. During the calculation were taken into account mass of construction elements and safety coefficient 1.5 For turning bucket (up and down and to side) it was decided use servo MG996R (torque 11kg\*cm) for cover - HS-485HB(torque 5.9 kg\*cm).

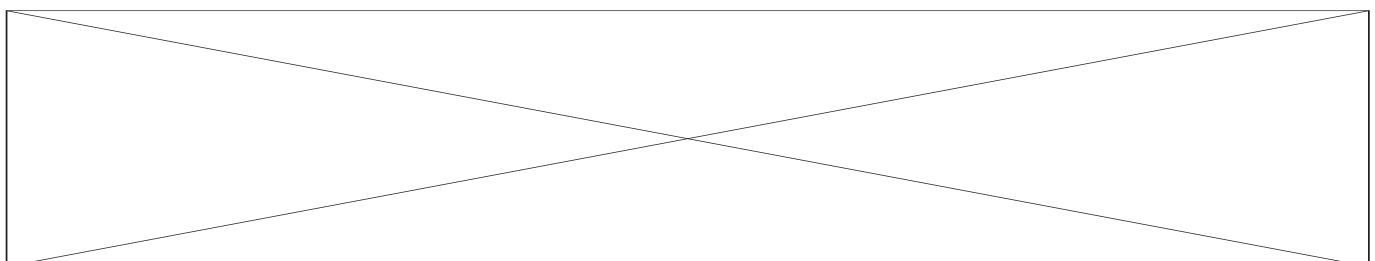
	bucket	debris	cover servo	beams for mount bucket	cover	K
weight, g	50	250	43		57	
arm of force for bucket servo, cm	9,5	9,5	5,60		9,5	18
arm of force for cover servo, cm						2
arm of force for servo that turn bucket to side	14,3	14,3	10,4		14,3	22,8
torque, kg*cm						4,8
bucket up-down servo		6,8877				
cover servo		0,171				
bucket to side servo		10,6317				

Рис. 19: The table of moments for servos

- In addition it was calculated moment of force that acts to DC motor that turn lift. So it was decided to install transmission with gear ratio 8:1.

	bucket	debris	servo bucket up-down	servo bucket to side	servo cover	cover	beams	K
weight, g	50	250		50	50	50	900	
arm of force, cm	70	70		70	52,5	62,5	70	35
moment		97,875						

Рис. 20: The table of moments for DC motor



### 3.4.4 Gripper for debris

For rotating brush it was decided to use DC motor. It allows for the fastest debris collection. The first part of the module is the mounting to the base and axis. The brush is fixed on the axis.



Also protection for wiring of the motor was made from a construction of Tetrix plates that were fixed to the base rigidly.



Рис. 21: Protection on DCmotor

The next element of the module is the brush. The brush should be tough enough so that it doesn't bend during collecting debris. But it should be elastic so when robot hits the wall of field the brush will bend but not broke.

At first the brush was made of a piece of a plastic bottle. During the test it collect debris well enough but it started to crack.

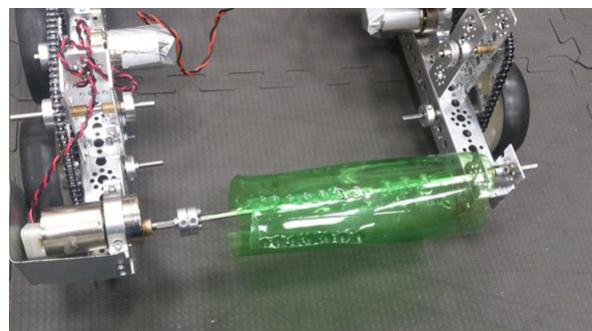


Рис. 22: Brush madde of plastic bottle

So it was decided to use pieces of rubber hose because it is elastic but more durable than plastic. The pieces of hose were fixed on the aluminium tube from Tetrix set with screws. The tube was installed on the shaft of the motor instead of the axis. This construction worked well enough. It collected the debris without problems.

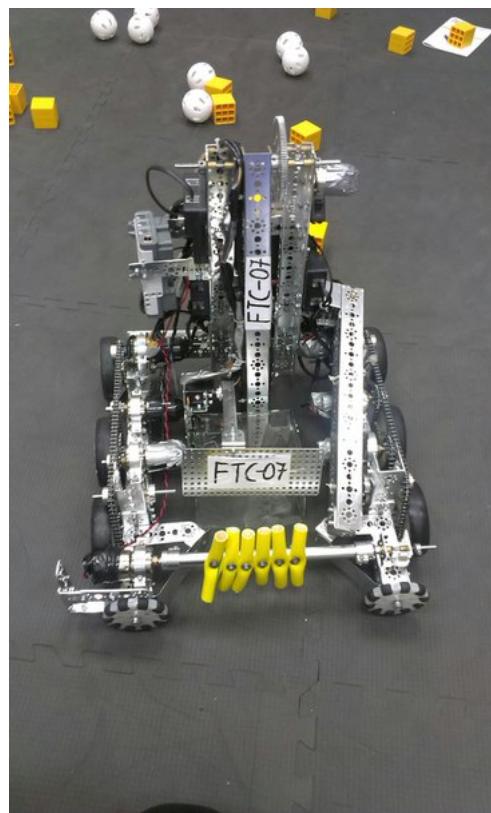


Рис. 23: Gripper with hose

Later it was decided to increase speed of rotation and install a transmission with gear ratio 2:1. It was needed for pushing away scoring elements during autonomous period.

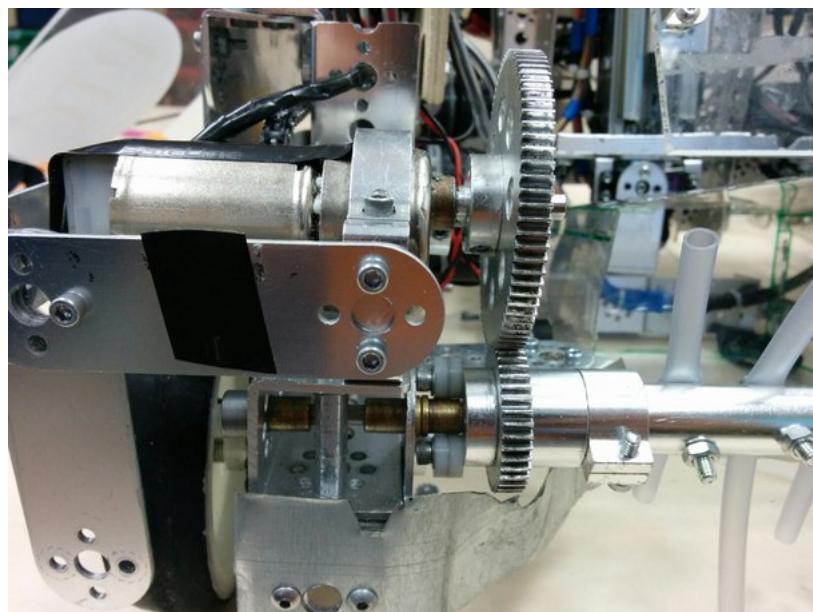


Рис. 24: Transmission with gear

But this construction didn't work, because the pieces of the hose were inflexible and got stuck in scoring elements while robot wasn't moving. So we decided to use tubes from a dropper. This also meant we could add more tubes, because they are not as wide. This construction worked very well.

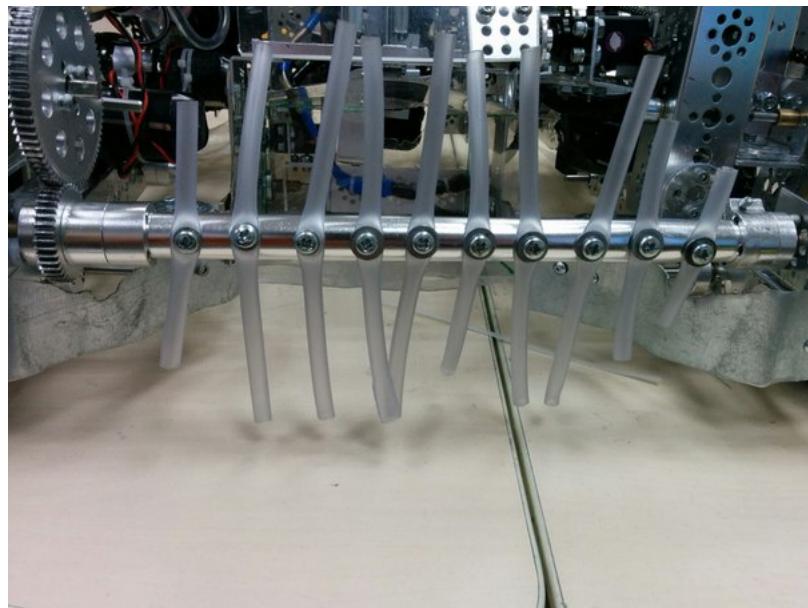
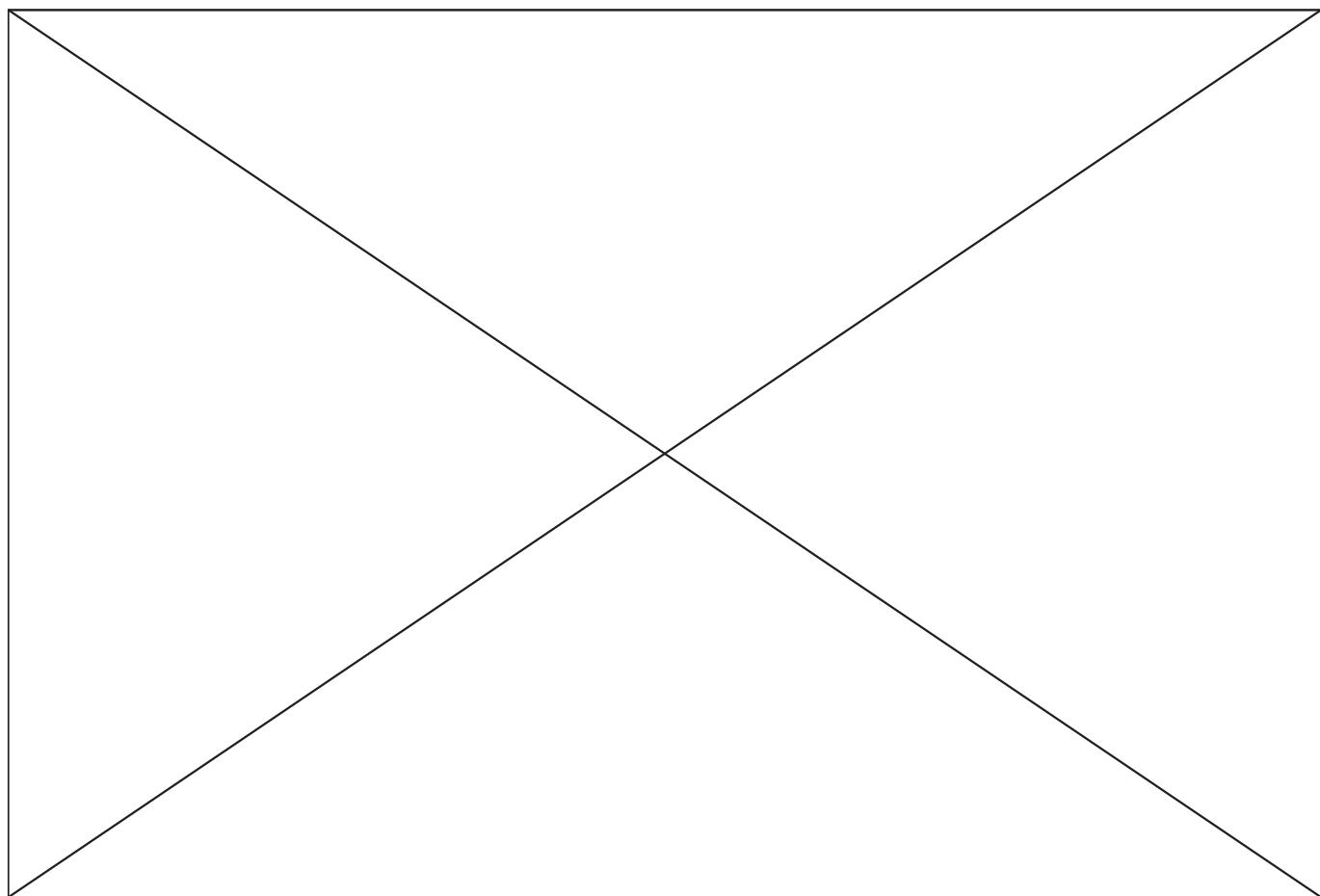


Рис. 25: Gripper with tubes from dropper



### 3.4.5 Mechanism for scoring autonomous climbers and pushing button

#### Plan of creating module:

1. Creating 3D model in Creo parametric.
2. Calculation of moments, distances and angels.
3. Testing and debugging of the mechanism

The module turns an F-shaped beam using a servo. On the top of beam there is a bucket with climbers. After the beam turns, the bucket turns over, and the climbers go to the box. At the end of other part of the beam is a light sensor. It detects the color of a button and presses it. The robot performs this during the autonomous period.



