1 How to read this book

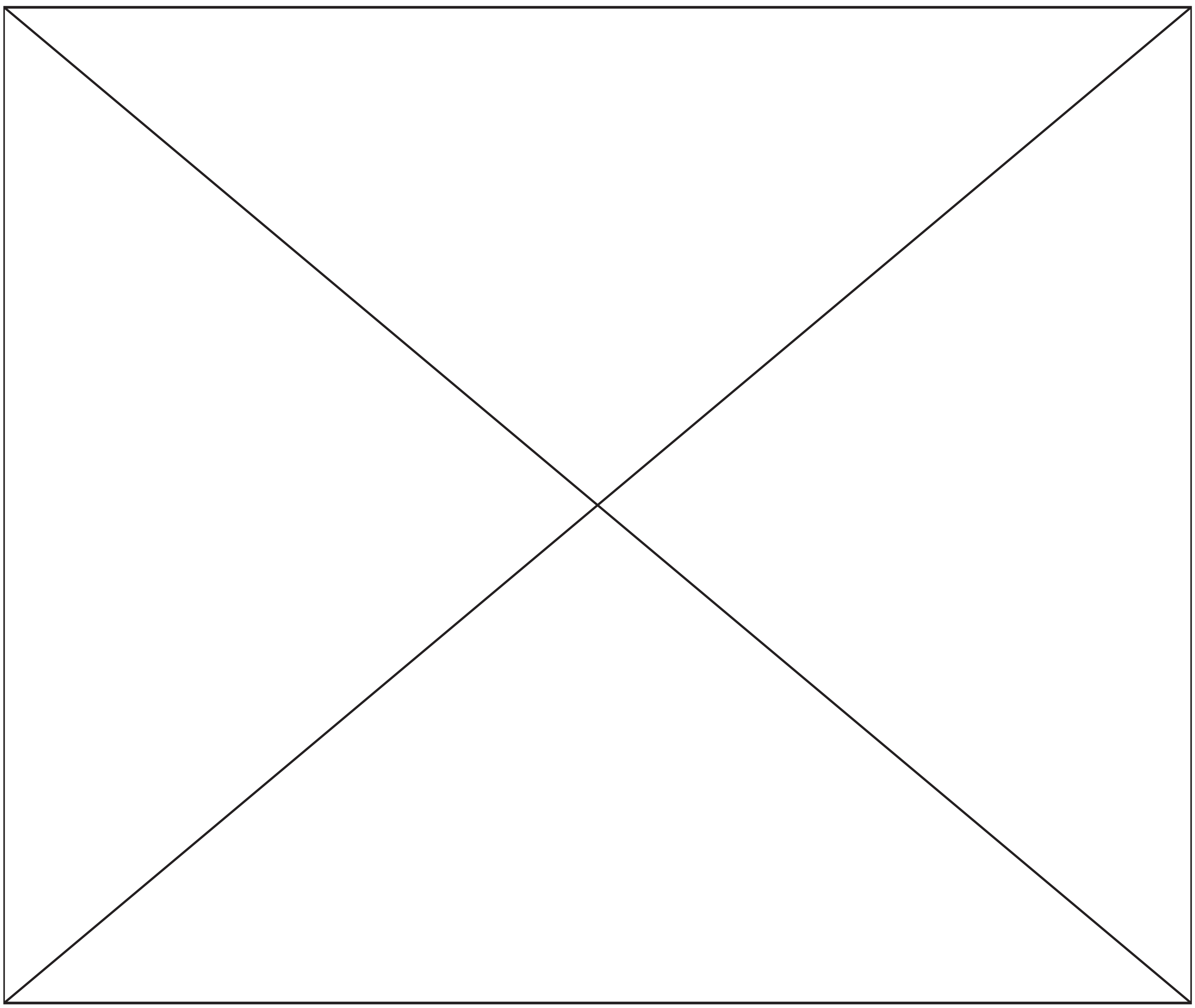
The book consists of 3 chapters.

1. The first is an introduction, here are represented our team, our instructors, our sponsors.

2. The Engineering chapter consists of two parts: consequence of meetings, which show our progress in elaborating and particular documentations for each module and for tele-op and autonomus programs. This approach allows to show the engineering process from two sides: a chronological one and an engineering one.

3. Appendix includes the list of materials applied in our robot.

Here is the detailed structure of Engineering chapter. Sections 1 to 3 show thinking over the project and on-paper calculations and design. Section 4 shows the development of real robot. Sections 5, 6 include specifications for modules and programmes.



2 Business plan

2.1 introduction

We take a responsible approach to finding sponsors. And also try to spend money effectively advance thinking through the details and equipment, finding ways to get them maximum benefit. Some sets we received as prizes in competitions.

2.2 Our sponsors and their support

2.2.1 PTC and Irisoft

PTC and Irisoft representative in Russia is the one company that has helped us to begin to engage FTC. They provided us the first set of Tetrx within the program's Score Thehnic which involved our Lyceum. They provide us with a different command symbols plus small gifts for other teams. They help us with the delivery of details from U.S.A. We use them programa Creo for creating 3D models. We also take part in events organized by them.

