ENGINEERING THE PERFECT PACE: ENERGY-CONSTRAINED TIME-OPTIMAL ELECTRIC VEHICLE CONTROL IN TERRAIN WITH VARYING ELEVATION

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Abstract

This study, under the research group COMEA led by Eero Immonen, is part of an ongoing project that aims to optimise the usage of the electric vehicle battery of an eRallycross car that is under development by the Turun Ammattikorkeankoulun (TUAS) eRallycross-autoprojekti. The optimisation will prioritise the efficiency and performance of the vehicle by enhancing the current optimisation methods employed by the research group and exploring a new optimisation approach.

Simulating a fundamental energy system based on a runner allowed for the initialisation of the project. This relatively simple energy system model utilised the Keller Theory alongside the Douglas-Peucker Method and Mountain Car Problem solution previously developed by the COMEA group to analyse a runner's pace. The Keller Theory allows for the formulation of four optimised physiological parameters which can be integrated into the runner optimisation simulations of the Mountain Car Problem. This gave optimum plots which entailed the fastest completion time relative to the original running data along with energy levels and a force profile for this optimum run.

Upon trying to implement the optimisation routine from the runner energy system into the electric vehicle it became apparent that it was not in a format which was suitable for effective integration. This led to a new optimisation approach being formulated to treat the force simulation as a discrete optimisation routine, rather than a continuous function. Discretising the force selection allowed for the runner to choose a force from a range of pre-set choices, this choice would be made for every slope in the track elevation simplification found though the Douglas-Peucker algorithm. This new optimisation technique was then capable of being reformulated to suit the eRallycross car.

The Simulink model for the electric vehicle, after many modifications to the original file, was capable of using the velocity outputs, in the form of a MATLAB file input, from the optimised routine to result in data which can be given to the rallycross driver to enable the best race strategy. This optimisation routine helps enhance the efficiency and performance of the battery while not comprising the speed of the vehicle. The throttle data and force graph that the Simulink model outputs, post optimisation, can be given to a driver to follow the instructions and race as quickly and efficiently as possible.

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Nomenclature

Symbol	Name	Units
α	Local slope angle	rad
a	Acceleration	m/s^2
a_{dr}	Action taken by agent	
Ah	Ampere-hour	
ATP	Adenosine triphosphate	
BMS	Battery Management System	
$BTMS$	Battery Thermal Management System	
C	Curve of the line	?
C_n	Battery nominal capacity	Ah
CMU	Cell Monitoring Unit	
$COMEA$		
D	Final distance	m
D_c	Critical Distance	m
D_{WR}	World record distances	m
DC	Direct Current	
DP	Douglas-Peucker	
d	Distance	m
ε_d	Distance dimension	
ε	Permittivity	$F\ /\ m$
E	Energy	J
E_0	Initial energy	J
e^0	Initial energy per unit mass	cal/kg
F	Propulsive force	N
F_u	Unbalanced force	N
F_P	Propulsive force setting varying with distance	
FIA	Fédération Internationale de l'Automobile	
$FLOP$	Floating-point operation per second	
f	Specific propulsive force	N/kg
f_e	Engine force	N
f_{max}	Maximum propulsive force per unit mass	N/kg
$f_{\max\_sim}$	Maximum force for simulation	N
g	Acceleration due to gravity	m/s^2
GHG	Greenhouse Gases	

GPS	Global Positioning System	
I	Current	A
LP	Linear Programming	
LTI	Linear Time Invariant	
m	Mass	kg
$MATLAB$	Matrix Laboratory	
MCP	Mountain Car Problem	
$MILP$	Mixed -Integer Linear Programming	
MMU	Module Management Unit	
η	Efficiency	
η_c	Efficiency of battery charging/discharging	
NLP	Nonlinear Programming	
ODE	Ordinary Differential Equation	
P	Point on the curve	
$P_{nominal}$	Nominal power	W
P_{max}	Maximum power	W
PCr	Phosphocreatine	
PID	Proportional Integral Derivative	
PMU	Pack Management Unit	
QP	Quadratic Programming	
r	Resistive force per unit mass	N/kg
R	Resistive force varying with distance	N
σ	Aerobic recovery rate	$cal/kg/s$
ς_{func}	Aging rate function	
$SoC(k)$	State of charge	%
$SoC(k_0)$	Initial state of charge	%
$SOCP$	Second-Order Cone Programming	
$SoH(T)$	State of health	%
$SoH(t_0)$	Initial state of health	%
$SoP(t)$	State of power	%
τ	Specific internal resistance	N/kg
T	Final Time	s
T_c	Time taken to reach critical distance	s
T_{WR}	Final world record time	s
t	Time	s
$TUAS$	Turku University of Applied Sciences	
μ	Friction coefficient	