Рис. 26: F-beam module

#### Ideas that were looked:

1. The first idea was the following: we decided to use two beams. The two beams turn, and the light sensor on the end of each beam detects the correct button. The beam, which detects the correct button rests in place. The other beam turns up. The robot goes forward and presses the correct button. But this idea isn't good, because we have to use two servos, and this is very difficult, and the module take up too much space.
2. Another idea was the following: we use one beam. The beam turns and the light sensor on the end of the beam detects the color of the right button. If this color is correct, the robot turns right and then goes forward. Otherwise the robot turns left and then goes forward. This algorithm is slower, but it's lighter, and the model takes not as much space. We decided to use this algorithm.

**Calculation of moments** We calculated the moments to compare it with the maximum moment of the servo. If the maximum moment of the servo is higher than the moment of module, the module will work. The maximum moment of the servo(HS-485HB) is 28 kg\*mm. The moment of gravity forces using the following formulae:

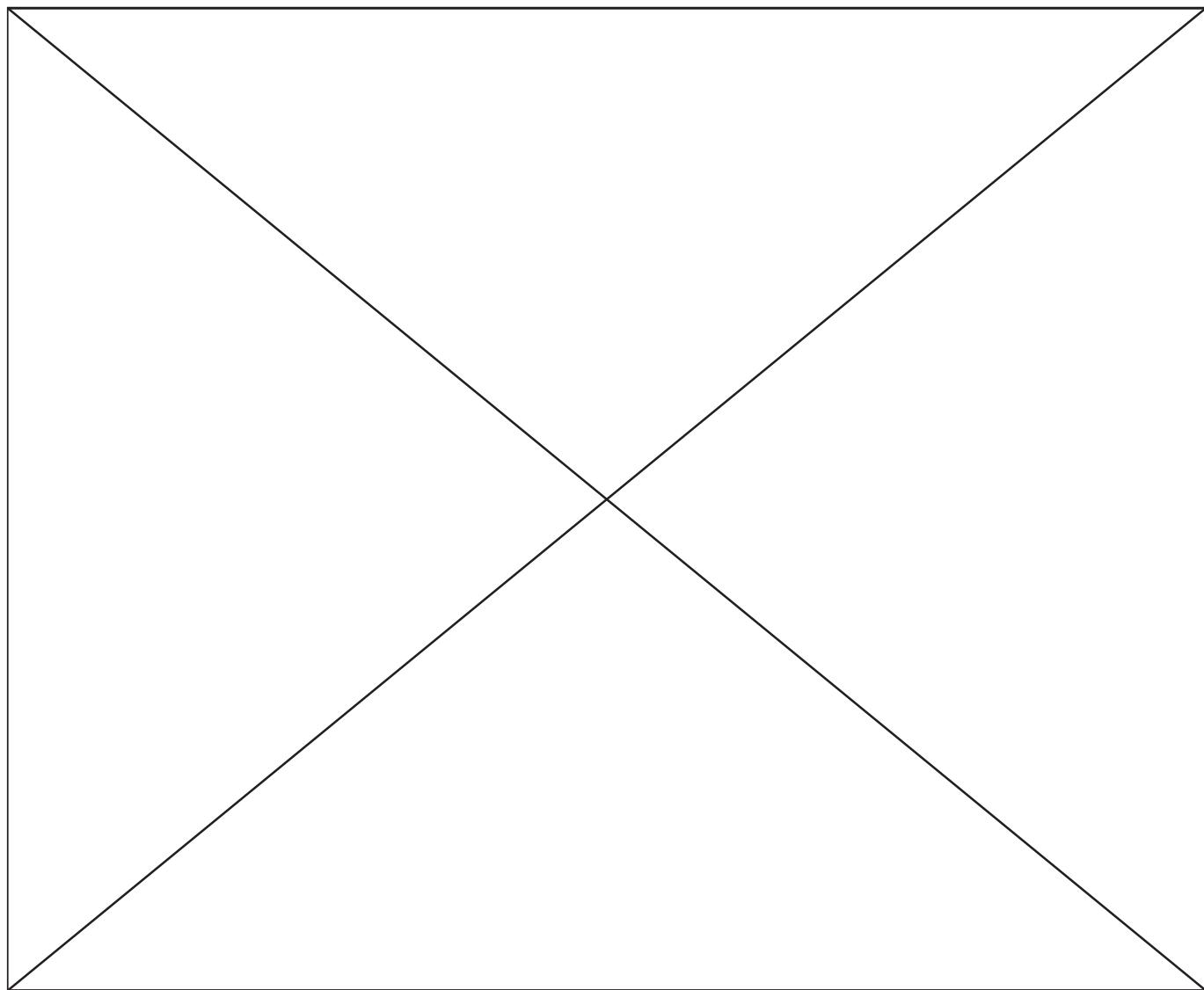
$m_{\text{constr}} \cdot l_{\text{constr}} + m_{\text{climbers}} \cdot l_{\text{climbers}}$ .  $M_{\text{constr}}$  is the total mass of the module without climbers.  $L_{\text{constr}}$  is the distance between the rotation axis and the COG of module without climber.  $M_{\text{climbers}}$  is the total mass of

the two climbers.  $L_{\text{climbers}}$  is the distance between the rotation axis and the COG of climbers. All values we find in Creo Parametric.

$M_{\text{constr}}$  is about 100 g or 0.1 kg.  $L_{\text{constr}}$  is about 93 mm. The moment of construction is about 9.3 kg\*mm. Mass of a climber is 22.7 g. Mass of two climbers is 0.0454 kg. The COG of climbers and geometrical center are in the same place, because the climbers are uniform. It is about 204 mm. The moment of gravity forces if the all module is 18.9 kg\*mm. Safety factor is 1.5. With this factor moment of module is 28 kg\*mm. The moment of module is not bigger than the maximum moment of the servo. The module will work.

## Work of module

- The dimensions of the bucket are 6x5.5x12 mm. The dimension of the main beam are 20x0.5x1.5 mm.
- The robot must stay near the button at a distance of 16.9 cm. Also, the main beam must be in the middle of the beacon. Then the robot turns the beam 48 degrees and the climbers go down. Then the robot must go forward for a distance of 5 cm. After that, the robot turns beam 42 degrees. Then the robot detects correct button and turns in its side 9 degrees. At the end the robot goes forward and presses correct button.



### 3.5 Team meetings and events

#### 3.5.1 16.11.2015

- Today it was assembled wheel base of the robot. The chain wasn't connected.

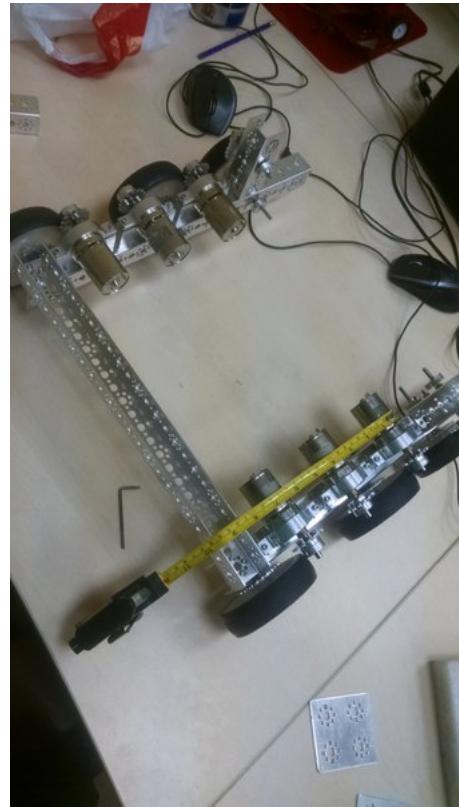


Рис. 27: Wheel base without chain

- Also it was made the gripper with plastic bottle.

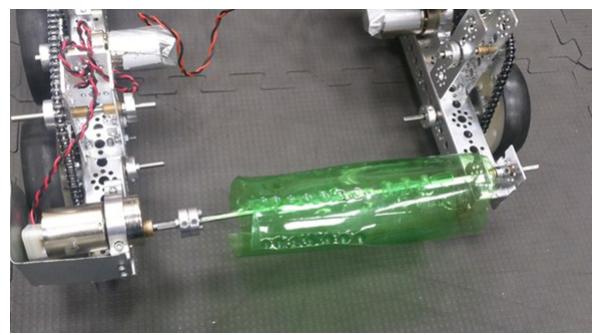


Рис. 28: Gripper with bottle

#### 3.5.2 19.11.2015

- Today the chains were connected to gears on the wheel base. It was wrote the programme for tele op and wheel base was tested on the field. Robot can move and turn fast and accurate

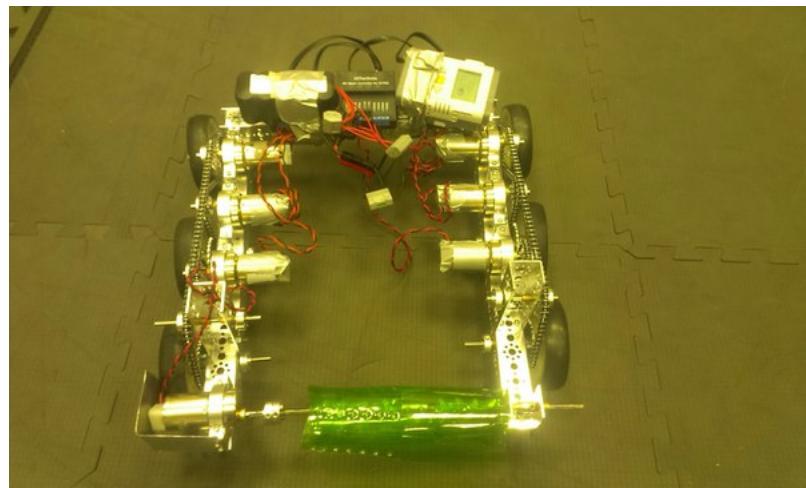


Рис. 29: Wheel base with chain

- Also it was assembled the lift. But it wasn't installed on the robot.