2.2.2 Robofinist

Robofinist Charitable Foundation organized by Temur Amindzhanov and by Starline. They offered us its assistance as an organization in our city with outstanding achievements. They help to financially each month to give us 2000 Dolars, parts and equipment.

2.2.3 Volnoe Delo

Volnoe Delo is one of the largest charitable foundations in Russia. It was established by Oleg Deripaska. We are participants of the program ROBOTOTEHNIKA.As support they sent us free game field.They also engaged in training teachers and judges, including our own.They engaged in the organization of competitions FTC in Russia and are sponsoring a trip this year's winners to St. Louis.

2.2.4 Physics-Mathematics Lyceum №30

Physics-Mathematics Lyceum №30 is a school in which is our organization. It provides us with a comfortable space and material assistance, as well as leaders.

2.3 Purchase of materials.

2.3.1 Our method

When we started robotics we had not a lot of money and we used only some basic materials. Now we found sponsors and firstly plan the details and equipment that we need to buy and then buy them.Such an approach allows us to find more effective solutions.

2.3.2 Our materials

We have 6 primary kits and 3 resource kits.We buy individual parts we need.At this point was made 2 large purchases from U.S.A for 1600 Dolar in November 2014 and March 2015.

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

Separation tasks between collaborators:

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

Days inside section:

2.4.1 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	Label
Wheel base	Six standard wheels with leaf suspension	wheel base
Lift	Scissor lift	lift
Gripper	Rotating brush and bucket	gripper
Scoring autonomous climber and pushing button	F - shaped beam	climbers + button
Scoring climbers in tele op	Retracktable slat	climbers
Pulling	Motor that reel the rope	pullup
Push the clear signal	Servo with beam	clear signal

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 choosed the scissor lift because it is compact and extend to a big height .

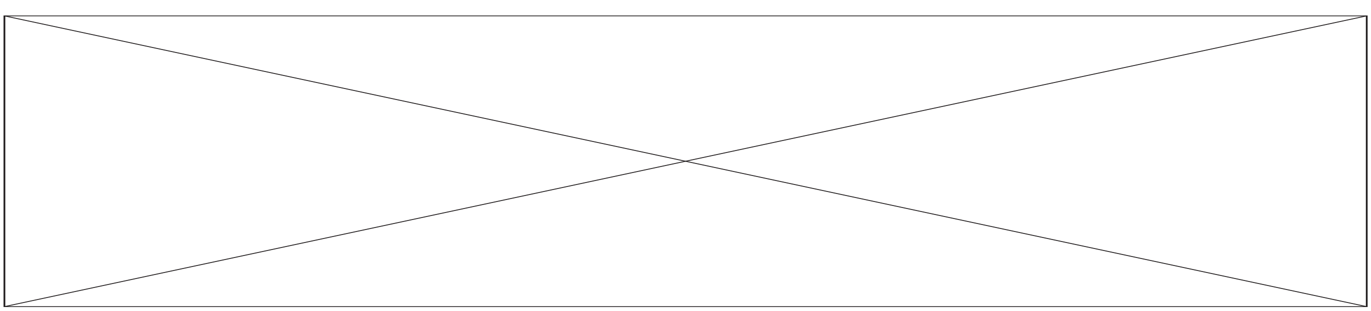
3. The robot will collect elements with help of rotating brush which pull them to the special bucket which connected with the lift. This method is the most simple and fast. After collecting elements the bucket rises by the lift. Then it overturns to the side and elements fall to the box.

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 retracktable slat that move to the both sides by the whhel 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.



2.4.2 26.09.2015

Time frame: 17:00-21:00

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

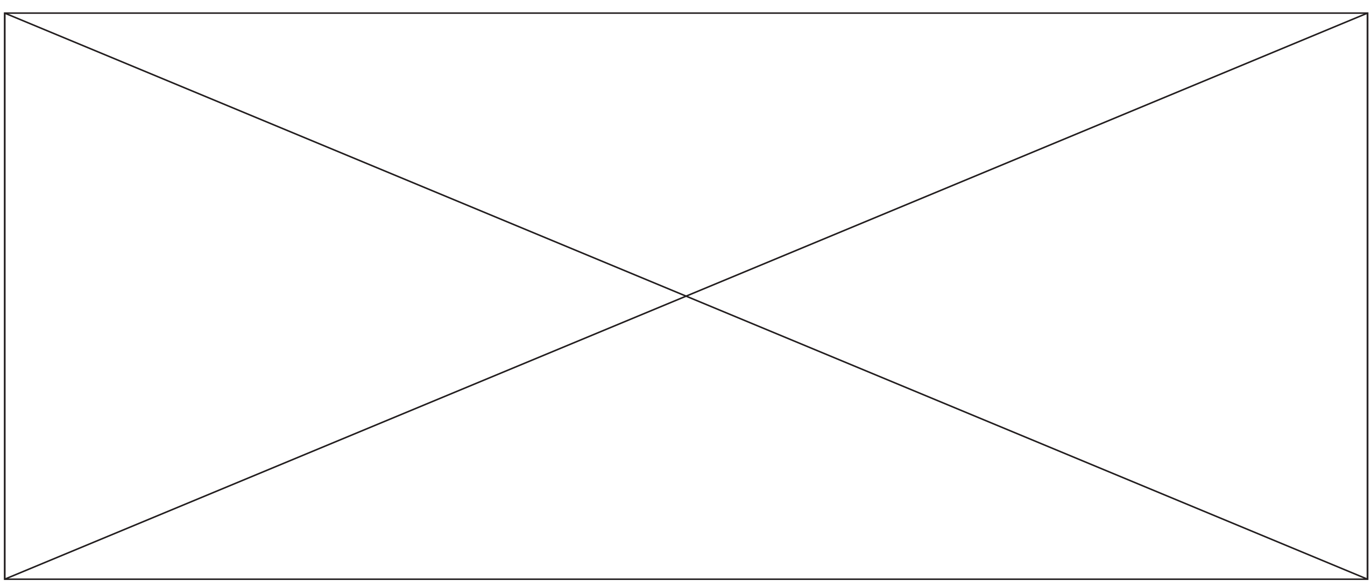
Module	Solutions	Label
Wheel base	6 standard wheels without suspension	wheel base
Lift	Retracktable slats	lift
Scoring elements	Bucket overturns back	gripper

