ENGG1000
Engineering Design and Innovation

2019 – Trimester 1

Project DELTA

Final Report for Team 15

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Executive Summary

This report provides an outline of the chosen design solution, a description of the various subsystems, how these subsystems interact to form a functional system and an evaluation of the performance of the vehicle. The DELTA project involved the design and fabrication of a grounded prototype vehicle with the function of efficiently transporting and unloading a payload across a set track in under 120 seconds. The performance of the vehicle was assessed on its ability to manoeuvre the track and the quantity of containers delivered successfully. This report expands upon systems of the final product. The vehicle consisted of a chassis which housed the five other main subsystems: payload storage, payload release mechanism, hooking mechanism, motor/drive system and the Arduino/electronics control system Complications are also discussed in detail. These included vehicle weight (1.991kg with a limit of 2kg), and a weak joint in the release arm. This restricted modification in final production, such as the addition of aesthetic features. The weak joint issue impacted the first competition run significantly but was promptly rectified. The track was successfully completed on the second run, carrying all available ball-bearings (28). The vehicle also scored full marks for both design/innovation and aesthetics score due to a unique and practical design. Future recommendations are also discussed in the report.

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Introduction

Team 15’s DELTA vehicle aims to fulfil criteria set by NASA and expand upon the objective of designing and manufacturing an efficient and fully functioning vehicle; aptly designed for transporting payloads in a hazardous Martian environment. A prototype is to be created in a bid for the NASA contract, in regulation with certain specifications. The team’s formulated problem statement (formulation meeting minutes in appendix) aims to summate the what the project is, who it is for, and why it is required:

"NASA has asked for the production of a prototype of an unmanned grounded DELTA vehicle capable of delivering a maximum load of spherical containers securely across hazardous terrain. This includes inclines, rough terrain and vertical drops, all under time, budget and spatial constraints."

The final design has been explored in detail, in addition to the reasoning behind each subsystem. Formulation of each subsystem design has occurred through several iterations of conceptual generation, with profuse incorporation of decision-making processes and diagrams (i.e. Morph charts, function-means trees, binary objectives comparison, etc.) (LATTE - Fac. Engineering, the Learning Centre & The University of New South Wales, 2014). These systems have been grouped into a “System Overview”, containing broader-spectrum information about the design. Specifics have been explored in the “Subsystem Breakdown” section, wherein sub-systems (i.e. fundamental components) are detailed.

The vehicle’s chassis structure (carbon fibre/balsa wood/metal) provides a lightweight and high-strength body for other subsystems to be contained in. The container storage has been integrated into the chassis – consisting of two inclined planes on each side to allow for efficient stacking of ball-bearings (maximum capacity of 40). This aids in a smooth release – controlled by a wooden arm attached to a servo. The hooking mechanism allows for safe decline down the zipline. Four high-torque motors have been introduced to get the ascend the incline and to increase manoeuvrability. All mechanisms were controlled by the Arduino, which in turn was operated remotely via Bluetooth. Decision-making processes and additional diagrams can be found in the appendix.

Finally, “Competition Analysis” examines the results of the DELTA competition and how the vehicle could be improved. Recommendations are included in both this section and the conclusion for if the vehicle was be tested again or developed to full-scale.