### 3.5.3 21.11.2015

- The trainings with wheel base were continued. Also the mount for bucket was installed on the lift.

### 3.5.4 23.11.2015

- It was made and fixed on the lift bucket for debris. In addition the lift was installed to wheel base.

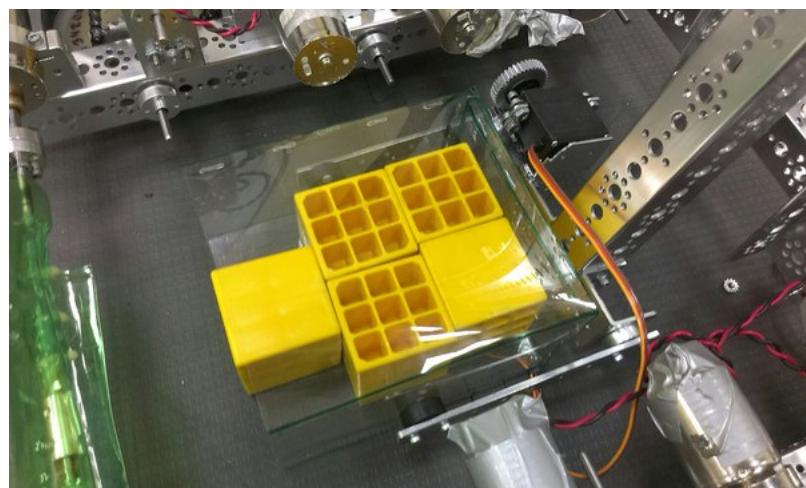


Рис. 30: The bucket for debris

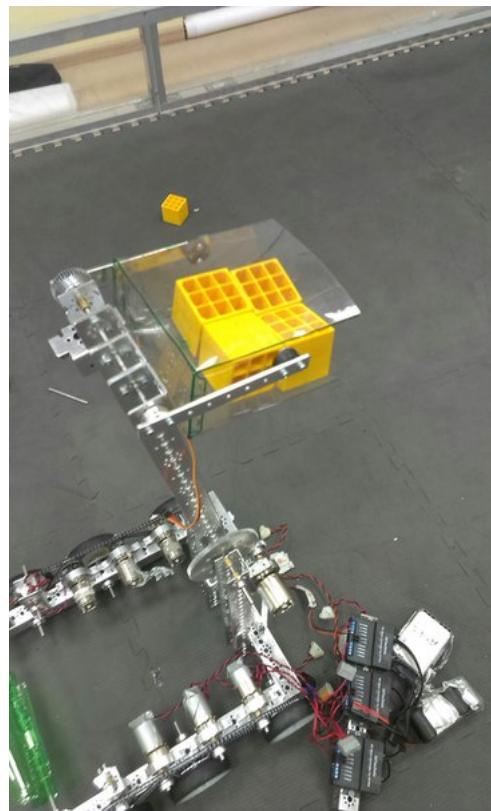


Рис. 31: The bucket on the rised position

### 3.5.5 24.11.2015

- It was found that gears on servo that turn bucket slip under the loads. So it was made the plate that doesn't allow to gears go away from each other.
- It was installed the cover for bucket.

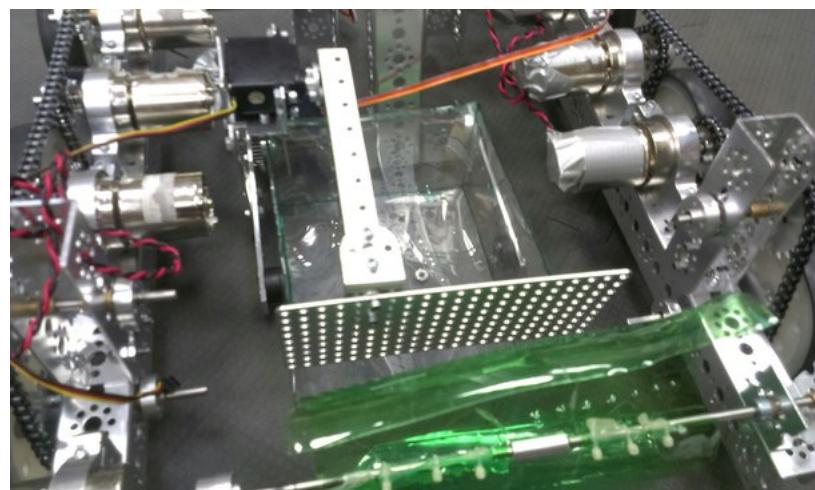


Рис. 32: Cover closed

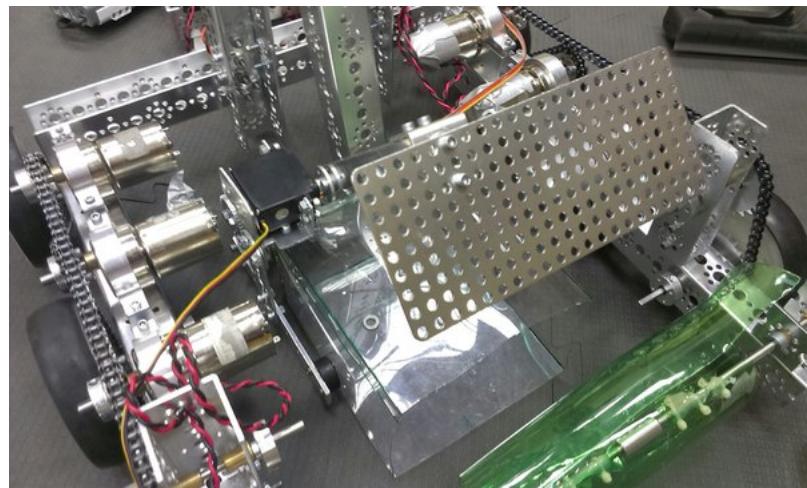


Рис. 33: Cover opened

- Also they were cut the slopes for gripper.

### 3.5.6 25.11.2015

- The slopes were installed on the robot. '
- Also today we bought the hose for gripper.
- Motor and servo controllers and NXT brick were installed on the robot.

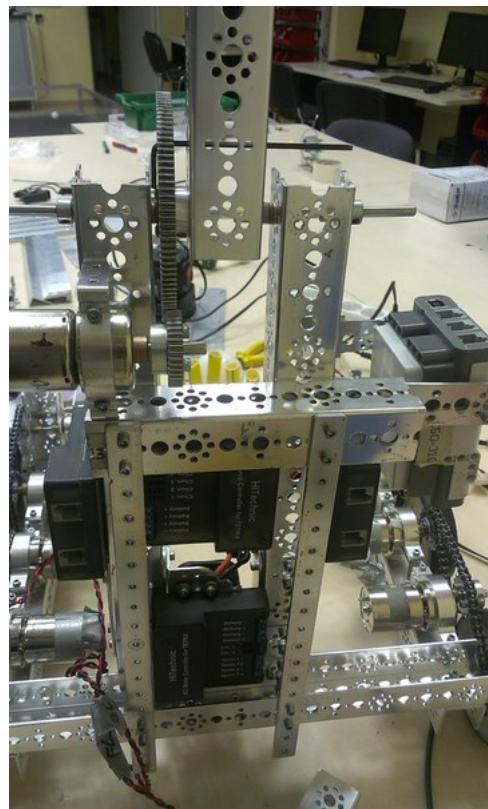


Рис. 34: Controllers

**3.5.7 26.11.2015**

- Today were hold wires of power for controllers.

**3.5.8 27.11.2015**

- The wiring of motors was hold.

**3.5.9 28.11.2015**

- It was found that the chain slip on back motors. So they were mounted so that chains touch larger sector of the gears that rotate by this motors.

**3.5.10 30.11.2015**

- The wires for servo were hold. Servos were set up. The programme for tele op was finished.
- They were connected encoder of the motor that turn lift and encoder of the right side of wheel base. The left encoder of the wheel base wasn't connected because we had not enough wires for encoder. But if we need move on straight line or turn by both wheels pairs one encoder is enough.
- The brush of gripper was remade.
- Also we tested climbing to the ramp. It was found that robot can't do it because the front wheel is too long from edge of robot. So it was decided to score only to low box on the closest competition (5 - 6 of December). That is because we haven't enough time to remake something so it is better to train score to low box and write good autonomous period (score climbers and push button). In addition we tested how robot can score to middle box if it climb to low zone. It was found that it is very hard if we turn by the robot. So we need mechanism that turn bucket to the side. It was decided to make it after the competition. In addition it was found that it is difficult to ride to middle zone. So we need make mechanism that extend moving beam so that it can reach high box from low zone. But it was decided make it after competition too.
- It was found that we can score bottom zip line climber if we push it by the bucket for debris.

**3.5.11 01.12.2015**

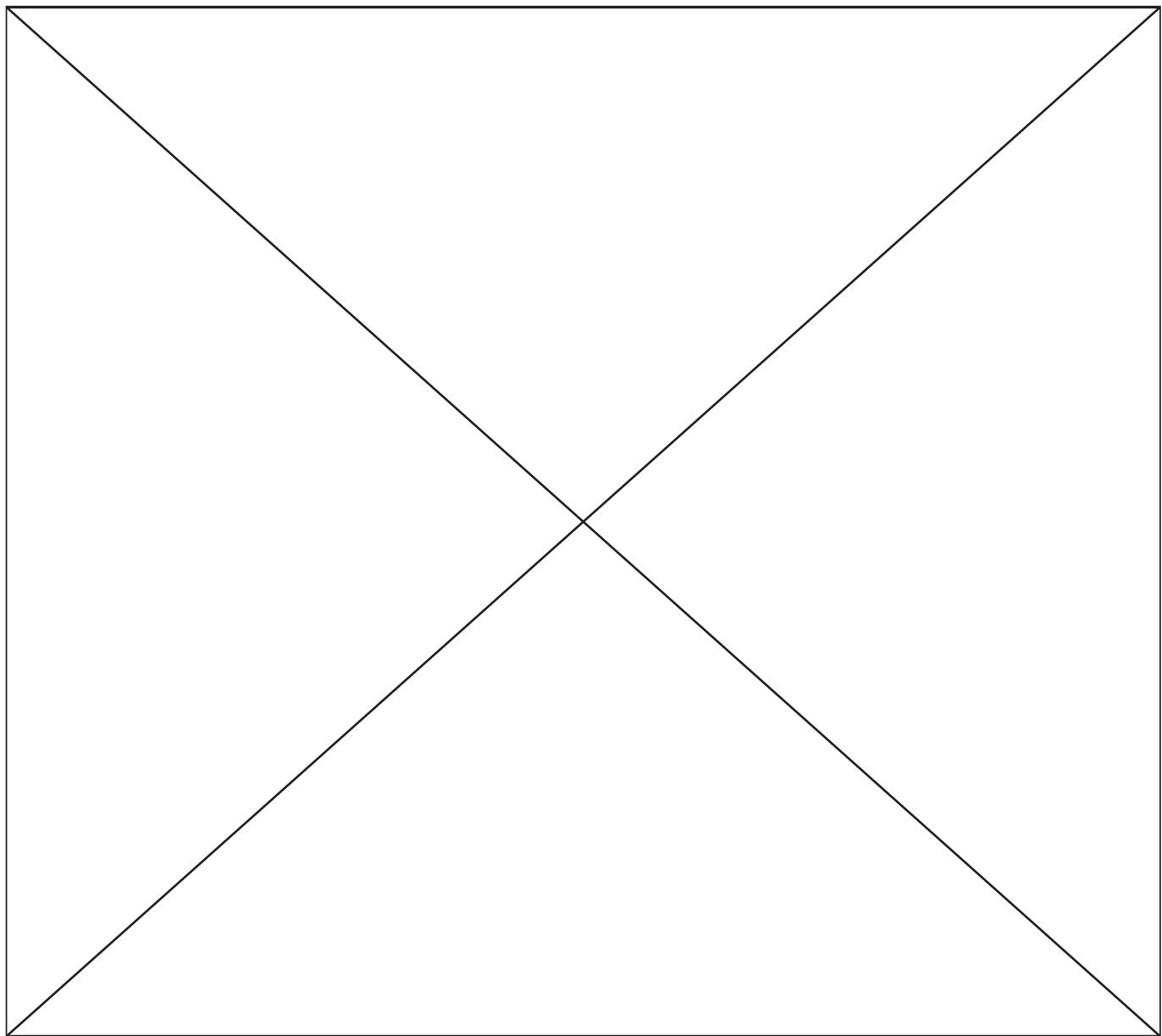
- Today operators trained on the robot control. In this process it was found that screws that fix gears on motors get out. So they were fixed with help of sealant.
- During trainings we reached the next result: full low box in 2 minutes.