Detailed explaination:

1. We decided to refuse from suspension on wheel base because it is too complex and reduse reliability of the robot.
2. We decided to use lift that consists of retracktable 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 overurn 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.



2.4.3 30.09.2015

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

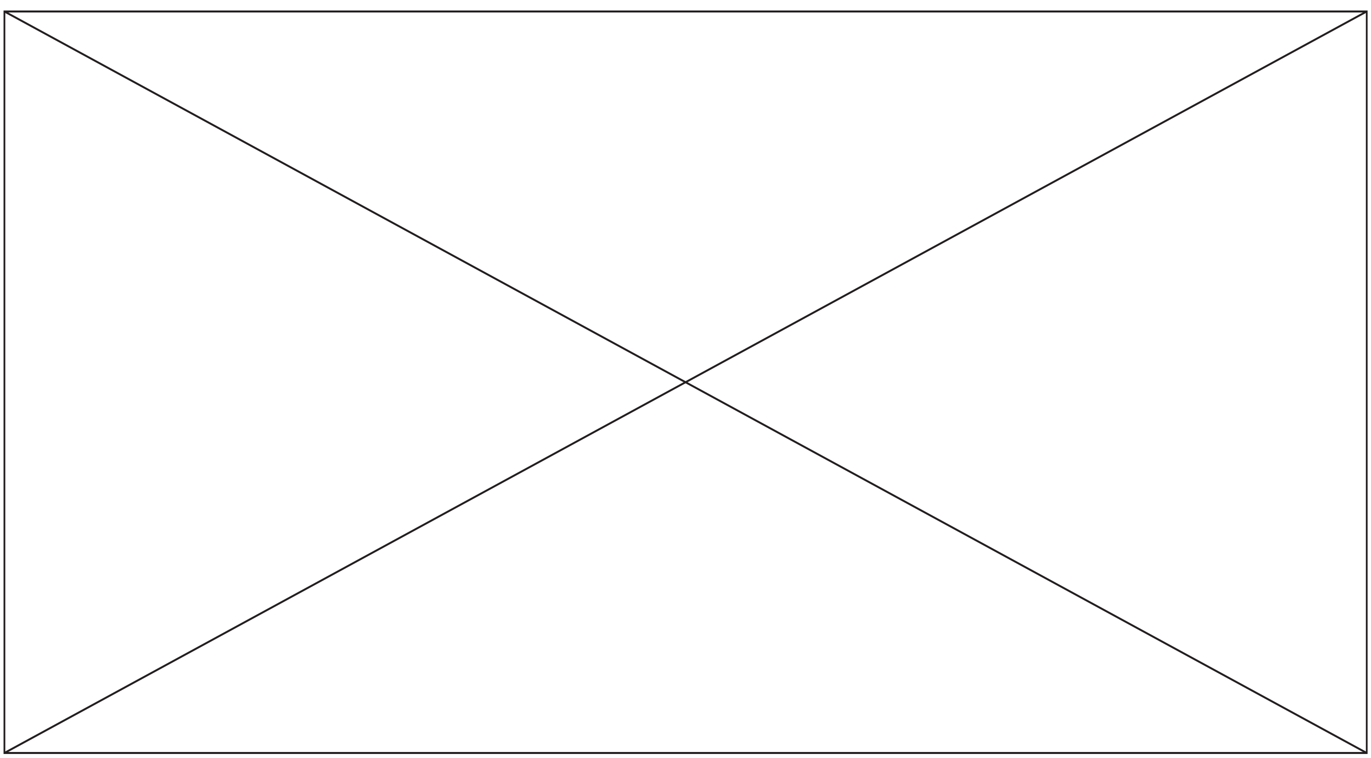
Tasks	Solutions	Label
To elaborate mechanism for turning lift	Servo of continuous rotation with worm gear	robot

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 esure power and allow to keep position.

Additional comments:
Tasks for the next meeting:

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



2.4.4 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 retracktable 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 pullup 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 continiously 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.