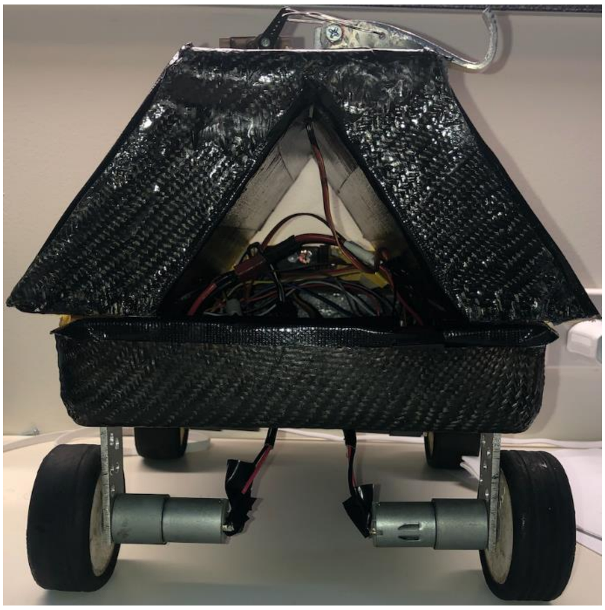
Final Design

System Overview/Interfacing

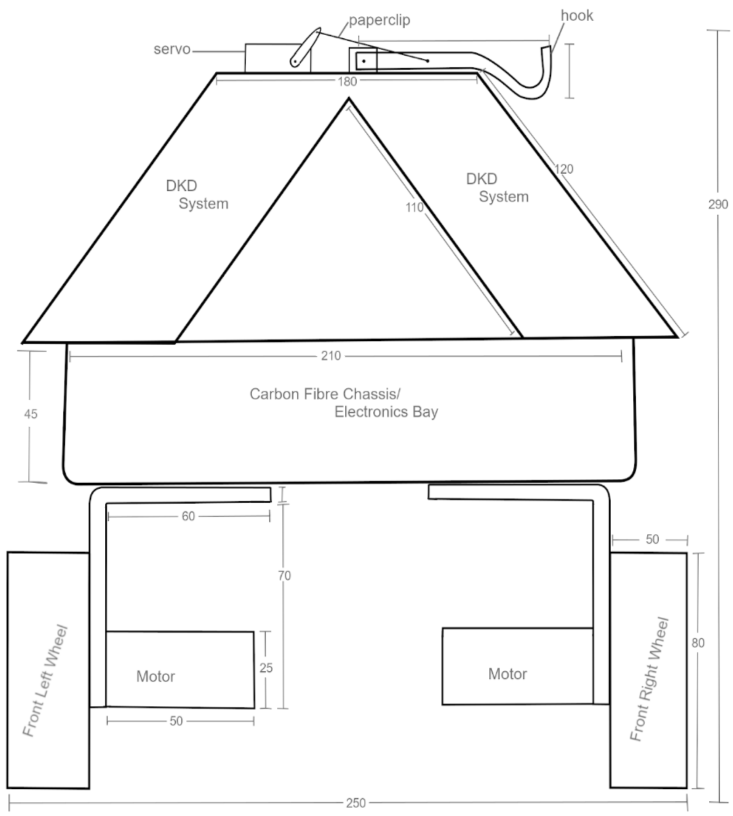
The Delta 15 Final design was an aesthetically pleasing, innovative system capable of carrying up to forty SCs through the Martian terrain simulation securely, and then depositing anywhere from 2 to 40 ball-bearings at a time in designated drop-off zones. The final system specifications were as follows (Briozzo, 2019):

- Height: 290mm
- Width: 250mm
- Length: 330mm
- Weight: 1.991 kg

Below are the final specifications for the vehicle (with real-life comparison [RL])