**3.5.12 02.12.2015**

- Today we were writing programme for autonomous period. It was wrote riding to the button and framework for pushing button. Now robot navigates by encoders. Also it was installed F-shaped beam.



Рис. 35: F-shaped beam



### 3.5.13 "Robofest-South"(5-6 of December)

The team members who were in this competition:

1. Evgeniy Maksimychev: programmer, operator
2. Timur Babadzhanov: public relation, operator

**5 of December** Today there were trainings and judging.

- This day we made autonomous period for these actions: ride to shelter, score climbers and stay at repair zone. It give us 45 points ( $2 \times (10 + 10)$  - climbers for autonomous and teleop 5 - robot in repair zone). During this process it was found that robot can't move on a straight line accurately with one encoder due to different tensions of the chain in different sides of the robot. So we decided to remove the wire for encoder from the motor that turned the lift and connect the second encoder to the wheel base. Then we wrote a proportional regulator that gave more power to motor that turned a smaller angle than the others. It allowed to solve this problem. Also it was found that cubes and balls can prevent to working of the robot during autonomous period. So we added intake rotation that would repel debris. But if the intake rotated faster it would work better. So we needed to install a transmission for increasing speed.
- Also today operators trained on the robot control. We reached the next result: full low box and scored button climber in 2 minutes.
- In addition we communicated with other teams. There are 13 teams in this competition (including our team). It was found that we are the only team that can score into low box. The rest of the teams are able to score debris into floor goal and 2-3 teams can score button climbers. Also about five teams can climb to low zone of mountain and one to the middle.

**6 of December** Today there were qualifying and final matches.

Qualifying matches (3 matches):

1. First match. In autonomous period we got 5 points (didn't score climbers, ally hadn't autonomous). In teleop period we didn't score debris because we hadn't charged our battery so our lift didn't work. Our ally scored about 7 elements to floor goal. We lost this match.
2. Second match. 5 points for autonomous (the same situation as in first match). In teleop we scored 10 elements to low box and pushed button climber. Our ally scored about 10 - 12 elements to floor goal and partially parked in low zone.
3. Third match. We scored climbers in autonomous and stayed in zone. In teleop we scored 13 elements to low goal and pushed button climber. Also we pushed our ally to the mountain. So it was able to park in low zone. In addition our ally scored 10 elements to floor goal.

By the results of qualifying matches we became 4th. So we could choose ally for final matches. But we decided to play with team PML 30 - Y (that came 2nd) because they could push button climber in teleop and score debris to floor goal very fast, so we could concentrate on scoring to low box.

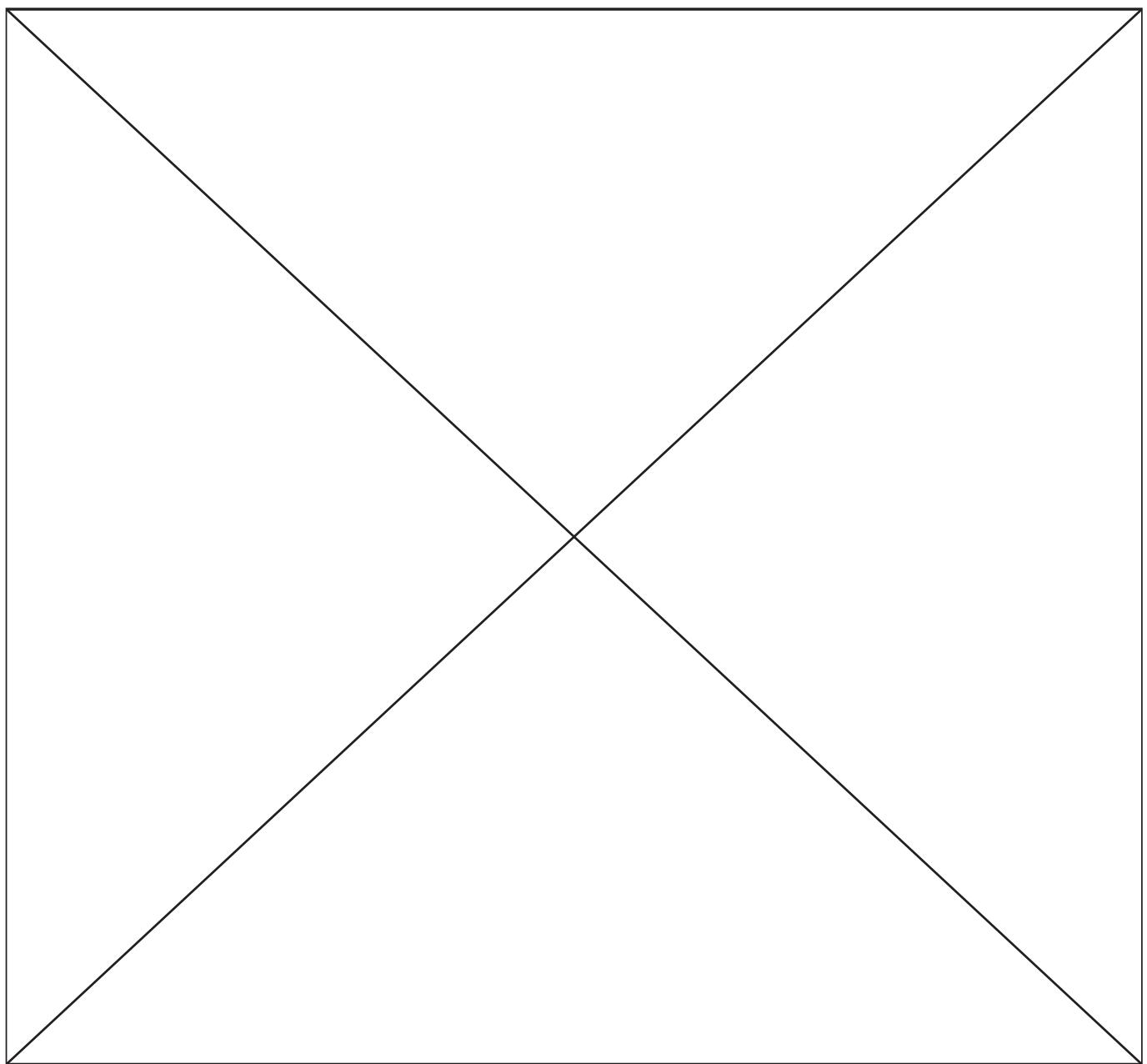
Final matches:

1. Semi final 1. We didn't score climbers in autonomous (got points only for repair zone). In teleop we scored 9 elements to low box. Our ally scored 12 elements to floor goal, pushed climber and partially parked in low zone. We scored so little debris to low box because our opponent dropped our box from the mountain and we didn't understand what should we do immediately.

2. Semi final 2. We didn't score climbers in autonomous (got points only for repair zone). In teleop we scored 13 elements to low box. Our ally scored 15 elements to floor goal and pushed climber.
3. Final 1. We didn't score climbers in autonomous (got points only for repair zone). In teleop we scored 12 elements to low box. Our ally scored 14 elements to floor goal and pushed climber.
4. Final 2. We scored climbers in autonomous and stayed in zone. In teleop we scored 11 elements to low box. Our ally scored 12 elements to floor goal and pushed climber.

Summary:

1. We scored to low box stably.
2. Programme of autonomous period worked badly (2 times from 7 matches it worked).
3. In general mechanisms worked stable. But one motor that turn lift had broken (reductor failure). Also during one match the chain fell due to collision with other robot.



**3.5.14 8.12.15**

Today we discussed results of competition and improvements that we should make in the robot  
Problems and solutions for each module:

1. Wheel base:

Problem	Solution
Can't climb to mountain	To move front wheels forward
Chain isn't protected	Install protection of plexiglass or metal

2. Lift and bucket:

Problem	Solution
Bucket don't turn to side	To make mechanism that turn bucket to side
Lift can't reach high box from low zone	To make mechanism that extend moving beam of the lift
Reducer of the motor that move lift broke	To fix axis of the motor more rigidly

3. Gripper for debris

Problem	Solution
Rotates too slow	To install transmission with gear ratio 1:2

4. Mechanism for scoring climbers

Problem	Solution
Climbers sometimes get stuck in bucket	To extend bucket or make it narrower and put climbers on each other

5. Also we need to improve programme of aotonomous period. It was decided to turn with help of gyro or compass sensor.

6. In addition during one match NXT brick fell off. So we need fix it more reliable.

**3.5.15 9.12.15**

- It was estimated place for front wheels.
- It was started designing of mechanism that turn bucket to side.

**3.5.16 10.12.15**

- It was finished designing mechanism for turning bucket for debris to side.
- Bucket on F-shaped beam was extended. So climbers don't get stuck in it.

**3.5.17 12.12.15**

- Front wheels were moved forward.
- Mechanism for turning bucket to side was assembled but servo that move it wasn't installed.

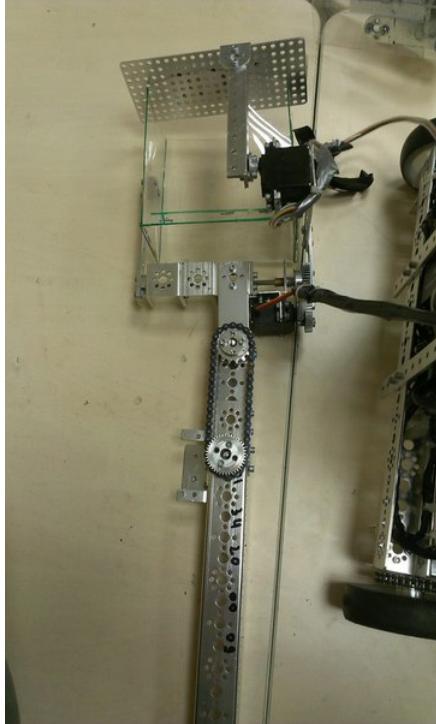


Рис. 36: Mechanism for turning bucket to side

- It was started assembling new gripper for debris.