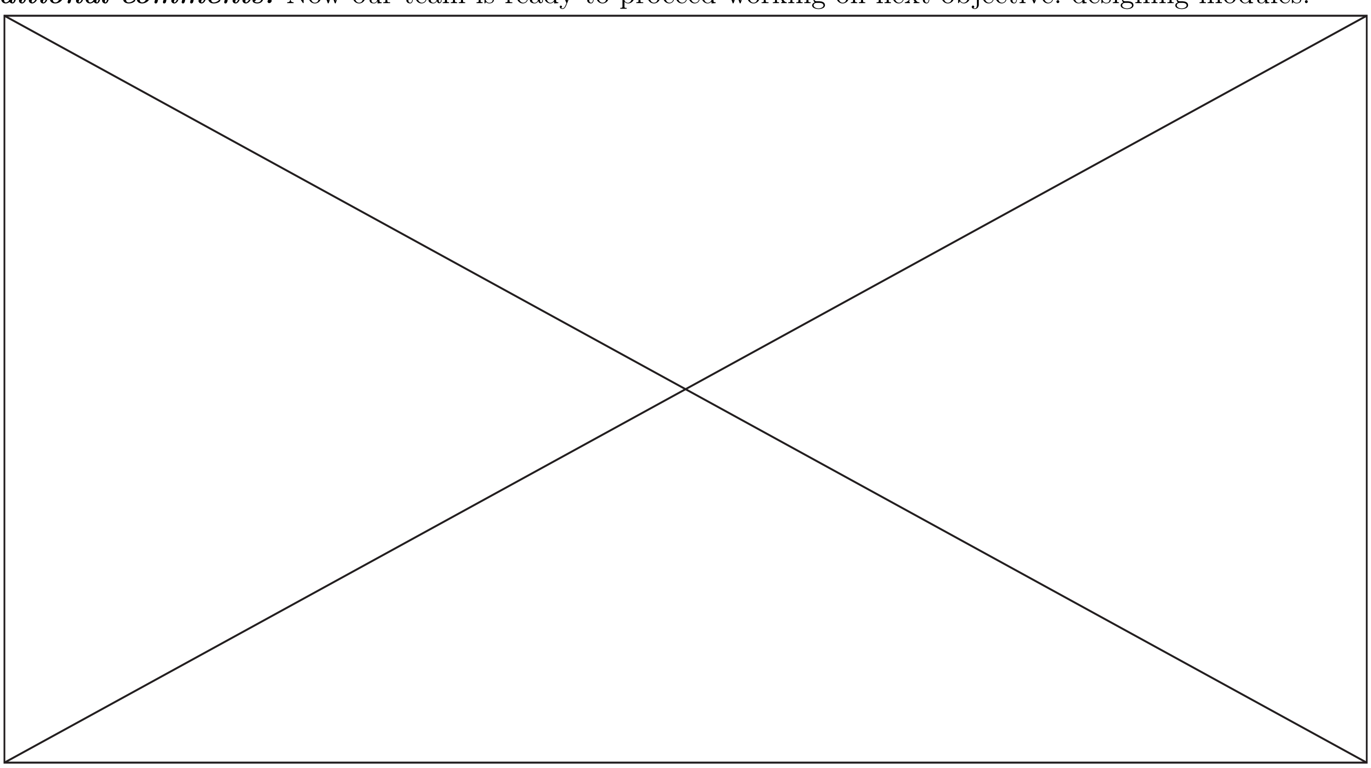
6. Scoring autonomous climbers + pushing button
    6.1. The mechanism for scoring autonomus alpinists will be placed at the front right side of robot. It's definite position will be determined after discussion of autonomus strategy.
    6.2. Mechanism consists of F-shaped beam powered by standard servo.
    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 autonomus 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.



2.5 Specifications for modules

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

2.5.1 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 pullup 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 exstracts so that we can through debris to the top box from the low zone, in the second psition the angle of incline allows us to grasp the pullup 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 folowing: 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. Next, it was started the designing of the robot.

   2.1. Lifting mechanism

   2.1.1. 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.

2.1.2. 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.

2.1.3. Knowing that the individual beams are 350mm long, we calculated that in order to reach this height, we need four beams.

2.1.4. Lifting four beams requires a block system - e.g. we need to add blocks with twine that, when reeled in, would lift the system.

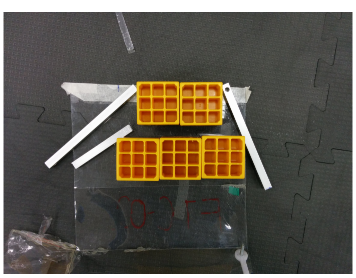
2.1.5. In order to fasten the braces we need to add caps on the end faces of the beams. I came to the conclusion that I needed to change the caps: drill a hole through their legs, so that the twine could be put through them, and grind off the heads somewhat in order to make a trough, through which to pass the line. This allowed me to avoid adding additional blocks on the beams.

2.2. Turning mechanism

2.2.1. The turning mechanism consists of a servomotor attached to the base of the robot, a worm on the axis, and a gear on the first beam of the lifting mechanism. The servomotor turns the worm, which, in turn, rotates the gear, and the lifting mechanism tilts.

2.3. Reeling mechanism (winch)

2.3.1. The reeling mechanism is a system of two coils powered by 2-4 motors. It is both used for extracting elevator and pulling up. The principle of work is folowing: one coil pulls the cable and extracts the elevator when the another coil releases strong cable used for pulling up. When the elevator is fully put forward, so does the pullup cable. Next, when the coil rotates backwards, it pulls the pullup cable and releases elevator's cable causing it to fold back.