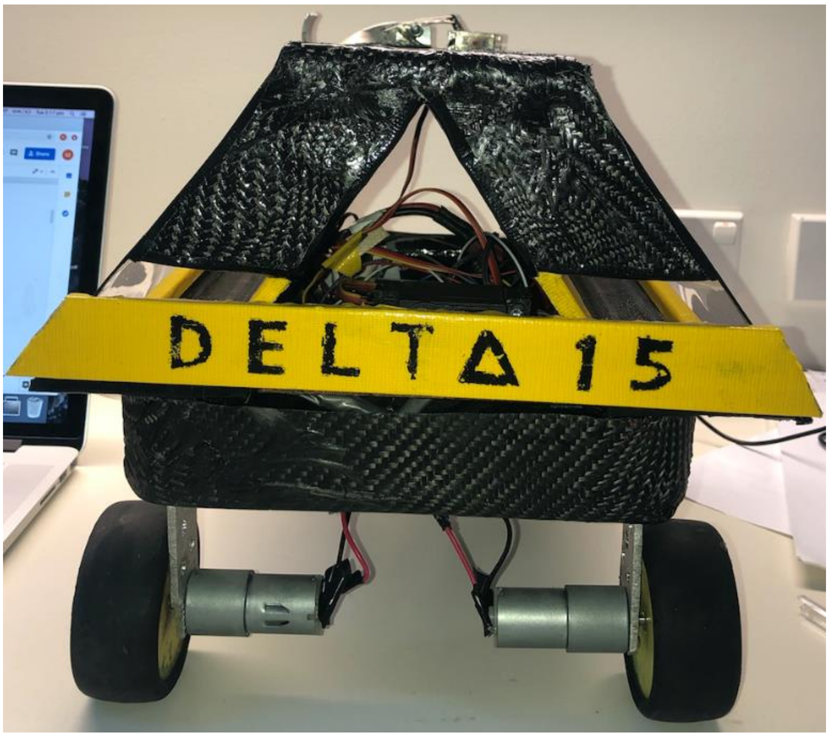


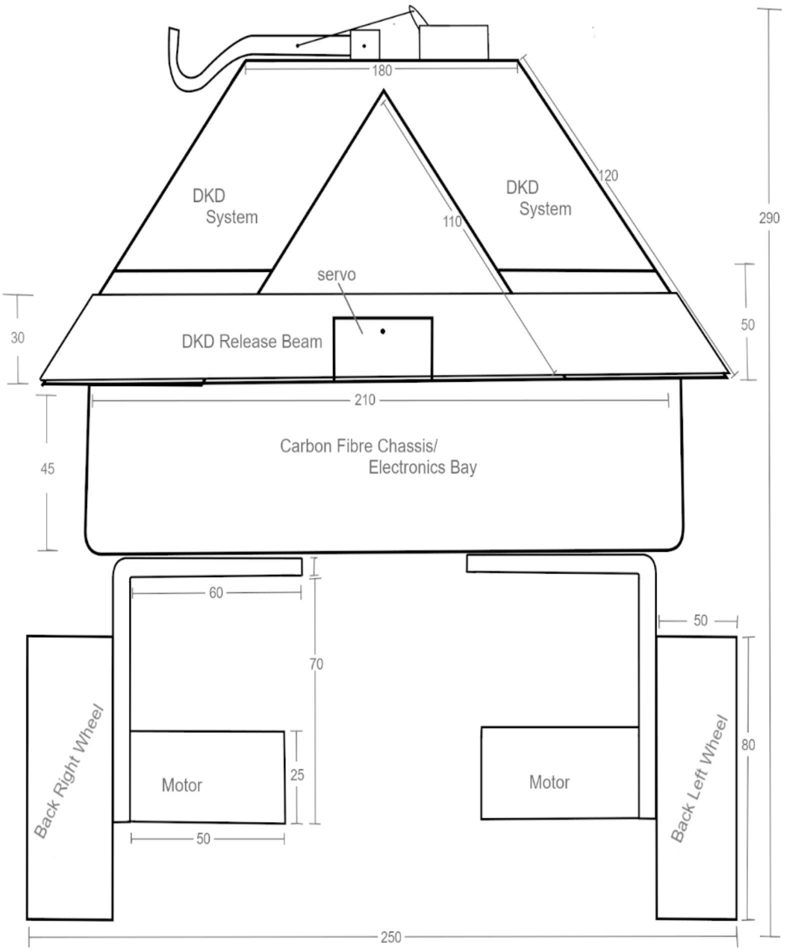
Final Design Front View RL



Final Design Front View Specifications

Final Design
Back View RL

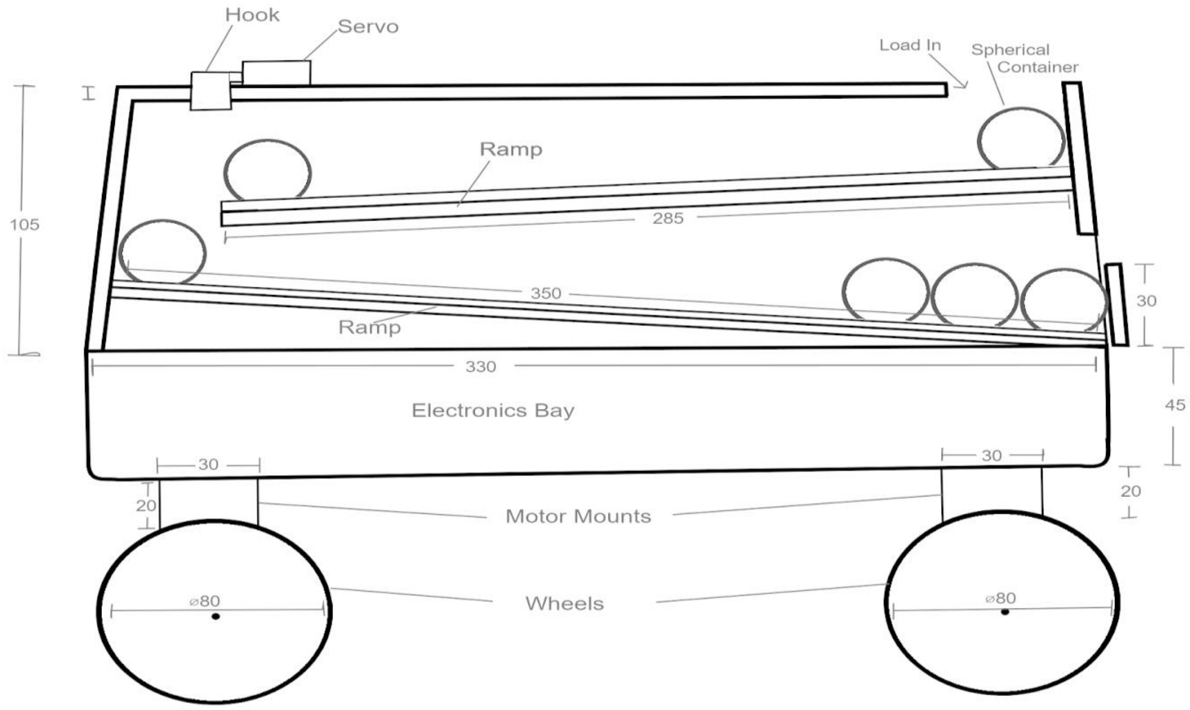




Final Design Back View Specifications

Final Design
Side View RL

Final Design Side View Specifications



Donkey Kong Delivery (DKD)

The Donkey Kong Delivery system is the most innovative subsystem in the design, and is a unique design solution to the challenge of securely transporting and unloading the payload. The system involves loading the ball-bearings onto inclined ramps along each side of the vehicle. 10 ball-bearings are stacked adjacently on each of the 4 railed ramps until the release hatch is opened and they roll out due to gravity. This system is interfaced with the servo-operated release hatch as this controls when the ball-bearings roll out. The DKD system was chosen as it provides an innovative solution to the problem of containing and delivering the payload safely. It provides secure transportation, even weight distribution, high-capacity storage, and an aesthetically pleasing design. The DKD had three main drawbacks in that it was a heavier container than just a simple box, was moderately difficult to construct, and if one of the releases were to break, the entire payload for that side was likely to be lost.

Servo-operated Release

The servo-operated release consists of a servo with a thin, trapezium-shaped piece of balsa wood mounted to it. This provides a method of reliably releasing the payload, and it is interfaced with both the DKD system (through releasing the ball-bearings from the DKD system) and the electronics system (through being controlled by the electronics system). The system operates through the Arudino telling the servo to rotate 70°, which raises one end of the trapezoidal plank and lowers the other, opening both release doors and allows the payload to be deposited. The servo can then be told to rotate back to its starting position if required. The servo-operated payload release was chosen as it provides a simple solution to releasing the ball-bearings from the DKD. Benefits include ease of use due to one-buttom command/control and that only one servo is required to release ball-bearings from both sides of the DKD. The primary drawback of this system was that if the system was opened by accidentally pressing the wrong button, the payload would be lost. This occurred during test runs occasionally. A two-step process in activating the release would be a good fix for this issue. Another drawback was that the additional servo added weight to the vehicle.