**3.5.18 14.12.15**

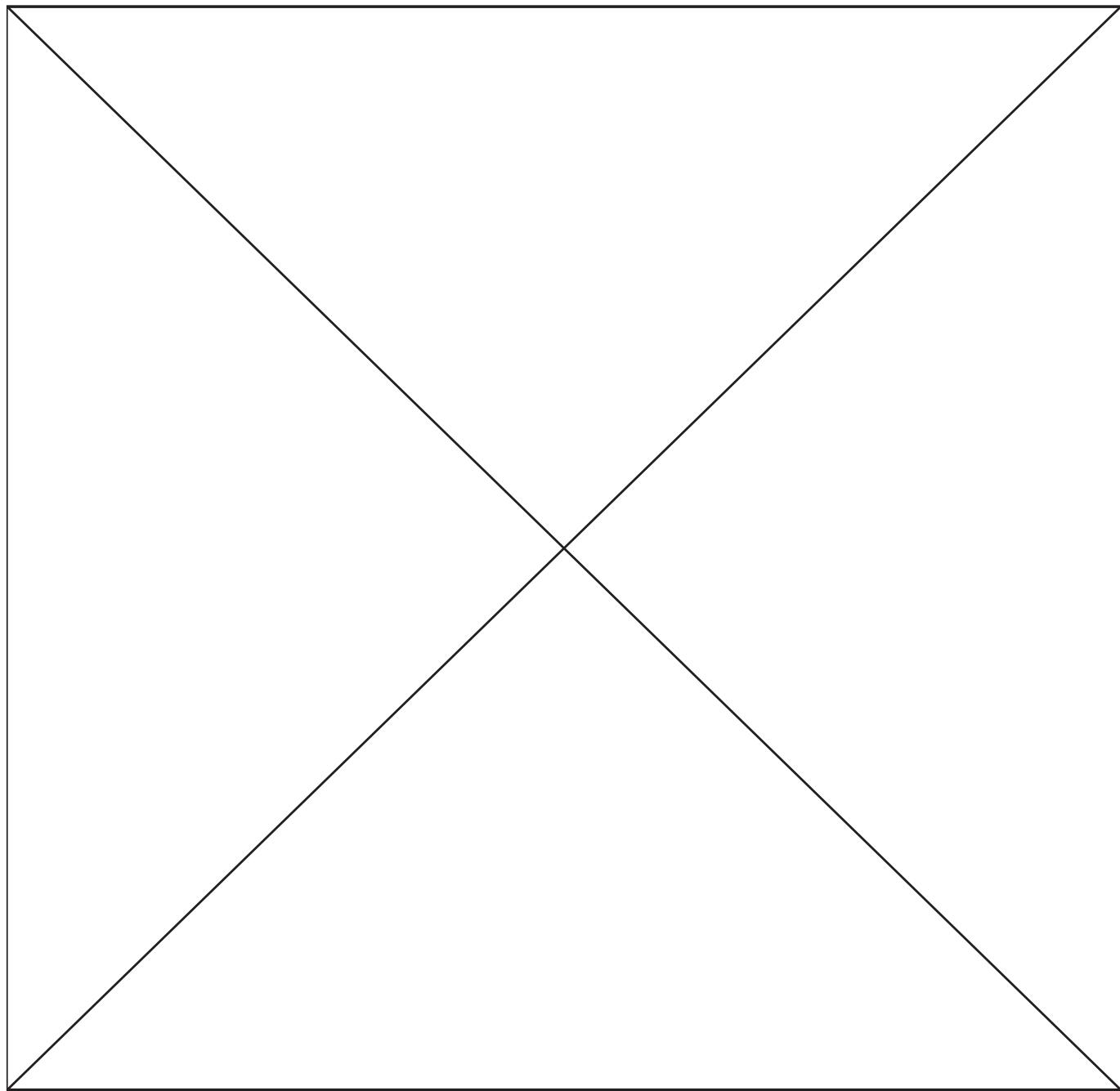
- Climbing to mountain was tested. Robot can reach low zone. It was decided install Lego caterpillars for better traction. After that robot was able to climb to low zone and overcome bottom obstacle by the back wheels. Also it was found that if we move central wheels forward so that back wheels touch second obstacle before central wheels touch first obstacle (now central wheels touch bottom obstacle first) robot most likely will be able to climb to middle zone.
- It was started installing new gripper for debris.

### 3.5.19 15.12.15

- It was installed servo that turn bucket to side.
- The axis of the motor that move lift was fixed rigidly.
- It was installed protection for chains.

### 3.5.20 16.12.15

- It was held wiring for servos that turn bucket.
- The gripper for debris was installed.



### 3.5.21 "Robofest-Ryazan"(19-20 of December)

The team members who were in this competition:

1. Evgeniy Maksimychev: programmer, operator
2. Timur Babadzhanov: public relation, operator

**19 of December** Today there were training matches

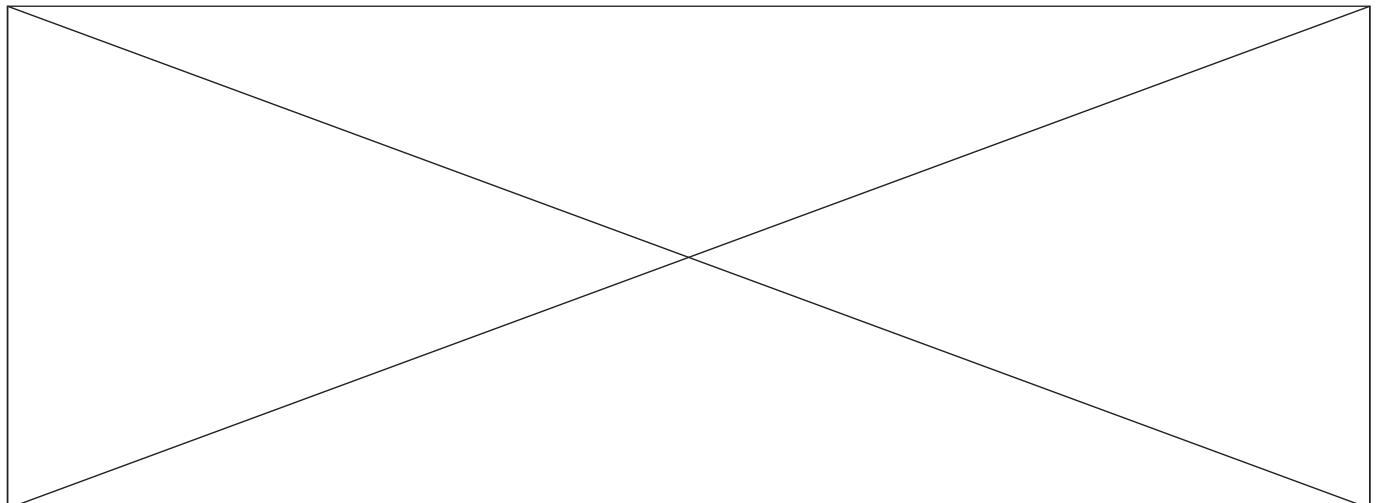
- Wiring for servos finished. Servos set up.
- Gripper with speed transmission 1:2 tested. It was found that it can't grip elements because brush is too rigid and the motor can't turn. So it was decided to make transmission 1:1.
- Also we debuged the program for autonomous period that scores climbers.
- During the trainings of teleop period it was found that robot still couldn't climb the ramp. The robot could reach the first churro but after that it slipped down. We didn't understand why it happened. To solve this problem we tried to remove the treads from the back wheels. We thought that it lifted them and the distance that robot must rise for climbing to first churro would reduce. But it was not enough. So during the matches we scored only to low box.
- Also we communicated with other teams. There were 3 teams (not counting ours). Nobody had a program for the autonomous period and nobody was able to score debris to boxes.

**20 of December** Today there were qualifying and final matches.

We won 3 of 4 qualifying matches. One match we lost because the chain on the wheels base came off. So we became 3 by the results of qualifying matches and played final match and won it.

Summary:

1. During matches we scored about 10 debris for match (worse than in "Robofest-South").
2. There was a problem that chain on wheel base came off. Maybe that's due to bias of it. Other mechanisms worked stably.
3. In addition we saw competitions of RC cars and payed attention on their wheels. They are very soft. Maybe if we install similar wheels on our robot it would help us climb the mountain. They will bend when robot gets to the churro and so robot don't get stuck, as with rigid wheels.



**3.5.22 22.12.15**

Today we discussed improvements in robot that we should make.

Problems and solutions for each module:

1. Wheel base:

Problem	Solution
Can't climb to mountain	To try soft wheels or make mechanism that hook churro when we reach it
Chain come off	To fix displacements of gears

2. Lift and bucket:

Problem	Solution
Bucket can't reach boxes to side	To test and think about solution
Lift can't reach high box from low zone	To make mechanism that extend moving beam of the lift
The bottom of bucket is frayed	To make spare bottom part

3. Gripper for debris

Problem	Solution
Brush is too rigidly	To install more soft tubes
The axis is too close to bucket and prevent it's moving	Move it forward
When it rotates the robot shakes	To install in front part of robot beam that bond two beams where fixed wheels

4. Mechanism for scoring climbers - no problems.

5. Programme of autonomous period

Problem	Solution
There is no pushing button	Do it
Robot move not accurate	Make turnings by compass and move by white line when we ride to shelter

**3.5.23 23.12.15**

- It was tested mechanism for turning bucket to side. It was found that it can't reach box. It was decided to change a cover so that cubes slide on it to the box.

- It was invented mechanism of extracting lift (hereinafter it will call MEL) with construction profile.
- Also today we met with other FTC team from St-Petersburg. They came to our robotics laboratory, tested their robot on our field. In addition we discussed some technical solutions and we gave them an advice how improve their robot.

### **3.5.24 26.12.15**

- It was came up with mount for construction profile to Tetrix beam.
- It was made the test sample MEL with construction profile.

### **3.5.25 04.01.15**

- The compass sensor was installed to robot. It was made turning by compass.
- We found that we can't make MEL with construction profile and decided make lift with retractable slats.

### **3.5.26 05.01.15**

- It was wrote programme for moving by line.
- It was made gripper with less rigidly tubes.
- It was made programme of autonomous period for scoring climbers with using compass and light sensor. It worked stable (we tested 5 times and it worked in all cases).

### **3.5.27 06.01.15**

- It was removed lift and controllers.
- It was wrote programme for pushing button. Since the controllers of robot were removed it was tested and debuged on the Lego robot. So an algorithm is ready and we'll need to debug it on the FTC robot.
- It was made and installed on the robot tested sample of the lift with retractable slats.
- It was decided to install controllers on the list of plywood that fixed on the side of the robot.



Рис. 37: Lift and new mount for controllers

### 3.5.28 10.01.15

- Today there was discussing of results of the last week.

1. Wheel base:

Problem	Solution
Can't climb to mountain	To make mechanism that hook churro (because we didn't find other wheels that we can use)

2. Lift and bucket:

Problem	Solution
Lift can't reach high box from low zone	To make mechanism that extend moving beam of the lift (it was decided to refuse from the lift with retracatable slats)

3. Gripper for debris - no problems.
4. Mechanism for scoring climbers - no problems.
5. Programme of autonomous period works but there is possible problem that it won't find the line.
6. In addition we need to finish electricity and make protection for controllers.

#### **3.5.29 12.01.15**

- It was invented MEL with retractable slats. It was came up with way to mount slats to Tetrix profiles.
- We started assemble new lift. The motor and gears for transmission 6:1 were mounted to stationar beam.

#### **3.5.30 13.01.15**

- It was assembled moving beam of the lift that consists of two Tetrix beams that connected by slats.
- Lift was assembled and installed to robot. Bucket wasn't installed because we hadn't enough elements(we need servo joint pivot brackets).