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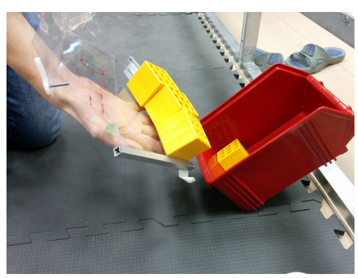

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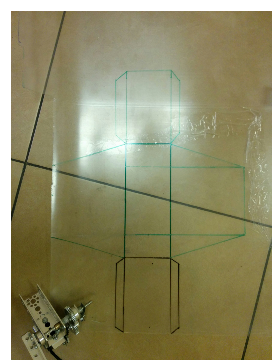


Рис. 3:

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.

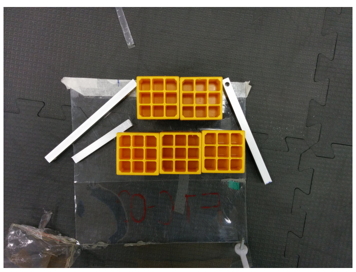
3.1. It was decided to use the furniture rails instead of construction profiles because our team had used them in 2 previous FTC seasons and we have an experience in developing the elevator with furniture slats.

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.

   Next, there was assembled a winch. 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).



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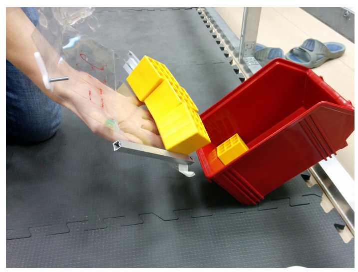

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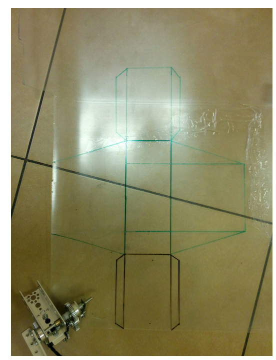


Рис. 6:

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

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

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

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

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

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

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.
9. The elevator was tested in the position, when the robot was standing on the horizontal surface. It was able to entierly 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 cabe 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 strethened 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 increas the power of the winch. There were installed 3 NeveRest AndyMark motors instead of 2 standard TETRIX ones. It increased torque 2 times (3 AndyMarks give torque of $3 \cdot 25 = 75 kg \cdot cm$, while 2 standard - only $2 \cdot 20 = 40 kg \cdot cm$).

    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.

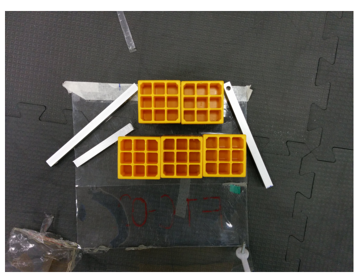


Рис. 7:

11. The system of blocks and cables at the lifting mechanism was changed. The coils were also recreated.
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.

    The winch is a mechanism for extracting of the elevator.

    The concept of the module:

    The winch has two functions: firstly, it extracts the elevator and secondly pulls the robot up. It should have 4 similar coils - 2 for each side of the elevator. All the coils should rotate dependently. It is possible to put them to the one axis. While the first coil reels the elevator's cable and extracts it, the second one releases the cable for pulling up. It is needed because the end of the cable for pulling up is fixed at the top of the elevator. When the coils turn another direction, elevator goes down and the cable for pulling up is being reeled. Since the mechanism for grasping the pullup bar connects the cables to the bar, the cable don't contact the elevator anymore. So, when the robot will pull itself up, it won't harm the elevator.

    On the ... There was created an assembly of 3 motors for the winch. The gear ratio was 1:1. The next day it was created the strong axis for coils.

    It was calculated, that to pull the robot up with 3 TETRIX DC motors, the coils should be 4 cm in diameter. The coils were made of plastic pipe. The space between the axis and the pipe was filled with the glued rope. Coils were connected to the axis by the nails. The axis was connected to the motors by the 3-mm screw, put through the hole in the axis.

    On the ... The cables from the elevator were held to the coils and fixed on them.

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

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

    After our team returned from the competition, the problems in all the modules were discussed and the concept of the elevator also changed. It was decided, that one mechanism will extract the elevator and another mechanism will pull the robot up. The implementation of the mechanism for extracting the elevator got higher priority.

    Since the construction of the robot was reconsidered, the new place for the winch was above the gripper.

2.5.2 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. содержимое...

2. The first stage of development was creating the general concept of the module, its structure and method of operation. In result, was decided on the following mechanism: The bucket is shifted outside of the robot and turned 90 degrees around an axis parallel to the axis of shift; both movements are done by one servo. This allows to place the bucket opening to be parallel to the ground and increase the accuracy of debris delivery. Movement in two planes at once is accomplished through sloped guide rails,

which turn the beams with the bucket during their sideways movement. To prevent premature release of debris from the bucket, the bucket opening will be closed.