Servo-operated Hooking Mechanism

The servo-operated hooking mechanism consisted of a metal angle bracket mounted on the bals frame oh the DKD, underneath the carbon fibre layer. This helped to disperse the weight of the vehicle when the vehicle hung from the hook. The hook was screwed loosely onto the metal bracket so that it could rotate up and down – allowing the vehicle to pass under the 30cm bar and hook onto and off of the bar with ease. A servo with a paperclip was used to pull/push the hook up and down, as shown in the figure. This system is interfaced with the electronics system (through being controlled electronically), and the balsa/carbon fibre/metal structure (as it is mounted between the carbon fibre and balsa layer). The servo-operated hooking mechanism was chosen as it provides a reliable solution for descending the drop safely. Benefits include minimal risk, easy operation due to one buttom/command, and reliability (more reliable than simply dropping off). Minor connection issues occurred between the servo and the Arduino during testing, which lead to the hook being temporarily unreliable. However, this was solved by soldering faulty pins together, which resolved the issues immediately.

Electronics and Arduino

The electronics and Arduino system interfaced with all the other systems. This is the central system, and was used to connect the driver's controller with the vehicle via a bluetooth module. An Arduino was connected to a bluetooth receiver, as well as the motor driver and the servo-operated systems. The electronics and Arduino system was chosen as it is an effective way to allow the subsystems to communicate and for the driver to remotely control the car. Benefits include the ability for vehicle to be remotely controlled, relatively easy programming, as well as instant and reliable communication. Initially, there were issues with pins falling out of the Arduino. This was solved by soldering the pins into the arduino (permanent but effective).

12kg/cm Torque 36 RPM Motors

These motors where used to drive each of the four wheels. This provided the vehicle with four-wheel drive, and ample torque to carry 40 ball-bearings (4.4kg) up the incline. These motors interfaced with the balsa/carbon fibre/metal structure as well as the electronics, as they were mounted to the structure and controlled by the electronics. These motors were chosen due to their high torque output as intially tested motors could not carry high payloads up the incline. Other benefits of these motors include power to overcome the foam mat, incline and speed bumps and a slow rpm for easy control of the device. The two drawbacks of these motors were that although their low rpm aided in control, time required to complete the track was increased, and that they were heavy – contributing a significant amount to the total weight of the vehicle.

Balsa/Carbon Fibre/Metal Structure

The system that held all the other systems together was the balsa wood, carbon fibre and metal structure. The chassis was made from carbon fibre reinforced with wooden slats, and housed the electronics. Metal angle brackets were bolted to the bottom of the chassis, upon which the motors and wheels were mounted. The DKD was mounted on top of the chassis with wood screws. The DKD itself was made from balsa, and the outer parts were layered with carbon fibre, in order to disperse forces when hanging from the hook and maintain structural integrity. These materials and this structure were chosen due to their low weight and high strength. The two primary drawbacks to this system were the cost of the carbon fibre (estimated $80), and the hazardous nature of working with the carbon fibre (e.g. inhaling fibre particles while cutting).

These 6 subsystems combined to create an operational universal system that was able to provide an innovative solution to our problem statement.

Subsystem Breakdown

Difficulty rated on a scale of 1-10 (Easy-Difficult)

Donkey Kong Delivery (DKD)

Build Details

- Weight: 200g
- Maximum capacity: 40 ball-bearings
- Estimated Build Time: 6 hours
- Estimated Cost: $5
- Difficulty: 5

Build

The DKD container was constructed using sheets of balsa wood. See schematics above. Each piece is fit to each other using wood glue/super glue instead of screws to reduce weight. A thin sheet of plastic is used to cover each side of the container. 2 metal mounts are found at the front end of the container relative to the vehicle front which is the mounting point for the servo and hook.

Build evolution (difficulties, compromises and improvements)

- Multiple different containers designed, though all had the issue of unloading the payload successfully. The DKD design was believed to address most issues pertaining to this design problem.
- Early designs could theoretically take 100 balls, until construction where our total volume was reduced to 40, which was still an ambitious load to take.
- Making the incline angle steeper reduced the chance of jams, which could endanger our final performance.

- Coating the system in carbon fibre increased rigidity and proved an interesting aesthetic touch for our vehicle.
- Holes were added or widened so that the payload could be loaded and unloaded without jamming.
- The container – due its size – contributed a large proportion to the final weight of the vehicle, which could have been spared by reducing capacity or redesigning the container.

Servo-operated Payload Release

Servo Specs

- Torque: 4.6kg.cm
- Operating Voltage: 4.8V
- Dimensions: 40x27x20 mm

Build Details

- Difficulty: 4
- Estimated Build time: 3 hours
- Estimated Cost: $20

Build:

The servo used is mounted directly onto the DKD subsystem, using wooden mounts with epoxy resin. These mounts allows the servo to be drilled and locked in place. Using a servo horn of appropriate modulus, the servo is attached to the release beam on its central axis.