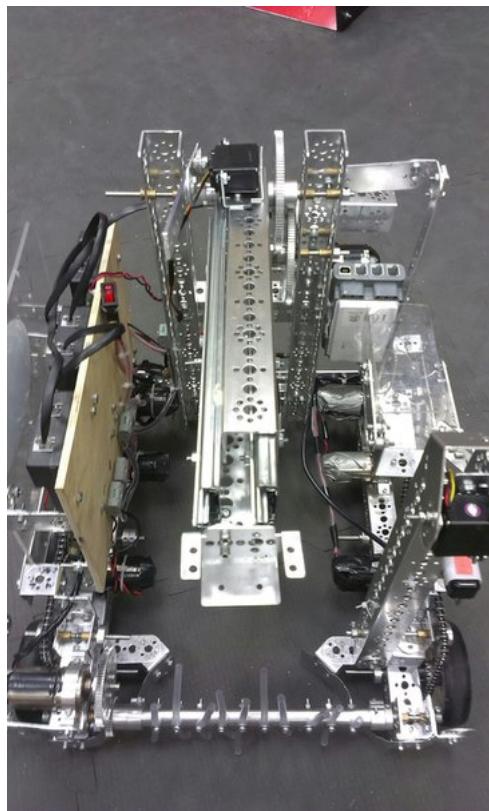


Рис. 38: New lift (lowered position)

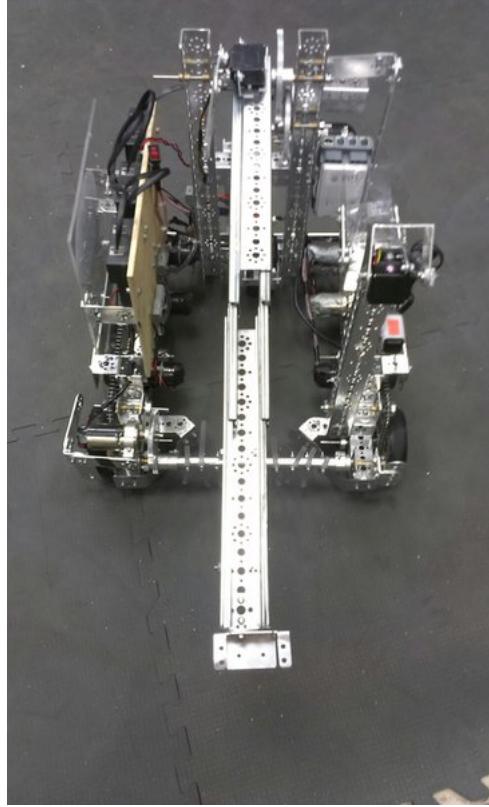


Рис. 39: Rised position

- It was invented idea with small wheels that rise robot when they balk the churro.

### **3.5.31 14.01.15**

- It was hold wires for controllers power.

### **3.5.32 16.01.15**

- They were mounted small wheels that provide climbing to mountain.

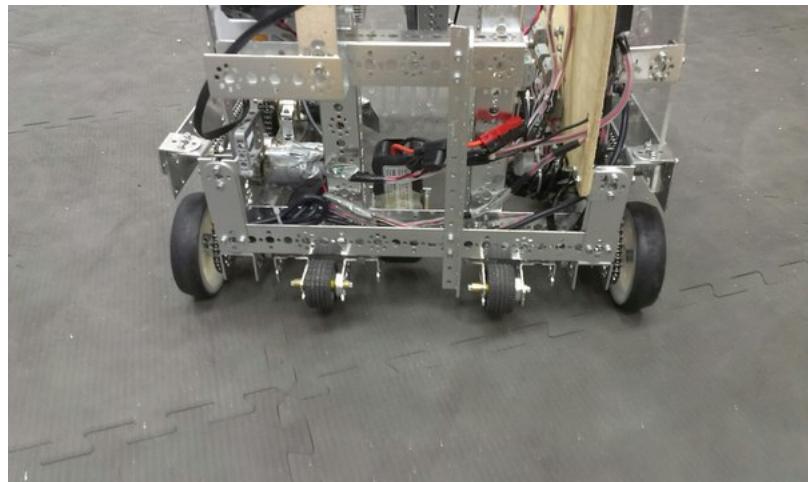


Рис. 40: Small wheels for climbing

- It was hold wires for motors power.

### **3.5.33 18.01.15**

- It was tested climbing to mountain. Robot can't climb because it rise by wheels on too smal height. So it was decided slightly lower them. After that robot was able to climb to low zone and hook by back wheels to first churro. But robot must stay at a slight angle to churro for climbing so that firstly it climb by one wheel pair then - by other. So operator that control robot's movement should train to climb to the ramp.
- In addition it was made plexiglass protection for controllers.

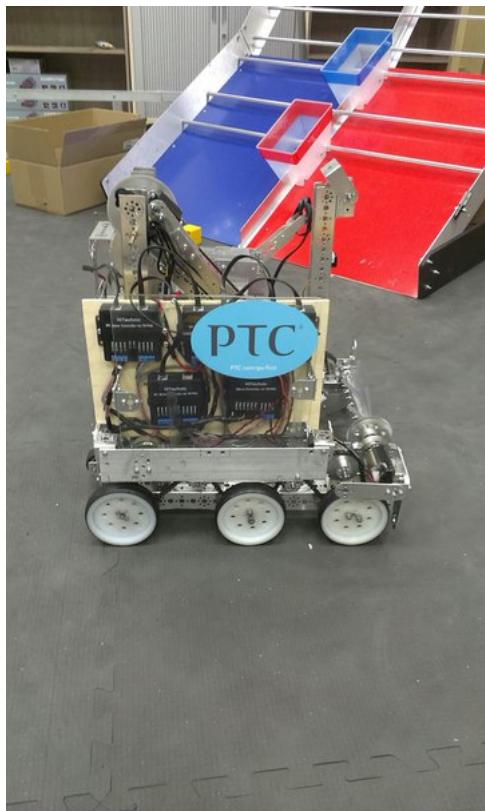


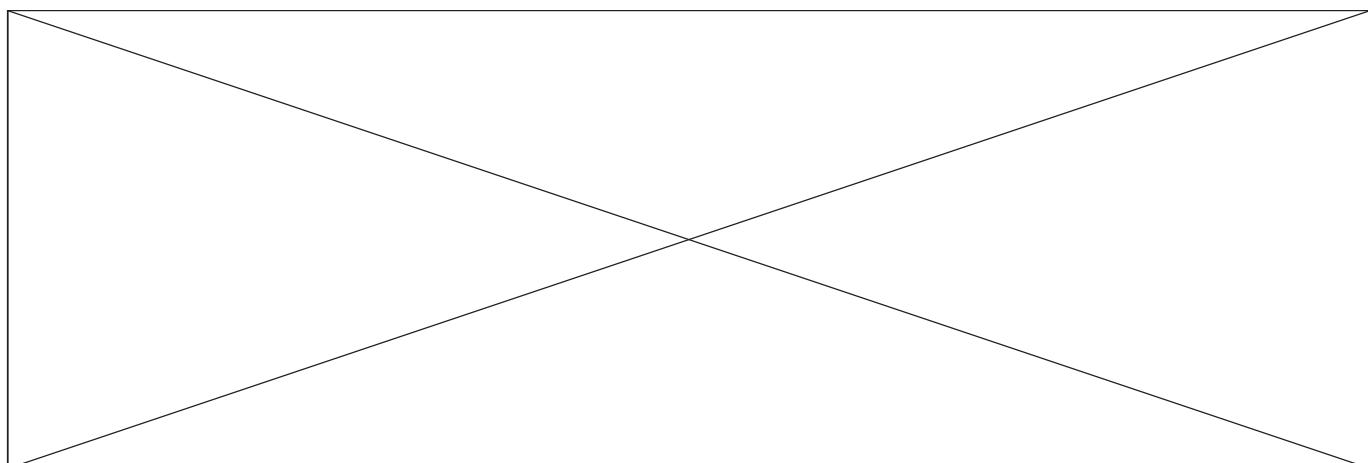
Рис. 41: Protection for controllers

### 3.5.34 20.01.15

- Today we trained in climbing to mountain. During it one caterpillar torned. So we need remove them and test climbing without caterpillars.

### 3.5.35 21.01.15

- Caterpillars were removed from wheels and it was tested climbing to mountain. It can move through the first churro by back and middle wheels. After that it can't move because beams on which mounted wheels touch churro. So we need to whittle down bottom part of it.



### 3.5.36 PML30 Scrimage (23.01.16)

The team members who were in this competition:

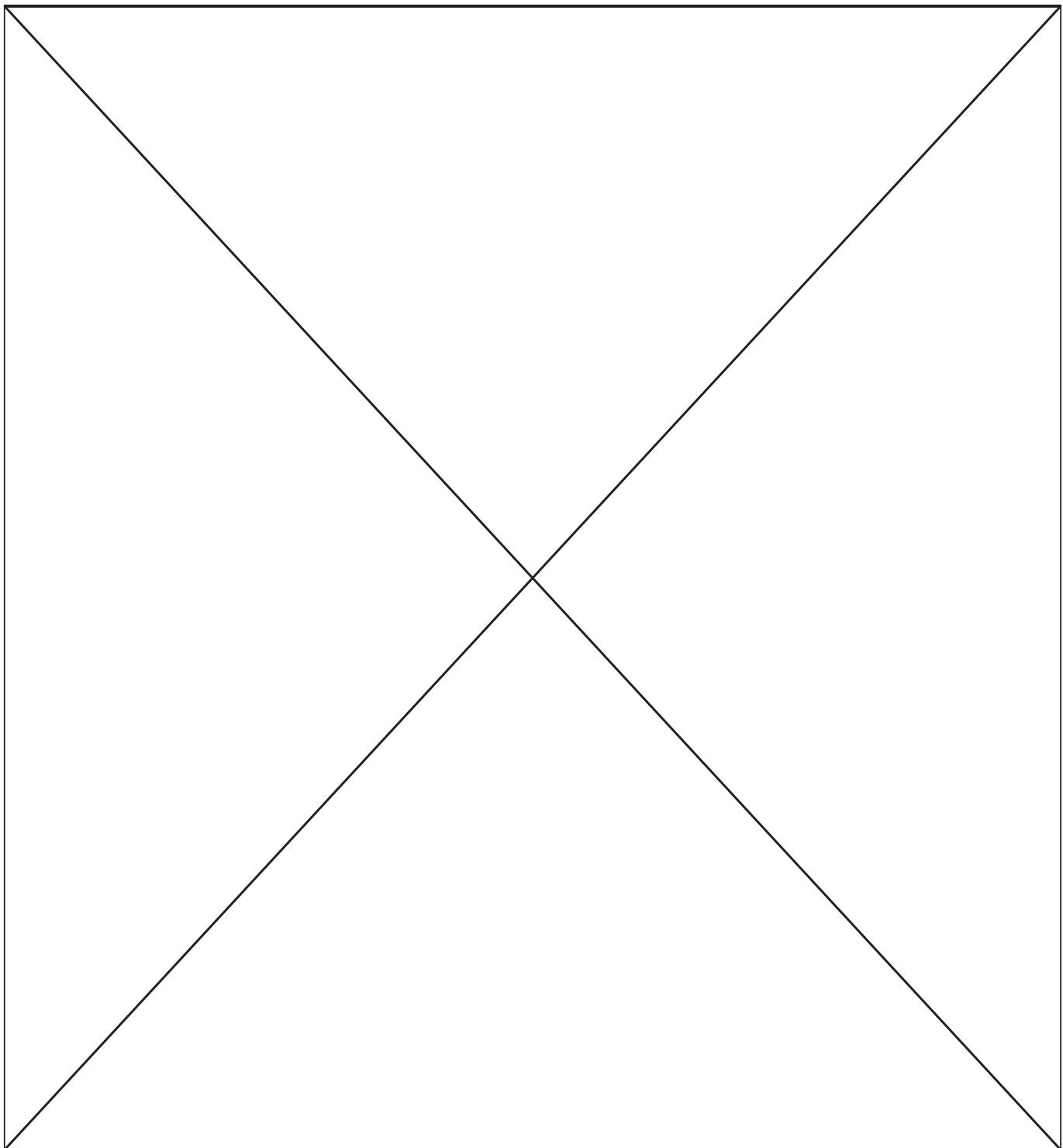
1. Evgeniy Maksimychev: programmer, operator

2. Timur Babadzhanov: programmer

3. Victoria Loseva: operator

There were 3 teams here (including ours). So it was decided play matches 2x1. Nobody couldn't score debris to boxes. But we had the advantage that we had a good autonomous period (other teams didn't).