3. The next step was developing the closing mechanism. To minimize the load on the servo completing the turning movement, the center of mass of the module has to be situated as close as possible to the mounting point on the lifting mechanism. Thus, the following system was developed:

   - On the beam which is mounted to the lifting mechanism, is installed a reel with twine.
   - The twine is fixed in such a way that when the reel turns in one direction, one of the ends is pulled taut while the other slacks, and vice versa.
   - The twine wraps around several fixed blocks along all the beams which support the bucket.
   - Above the bucket opening there is another axis with another reel identical to the first, and the surface which blocks the opening.

   This allows to open and close the bucket without adding any additional significant load on the servo which turns it. To make sure that such a mechanism for transmitting rotational movement indeed works, a simplified model was assembled. The results of our tests showed that this transmission is operable, but the angle between the extreme positions is slightly more than 135 degrees, rather than 180 degrees, but this is still enough to complete the task.

4. After that the parameters of the guiding rails (slope relative to the vertical direction, maximum height) were calculated depending on where they are mounted: The bucket, mounted on the beams, which in

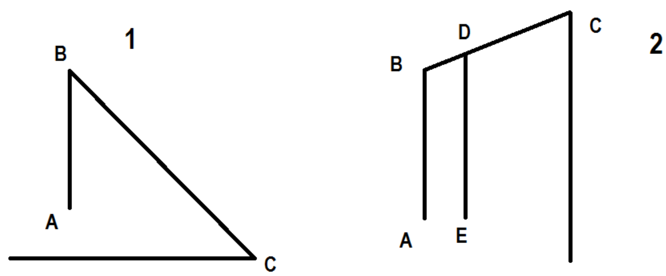


Рис. 8: Side view of beams onto which the bucket is mounted

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

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

6. Then the servo with a 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

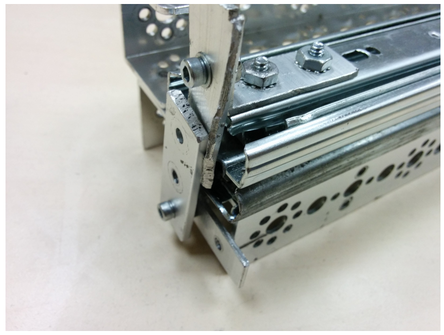


Рис. 9: Structure of limiters

of the slats, which allows them to move as needed. The servo direction of rotation defines the direction of movement of the slats and the bucket.

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

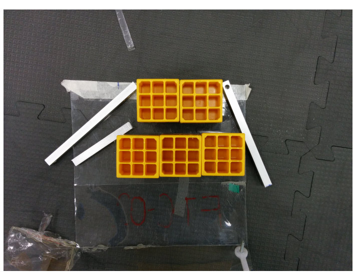


Рис. 10: Structure of guides

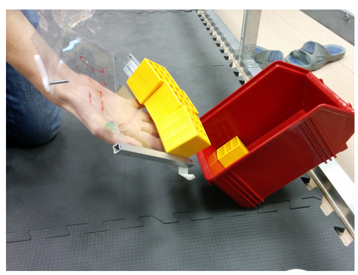


Рис. 11: Process of guides testing

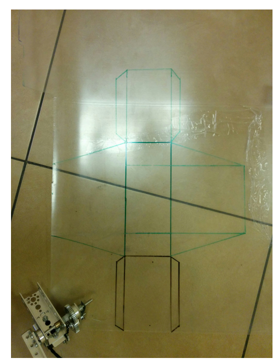


Рис. 12: Marking of bucket

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 assymetric guide slows one debri to make all the debris fall as 2-2-1, not 2-3.

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

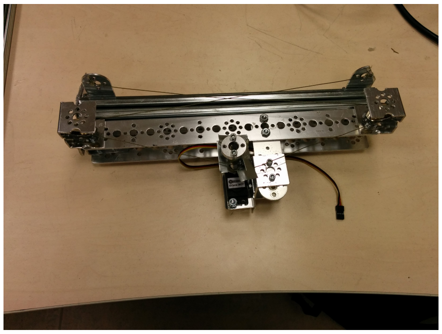


Рис. 13: Construction of line and pulling it servo

Рис. 14: Final construction of the slats

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

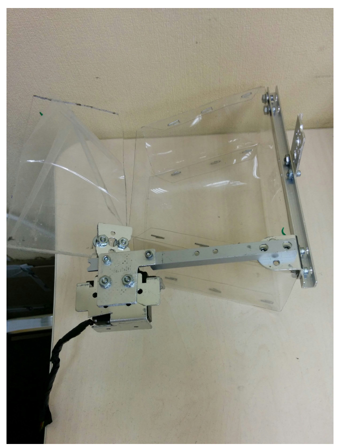


Рис. 15: Final construction of the bucket with closing mechanism

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

11. After the end of competitions slats were replaced by longer ones (40 cm instead of 35) to make bucket shifting completely out of robot teoreticaly 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 int end of the robot above two beams. It would make lifting easier because bucket would move inside robots projection much less time than before, also it is easier to transport debris throw the robot than to transport the bucket.