Build evolution (difficulties, compromises and improvements)

- Originally intended to use 2 servos to operate each hatch. This was scrapped in favour of using 1 servo to control a single beam as a hatch, reducing complexity, code and demand for Arduino pins.
- Arduino 5V output pins were not sufficient to drive the servo. This required a voltage regulator to be sourced for the project.
- Weight was reduced by changing the beam material, which contributed to keeping the vehicle under 2kg. However, this did make the beam less rigid, which required immediate attention close to final testing.
- An ongoing issue was the chance of accidently releasing the payload due to the mobile application used to drive the vehicle. Having a 2-stage process would eliminate this problem.

Servo-operated Hooking Mechanism

Servo Specs

- Torque: 1kg.cm
- Operating Voltage: 4.8V

Build Details

- Difficulty: 4
- Estimated Build Time: 3 hours
- Estimated Cost: $10

Build

The servo used is directly mounted to the top of the DKD container system using super glue/epoxy. A small servo horn is attached to the servo, which is attached to the hook. The hook is attached to the DKD container via a metal prop – extending from the container – and is mounted in place using a nut and bolt. To connect the servo to the Arduino, a connector wire is run through a hole in the DKD container.

Build evolution (difficulties, compromises and improvements)

- The design process was complicated and tedious. A disproportionate amount of time was spent figuring out how it would work. (Nedelkovski, 2019)
- Hook mechanism had to be able to retract, which was imperative for the vehicle to unhook from the railing. A paperclip solved this issue and was a quick and easy fix.
- A new metal servo was sourced to address a potential risk of breakage.
- Connection issues occurred due to the poor build quality of CREATE store connectors. This was solved by soldering faulty pins together.

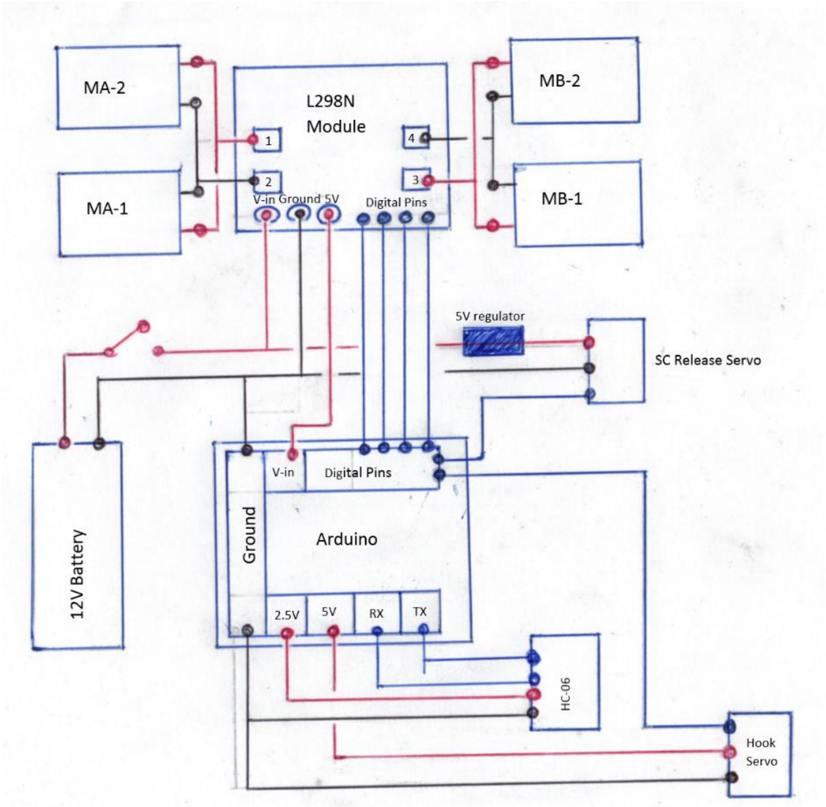
Electronics and Arduino

Components (not including components directly mentioned in other subsystems)

- Arduino Uno
- 5V voltage regulator
- 11V 1800mAH 20C LiPo
- Basic Switch
- HC-06 Arduino Bluetooth Module
- L298N Motor Shield

Build Details

- Difficulty: 5
- Estimated Build Time: 6-7 Hours
- Estimated Cost: $60



Electronics Configuration

Build

- Refer to electronics configuration diagram above
- 4 motors wired in parallel to l298N module - 2 motors to inputs A, 2 motors to inputs B
- No PWM is used
- SC release servo is connected to 5V regulator to supply power instead of Arduino's 5V output port (servo is too demanding of current)
- Hook servo is attached to Second Arduino 5V output port
- Battery connected using T connectors for easy removal
- Most components mounted to chassis using double sided tape with Velcro for easy removal and tinkering
- Refer to appendix for Arduino code

Build evolution (difficulties, compromises and improvements)

- RC components were originally intended to be used for the project, for the sake of simplicity and the fact that the electronics were already owned. This was decided against voted against as it would be recorded as part of the $200 budget.