We won all qualifying matches and decided play final matches alone. During final matches autonomous period didn't work in both rounds because debris get under the robot's wheels and it couldn't move normally. But we still won because in first round our opponent got 2 penalties due to controlling more than 5 debris elements. In the second round our opponent got 1 penalty, but even if they hadn't gotten it, we still would have won. That's because we pulled out debris from their floor goal before end game.



**3.5.37 25.01.16**

Today we discussed improvements that we need make in our robot Problems and solutions for each module:

1. Wheel base:

Problem	Solution
Cudes gets under the wheels	To make protection for wheels
Small wheels dents when robot try ride trough the churro	To fill tires with something rigidly
The beam on which fixed axles of wheels hook churro	To cut it

2. Lift and bucket:

Problem	Solution
MIL isn't finished	Finish it when we'll get necessary elements

3. Gripper for debris - no problems.

4. Mechanism for scoring climbers - no problems.

5. Programme of autonomous period - no problems.

6. In addition we need mount NXT lower because mechanism for scoring climbers hook it.

7. Also we need to remake electricity for new Android platform when we'll get Android devices, Core power module and controllers.

- Wheels were filled with cardboard.
- The beam that hook churro was cut.
- After this improvements robot was able to ride through first churro by two wheel pairs. But the front wheel pair can't do it. We thought that if we'll install caterpillar on front wheels or small rollers that will rise them robot will be able climb to middle zone. But it was decided test it after completing all rest tasks.

**3.5.38 26.01.16**

- Today we got necessary elements for mounting bucket and turning mechanism for it. It was found that during elaborating of lift it was made a mistake in estimating of beam's length (necessary length is smaller on 0.5cm). So we need to rise the lift. But in this case we need change transmission (install smaller gears) because else height of robot will be more than 45.72cm.



Рис. 42: Mount of bucket

- It was installed the protection for wheels.
- NXT was fixed lower.

### 3.5.39 27.01.16

- It was decided make transmission 8:1 (three-stage transmission each stage - 2:1). It allowed us to mount rotation axis of moving beam of lift higher.

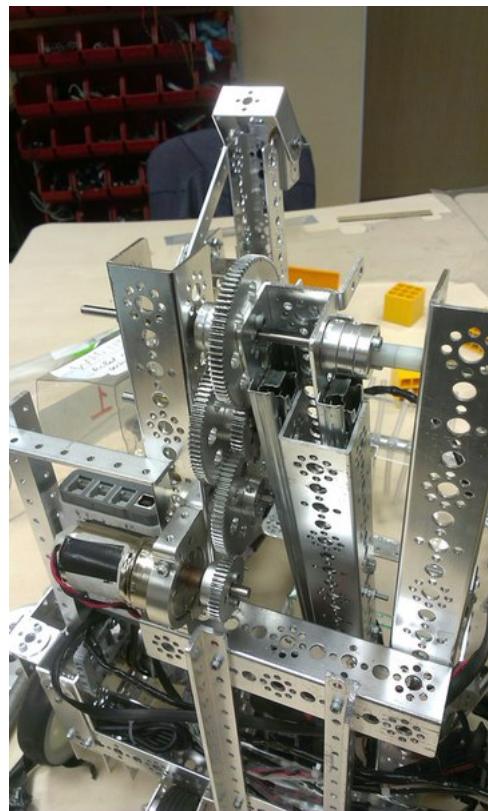


Рис. 43: New transmission

**3.5.40 28.01.16**

- Servos were connected to controllers.

**3.5.41 30.01.16**

- Today we got servo for MEL. MEL was assembled but during test it was found that servo is not able to extract lift. We need install second servo or invent other solution.
- Also it was found that motor that turn lift can't do it when it extracted. Maybe that's because of the failure of the motor.

**3.5.42 01.02.16**

- It was installed Andy Mark motor for turning lift. It can move it even if lift extracted.
- It was invented MEL with blocks.
- Reel for MEL and servo that rotate it were installed. The rope wasn't installed because we hadn't it today.

**3.5.43 03.02.16**

- They were fixed blocks and rope for MEL. MEL was tested. Result is positive: servo is able to extract lift in 2 seconds.

**3.5.44 04.02.16**

- They were hold wires for servos.
- Servos were set up.

**3.5.45 08.02.16**

- During tests it was found that robot can score debris to high goal very bad. So it was decided to score only to middle and low goal.

**3.5.46 9.02.16**

- Today operators trained in the control of the robot.

**3.5.47 11.02.16**

- Today it was FTC scrimmage in our robotics center.
- We understood that operators are very bad at robot control now. During 8 matches we were able to score maximum 5 cubes in 2 minutes.

- It was found that during autonomous period cubes get under the robot and it can't move. So it was decided install protection that made of plastic 0.5mm. It mounted on a small height from the floor so it doesn't allow to cubes get under the robot. But it's not prevent to climbing because it can bend.

### 3.5.48 12.02.16

- We decided to start move to new Android platform. It was written and tested programme for control one servo that connected to new servo controller and one motor that connected to Hi-Technic motor controller through Legacy module. We decided use 1 new servo controller, 4 Legacy motor controller and 1 new motor controller for get values of encoders because it's too slow to get encoders value from legacy controllers. We can't use new motor controllers for control motors because we haven't got connectors in order to plug them.

### 3.5.49 13.02.16

- Today operators played 6 training games where we scored debris to middle goal. Each game is 2 minutes time. The best result - 95 points middle - 45 points.
- During trainings it was found that gears on mechanism that turn bucket up and down slip. So it was remade without gears.

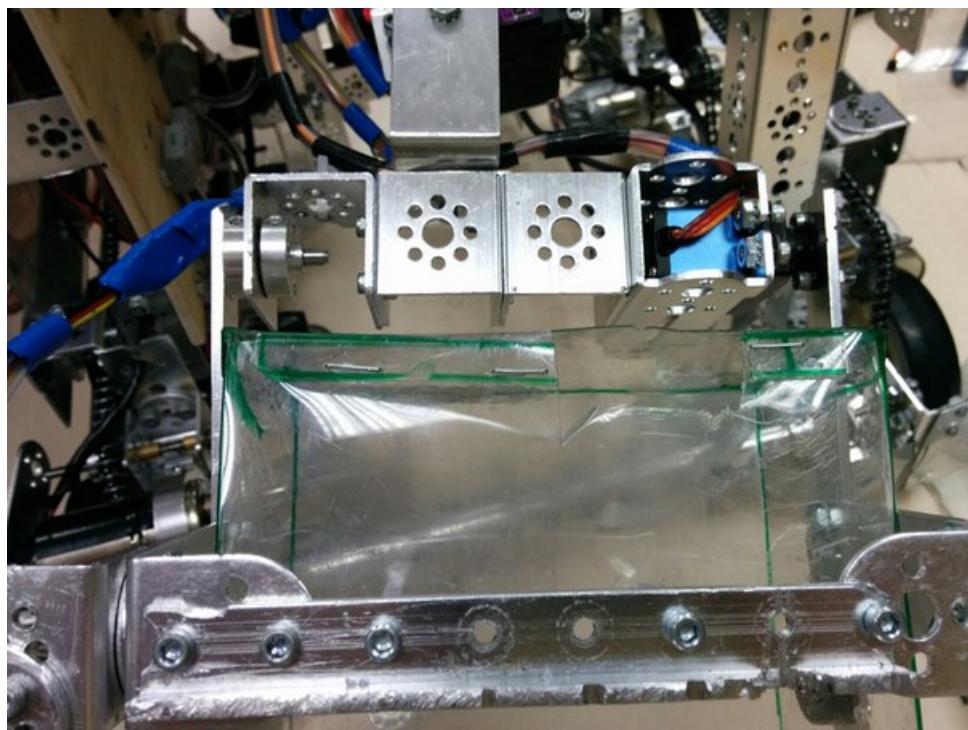


Рис. 44: Changed mechanism for turning bucket

- In addition it was installed Core Power Distribution module and Legacy module.

### **3.5.50 14.02.16**

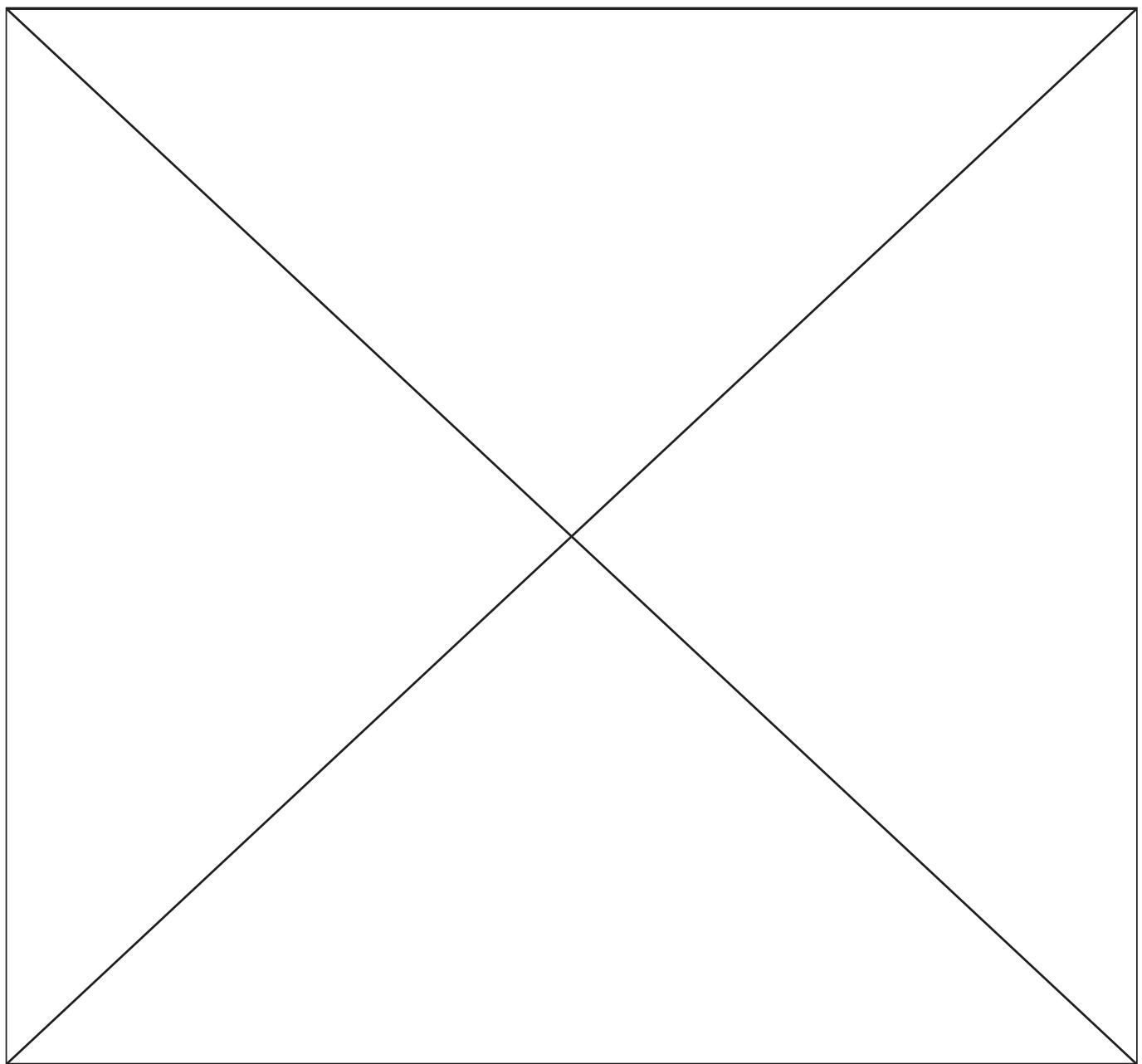
- Today operators played 23 training games (2 minutes each). The best result - 135 points middle - 70.
- In addition it was made mount for Android device.