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

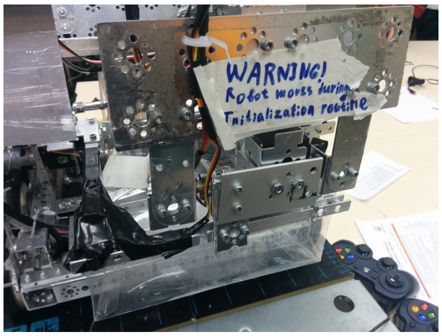


Рис. 16: Construction of bucket

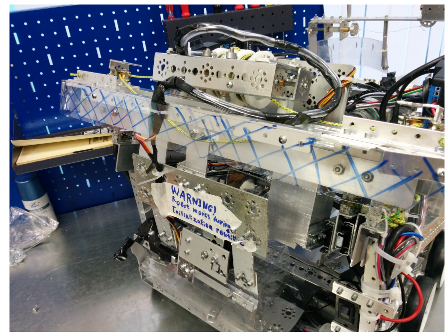


Рис. 17: The bucket mounted on robot

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

14. After that the new shape was devised.

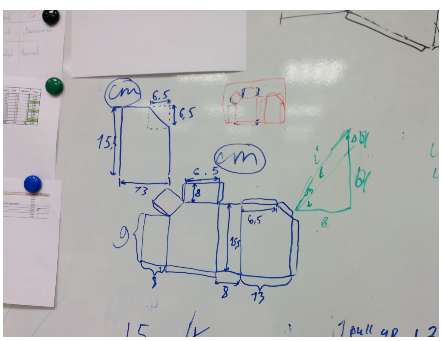


Рис. 18: Shape and scan of the bucket

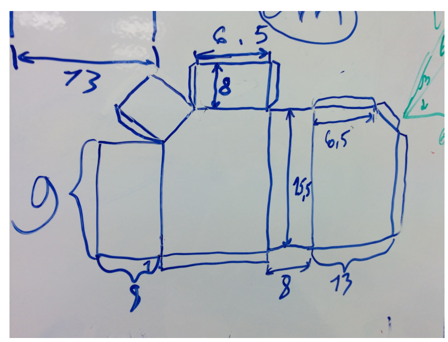


Рис. 19: Closer view of the scan

This shape was chosen because:

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

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

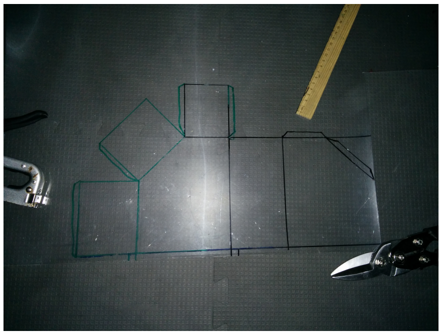


Рис. 20: Marking of bucket on the plastic sheet

Рис. 21: Fully assembled bucket with cubes inside

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

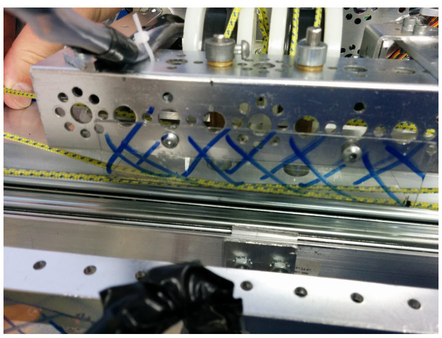


Рис. 22: Protection of rope

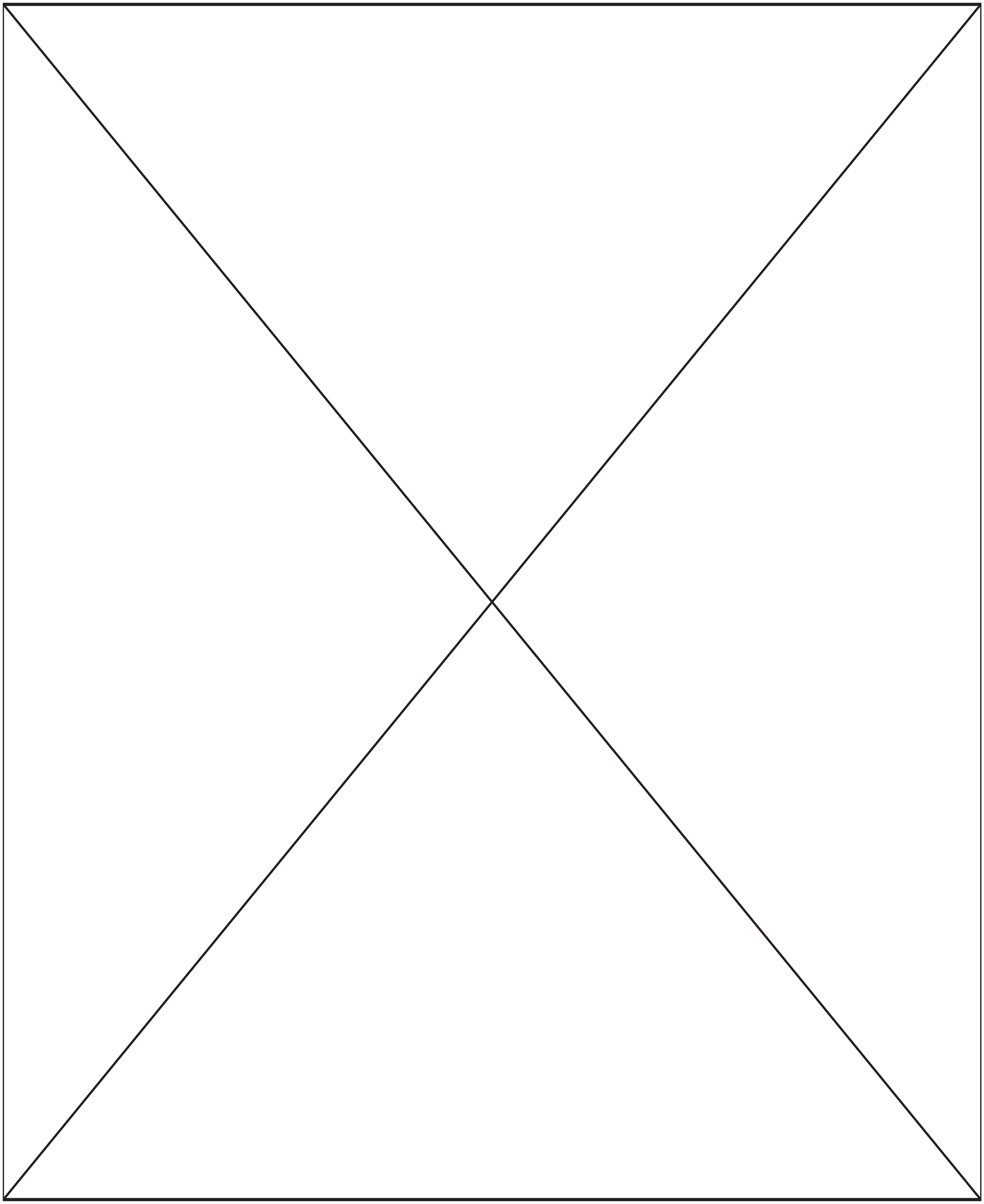
Рис. 23: Test of new bucket

2.5.3 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 verticallywith 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.



2.6 Leaflet for teams

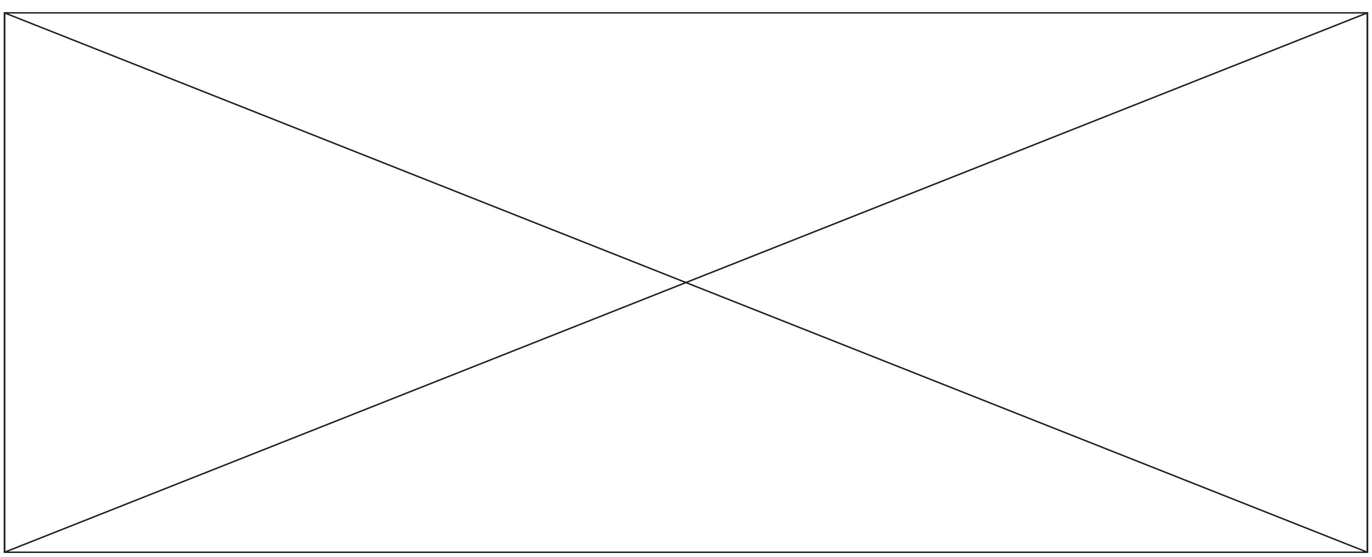
Nikita Safronov
Role in team: captain, reserve drive-operator, responsible for writing the technical book, responsible for elevator and winch.
Information: 17 years old, in robotics 4 years, in FTC 2 years.
Why I chose FTC: "I have chosen FIRST because I enjoy working with mechanisms and finding unusual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

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

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

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

Gordei Kravzov
Role in team: 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."



2.7 Information for judges

Team PML30-Y (FTC-15)

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

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

In our technical documentation there is a special section named "Specifications for modules"which is dedicated to the development process of modules in particular. In this section you can find more information about modules mentioned above.
Software specifications are available in section named "Specifications for programs".
General development of the robot in progress is represented in chronological section. This section contains information about all the team meetings including discussions and days of competitions (it mentioned in the title of meeting).
Our abilities and our strategy in the game are provided in section "Key summary".
In the section "Appendix"you can find":

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

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