- Early designs required 2 l298N motor modules. This was reduced to 1 with the utilisation of paralleling motors, requiring simpler circuitry and less money to be spent.
- 2WD and other alternatives were voted out in favour of an easier to use and build 4WD system with pivot steering.
- Faulty pin connections were fixed by soldering every pin to the Arduino.

12kg/cm Torque 36 RPM motors

Motor Specs

- Torque: 12kg.cm
- RPM: 36
- Operating Voltage:12V
- Estimated Cost: $50

Build Details

- Difficulty: 1
- Estimated Build Time: 1 Hour

Build evolution (difficulties, compromises and improvements)

- Early designs needed 2 motors for a vehicle driven by RC tank tracks. This was agreed to be an overly complicated design, inconvenient and too expensive to be viable.
- Using motors directly attached to the wheels reduced the complexity tenfold, while producing similar torque, grip, controllability and was altogether less expensive.
- Later testing showed our combination of 70RPM and 100RPM motors did not produce enough torque for $\geq$ 20 spheres (2.2kg). These motors were replaced with 4 36RPM motors which could theoretically carry up to 10kg including the vehicle.
- Motors contribute a large portion of the vehicles weight, requiring the team to trim weight in other areas, which was quite difficult.

Balsa/Carbon Fibre/Metal Structure

Build Details

- Metal Arm Material: Aluminium
- Chassis Material: Carbon Fibre
- Container Material: Balsa Wood (Carbon Fibre Coating)
- Estimated Weight: 600g
- Estimated Cost: $20
- Difficulty: 4
- Estimated Build Time: 4 Hours

Build

Each one of the components mentioned belongs to a separate subsystem. In final building, the container is mounted to the carbon fibre chassis using wood screws. The metal arms can be mounted using nuts and bolts and held in place with epoxy resin. The metal arms have holes for the mounting points for the motors.

Build evolution (difficulties, compromises and improvements)

- Early designs were made completely of PVA, as it could be easily sourced and used in construction. Later developments opened up the potential of using aluminium, balsa wood and carbon fibre as base materials.
- Carbon fibre helped to reduce our weight, though it made finding mounting points difficult for the container and metal arms.
- Weight had to be stripped from this subsystem, which proved difficult, and could only be done by drilling out holes in the metal arms.
- In hindsight, the potential risks of working with carbon fibre and the difficulty sourcing it would give preference to other materials such as PVA for the chassis construction.

Competition Performance Analysis

The final testing run for the Delta project for team 15 was a tremendous success, with the team and vehicle achieving a Delta record high Total Run Score of 168.37 and Total Design Score of 50, both accumulating to an Overall Competition Score of 218.37 out of 200.

The entire track had 5 primary obstacles that the vehicle had to traverse and successfully overcome. Prior to the testing run, the vehicle was assessed on innovation and aesthetics, where it was awarded full marks. The team then transferred all 28 of the available ball bearings onto the vehicle, with 14 on either side of the Donkey Kong Delivery container, and placed it at the start of the track within the 60 second time limit. The Bluetooth module was connected to the Remote controller which allowed the device to be driven.

The first obstacle the vehicle had to overcome was the varying incline up the ramp.The vehicle overcame this using the 12 Kg/cm torque motors that were able to power and carry the entire payload up the ramp. The high torque motors and 80mm diameter wheels were then able to drive over the speed bumps on the flat leading to the drop. Once the vehicle arrived at the edge of the ramp, it was re-aligned so that the hook was directly under the zip line section. The servo operated hooking mechanism was then operated using the arduino, which enabled the device to hook on and slide down once it was driven over the edge. The hook was then released once the device was at the bottom of the drop safely again using the arduino. The vehicle then crossed the foam pit, again using the 80mm diameter wheels and four high torque motors. After arriving in the final zone, the four wheel drive was utilised to pivot the vehicle so that its rear was aligned with the designated SC drop off zone. The servo operated SC release was opened, allowing the SC's to roll down into the drop off zone, due to the innovative inclined Donkey Kong Delivery system. This completed the run in a time of 98 seconds, with the maximum possible score. Overall, DELTA 15's final testing run was truly remarkable, where the vehicle's design brought innovation, simplicity, ease of manufacture and style onto the table. The aesthetically pleasing carbon fibre chassis, along with the yellow tape around some areas of the vehicle, combined with the innovative subsystems, such as the servo operated hooking mechanism and SC release, brought a whole new level of innovation to the table. The use of the Donkey Kong Delivery container was truly original and groundbreaking, as it allowed the vehicle to carry up to 40 ball bearings. The use of carbon fibre really took the vehicles design to a whole new level as it combined functionality with pleasing style. In summary, the innovative and aesthetically pleasing vehicle was able to hold, transport and deliver a maximum payload of 28 ball bearings across the entire track with ease, completing all of the aims of the DELTA design task. As expected, this resulted in a first placed position with an Overall Competition Run score of 218.37 out of a possible 200, with the 18.37 being a bonus.