### **3.5.51 15.02.16**

- We started translate programme of tele op in RobotC to Java.

### **3.5.52 16.02.16**

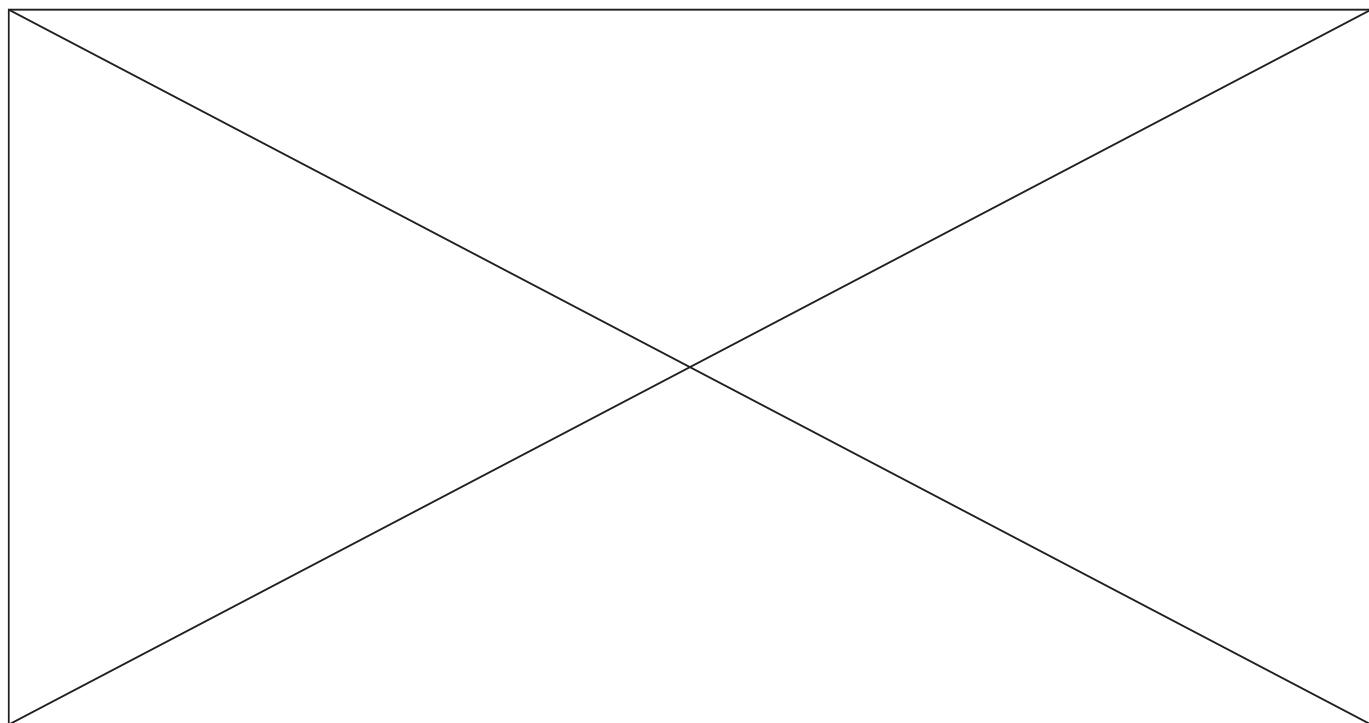
- Today we finished programme of tele op for new platform.



## 4 Appendix

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

1. List of PET 0.5mm.
2. Tape and cable screeds.
3. List of plexiglass 4mm.
4. List of galvanized steel 0.5mm.
5. Aluminium plates.
6. Aluminium L-shaped profile.
7. Rubber hose.
8. Servo MG995.
9. Plywood.
10. Wires 1.5mm.
11. Foam.
12. Lego wheels.
13. Andy Mark Neverest motor.
14. Servo S4315R.
15. Servo F5519M.
16. Rope.
17. Blocks.



## 5 Business plan

1. Resources that we had at the beginning of season 2015-2016:
  - 1.1. 4 basic Tetrix Max kits
  - 1.2. 4 resource Tetrix Max kits
  - 1.3. 12 Andy Mark Neverest motors
  - 1.4. 10 Tetrix motors (except motors that contain basic lists)
  - 1.5. Tetrix Max chains and gears for them
  - 1.6. 8 Tetrix Max 4 inch omni-wheels
  - 1.7. 25 servos MG 995
  - 1.8. 4 Tetrix Max Battery packs (separated from kits)
  - 1.9. Tetrix Max caterpillars
  - 1.10. Box for robot and elements
  - 1.11. Matrix resource kit
  - 1.12. 2 joysticks Logitech F310
  - 1.13. Raw materials (aluminium profiles, plexiglass, list of PET)
  - 1.14. Lego Light, Touch and RGB Sensors
  - 1.15. Hi-Technic Compass, Gyro and Color sensors
2. Equipment of our engineering laboratory:
  - 2.1. Drilling machine.
  - 2.2. 3D printer.
  - 2.3. Laser cut machine.
3. New components that were purchased during this season and how much money we spent on it:
  - 3.1. FTC RESQ playing field - 106000 rubles
  - 3.2. New Android system (3 Modern Robotics Electronic Modules and Sensors Kit + 2 phones ZTE Speed) - 178000 rubles
  - 3.3. Another one box for robot and elements - 4500 rubles
  - 3.4. 2 Servo S4315R - 4000 rubles
  - 3.5. 1 Servo F5519M - 3000 rubles
  - 3.6. Wires 1.5mm - 720 rubles
  - 3.7. Consumable materials (tape, cable ties) - 500 rubles
  - 3.8. Tetrix components - 70000 rubles
  - 3.9. Rubber hose - 500 rubles
  - 3.10. USB hub - 700 rubles

3.11. Aluminium construction profiles - 4200 roubles

3.12. Blocks - 800 roubles

3.13. Rope - 180 roubles

3.14. Furniture slats - 300 roubles

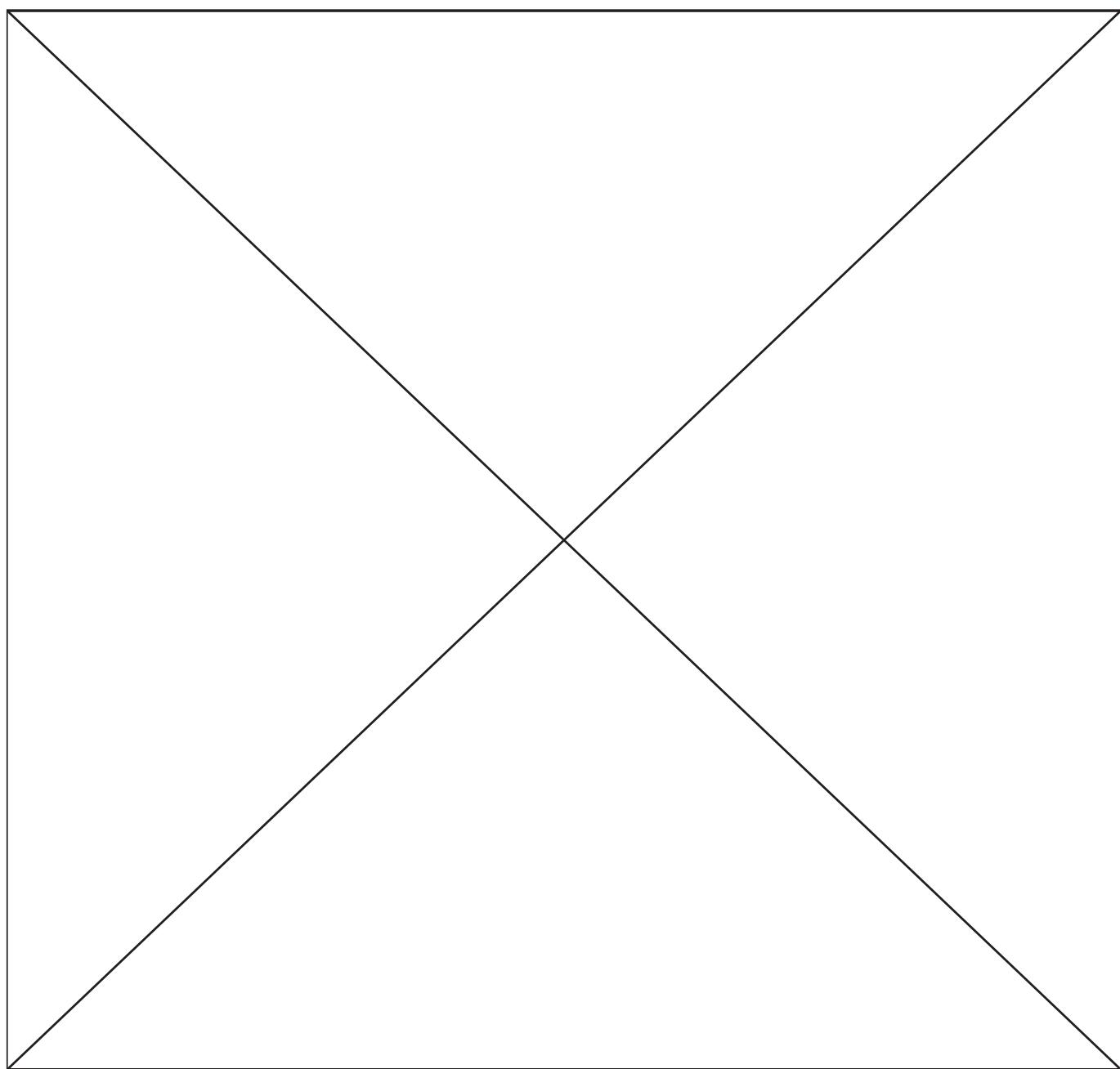
3.15. Workbench and vise 23500 roubles

3.16. Joysticks Logitech F310 - 6000 roubles

4. Competitions:

4.1. Trip to "Robofest-South" in Krasnodar - 38500 roubles

4.2. Trip to "Robofest-Ryazan" 16100 roubles



## 6 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 and setting new goals for ourselves in order to improve. This is our first year taking part in FTC and we will participate next year as well. If we don't realize ourselves this year, we'll look at all our mistakes, correct them, and perform 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 endeavors.

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

Team PML 30 X