Our team prioritised payload security, aesthetics and innovation over all else. Based on our final testing, it can be concluded that these prioritisations were well assigned. We were able to achieve a perfect score for aesthetics and innovation, and this paired with a perfect run score due to our SC security and innovative ways of overcoming the obstacles placed us at the very top of the competition, and allowed us to achieve the absolute maximum possible marks. Our design was not fast or light weight however it did not need to be, as it easily deposited the SC's within the 120 second time limit and was under the weight limit of 2 Kilograms. From our compliance testing, we learned that our motors did not have enough torque to carry more than 10 SC's, and this was key as it allowed us to make the decision to upgrade our motors to ones with 12Kg/cm of torque. The compliance testing went smoothly and confirmed for us that our design was going to work after the motor upgrade. Some potential limitations of the design that were no obvious in testing are that it can only contain 40 SCs (there were only 28 SCs available to test with), it could not do the run in under a minute, as it has a relatively slow speed, and it is possible to accidentally open the SC release accidentally and lose ball-bearings.

Conclusion and Recommendations

The DELTA 15 final design was a Bluetooth-controlled vehicle consisting of four high-torque motors, a zip line hook and a ball bearing storage and release system. The vehicle was capable of securely carrying and delivering a payload of twenty-eight ball-bearings and navigating all aspects of the competition track, thus successfully completing all aims of the set problem. This resulted in a run score of 168/150 and a design score of 50/50. The high-torque motors were key in the vehicle's ability to ascend the slope while carrying a large payload and also traverse the bumpy terrain. The servo-operated zipline hook also played an essential part in the vehicle being able to safely overcome the drop to complete the track.

The final design meets all the required aims of the brief. Team 15 recommends the use of a hook to navigate the drop, as featured on the vehicle. As observed in the final testing competition, the failure rate was significantly higher for vehicles that opted to drop over taking the zipline. It is also recommended to use motors with high torque, such as our 12kg/cm motors. Although they had a low speed of 36RPM, they were sufficient for completion of the track in under 2 minutes and provided ample torque for overcoming all obstacles encountered.

Ways in which the final design could be improved include the construction quality and the aesthetics. A full-scale production would also mean dimensions can be planned out more precisely, leading to a more cohesive and aesthetic design. The electronic components could also be secured better inside the chassis. This would avoid future problems of faulty wire connections and electronics malfunction. These components could be hidden to improve the aesthetics by covering the open body with material such as acrylic. This, however, may exceed the prototype weight limit of 2kg as the device is already at 1.991kg. Construction of future versions of this vehicle should focus on improved weight management to allow for more additions/modifications. Joints need to be made more secure to avoid the problem encountered in the initial run, where the release arm left a gap and several ball-bearings were lost. This was temporarily fixed with super glue before the official run; however, a permanent solution should be implemented for future production, namely – reprogramming the position/angle of the servo and using better adhesive. On a full-scale model, this is easily achievable (e.g. welding, riveting).

The run score would have been improved even further with the availability of more ball-bearings as our vehicle managed to carry all available ball bearings and deliver them successfully. However, it has the capacity and torque to carry 40 bearings. If these were available, the run score would be significantly improved, making it more appealing to the client, and would better meet their needs in terms of efficiency.

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Appendix

Problem Statement – Meeting Minutes

Venue: UNSW Library 407
Time: 4:00pm-5:00pm
Members Present:

- Maximilian Cullen Feng
- Rabie-Bin Asim
- Jacquelyn Davie
- Thomas Colley
- Andre Matkowski

Members Absent:

- Madison Weekes

Minutes:

i. Problem statements
   - Individual problem statement
     - Advised to complete in week 3 mentoring session (i.e. next Monday)
     - Should include (from common lecture):
       - Who?
       - What?
       - Why?
   - Group problem statement
     - Developed after individual problem statements
     - Combine best ideas and eliminate unnecessary information for a clear and concise statement

ii. Exploring design idea of a tank-like vehicle
   - Using treads increases traction
   - Treads require a lot of torque
   - Treads can easily maneuver over the ditch section
   - Treads are heavier
   - Rigid body of a tank-like vehicle can sustain impact from the drop better
   - Steering options
     - Differential
     - Skid-steer

I will volunteer to research different methods of steering in my own time.

iii. Arduino
   - Need to buy Arduino Board for team

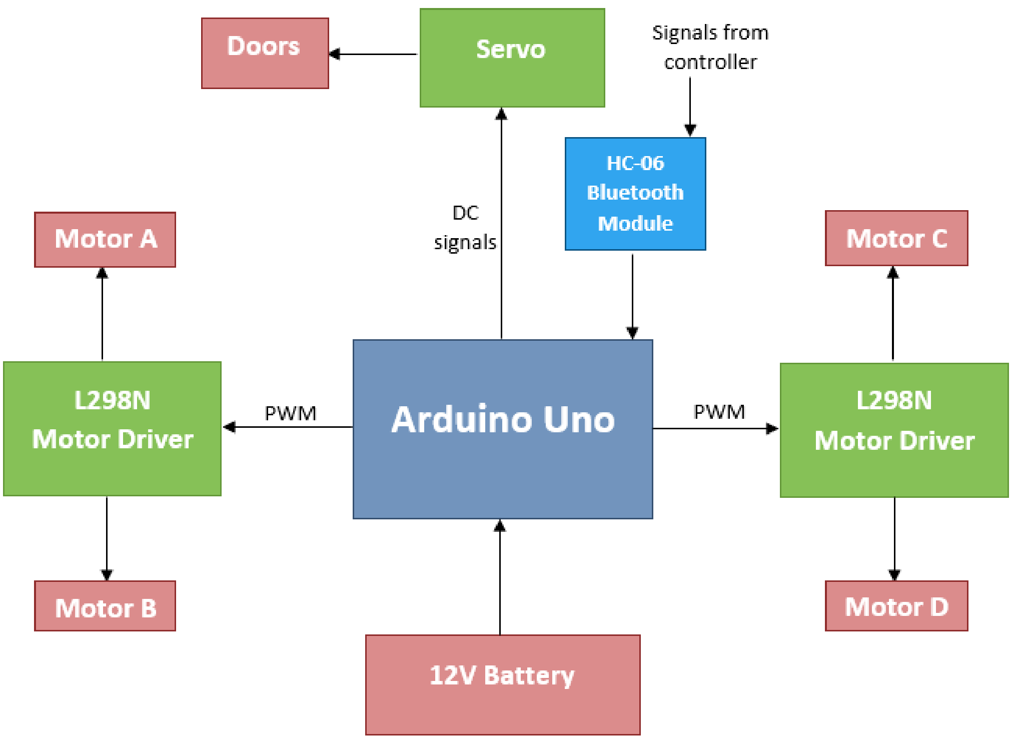
   Jacquelyn has offered to buy the recommended control kit from the 'create' store on campus
   - Tom and Andre will research Arduino coding

iv. Parts needed and where to buy them
   - Create store will sell required electronics
   - Andre can provide a LiPo battery (and maybe motors too)
   - Plywood can be sourced from off-cuts at makerspaces (or bought relatively cheap)
   - Wheels/Tracks will need to be bought online or at a hobby store

Decision Matrices – Binary Objectives Comparison

	Durability	Eas e of Use	Spee d	Power Usage	All terrain	Modification	Aesthetics	Scor e	Priority
Durability	------	0	1	1	0	0	1	3	4
Ease of use	1	------	1	1	0	1	1	5	2
Speed	0	0	------	1	0	0	1	2	5
Power Usage	0	0	0	------	0	0	1	1	6
All terrain	1	1	1	1	------	1	1	6	1
Modification	1	0	1	1	0	------	1	4	3
Aesthetics	0	0	0	0	0	0	-------	0	7

Block Diagram – Mechanical & Electronic Connections



Arduino Code

```
//https://play.google.com/store/apps/details?id=braulio.calle.bluetoothRCcontroller&rdid=braulio.calle.bluetoothRCcontroller
// ^^necessary bluetooth app
#include <Servo.h>
Servo hookServo;
Servo hatchServo;
int servoPos = 0;

// Assign ints to motor pins
//Motor A and B assignment
int maxSpeed = 255;
int motA_f = 12;
int motA_b = 9;
int motB_b = 13;
int motB_f = 8;

//bluetooth capability
int state = 0;

void setup() {
  // setting up pins for motors A,B
    pinMode(motA_f, OUTPUT);
    pinMode(motA_b, OUTPUT);

    pinMode(motB_f, OUTPUT);
    pinMode(motB_b, OUTPUT);
  //setting pins for bluetooth
    Serial.begin(9600);

  //Setup servo
    hatchServo.attach(7);
    hookServo.attach(6);
    hatchServo.write(0);
    hookServo.write(0);
}

void reverseCar(){
  digitalWrite(motA_f, LOW);
```

```
  digitalWrite(motA_b, HIGH);

  digitalWrite(motB_f, LOW);
  digitalWrite(motB_b, HIGH);

}

void forward() {
  digitalWrite(motA_f, HIGH);
  digitalWrite(motA_b, LOW);

  digitalWrite(motB_f, HIGH);
  digitalWrite(motB_b, LOW);
}

void turnCarLeft() {
  digitalWrite(motA_f, HIGH);
  digitalWrite(motA_b, LOW);

  digitalWrite(motB_f, LOW);
  digitalWrite(motB_b, HIGH);
}

void turnCarRight() {
  digitalWrite(motA_f, LOW);
  digitalWrite(motA_b, HIGH);

  digitalWrite(motB_f, HIGH);
  digitalWrite(motB_b, LOW);
}

void stopCar() {
  digitalWrite(motA_f, LOW);
  digitalWrite(motA_b, LOW);

  digitalWrite(motB_f, LOW);
  digitalWrite(motB_b, LOW);
}

void servoHookActivate() {
```

```
  hookServo.write(70);
  delay(15);
}

void servoHookDeactivate() {
  hookServo.write(0);
  delay(15);
}

void servoHatchOpen(){
    hatchServo.write(110);
    delay(15);
}

void servoHatchClose(){
    hatchServo.write(0);
    delay(15);
}

void loop() {
  if(Serial.available() > 0) {
    state = Serial.read();
    stopCar();

    switch(state){
      case 'F': forward(); break;
      case 'B': reverseCar(); break;
      case 'L': turnCarLeft(); break;
      case 'R': turnCarRight(); break;
      case 'G': turnCarLeftForward(); break;
      case 'I': turnCarRightForward(); break;
      case 'H': reverseCarLeft(); break;
      case 'J': reverseCarRight(); break;
      case 'W': servoHatchOpen(); break;
      case 'w': servoHatchClose(); break;
      case 'U': servoHookActivate(); break;
      case 'u': servoHookDeactivate(); break;
    }
  }
}
```