$\boldsymbol{v}$	Velocity	$m\ /\ s$
$\boldsymbol{v_{calc}}$	Calculated velocity	$m\ /\ s$
$\boldsymbol{v_{meas}}$	Measured velocity	$m\ /\ s$
$\boldsymbol{v(t)}$	Instantaneous velocity	$m\ /\ s$
$\boldsymbol{\dot{V}O2_{max}}$	Maximal volumetric oxygen uptake	$ml/kg/min$
$\boldsymbol{x}$	Current position of car	m
$\boldsymbol{x'}$	Position of car at next time step	m
$\boldsymbol{\dot{x}}$	Current velocity of car	$m\ /\ s$
$\boldsymbol{\dot{x}'}$	Velocity of car at next time step	$m\ /\ s$
$\boldsymbol{x_r}$	Point of charge from increasing to decreasing slope on graph	
$\boldsymbol{\varphi}$	Net energy dissipation	$m^2/_{s^3}$

1.0 Introduction

The persistent climate issues have risen globally which has necessitated the development of novel environmentally sustainable energy solutions- this has led to the widespread adoption of electric vehicles. The United Nations Sustainable Transport Conference, held in October of 2021, found that for 45% of countries the largest source of energy related emissions was from the transport sector [1]. Numerous leading car manufacturers have developed various iterations of electric vehicles to aid in combatting the global emissions issue. Whether it is an entirely electrical vehicle, a plug-in hybrid, or a mild hybrid - batteries play a crucial function in these technological advancements by supplying electrical energy to the powertrain. However, a critical factor in the adaptation of this technology is the maximisation of energy efficiency which is an objective partly achieved by the optimisation of battery control. This project aims to enhance the efficiency of the usage of the TUAS battery and optimise the race performance of the electric rallycross vehicle for a given 2D track of varying elevation.

The vast expansion of the electric vehicle sector has resulted in the cross over into the world of motorsport, where there are now many racing categories in the Fédération Internationale de l'Automobile (FIA), such as Formula E and Extreme E. These forms of motorsport allow for the integration of electric vehicles into the competitive scene giving them their own categories to enable technically fair yet more sustainable racing.

This study is part of ongoing work initiated by the COMEA research group, under the leadership of Eero Immonen. This project aims to build upon the earlier efforts of the group in optimising electric vehicle control of the Turku University of Applied Sciences (TUAS) eRallycross car. The study will explore alternative optimisation approaches to further enhance the efficiency and performance of the system. The group was given access to certain documents and code files of existing work completed by the COMEA group to give a starting point for this analysis, which included running data for the Naantali track (Appendix A), a Simulink model of the eRallycross car, and simple code for the Douglas-Peucker and Mountain Car Problem. All of these files were used and made more complex to better suit the problem posed of a track of varying elevation.

1.1 Rallycross

Rallycross is a racing form which takes place on a track which integrates both tarmac and loose surfaces on a single track. This results in an interesting fusion of rally and traditional circuit racing which is thrilling for both the drivers and fans. The races are brief, consisting of only four to six laps which is very different to motorsport categories which are perhaps more well-known to the public such as Formula 1. Every race consists of a maximum of eight vehicles competing for points in a series of heats and finals. These points are racked up based on the time for completion of the laps specified pre-race. The vehicles are frequently compact, high-performance, four-wheel drive hatchbacks [2] [3].

Rallycross drivers are assisted by a ‘spotter’ who communicates with the driver from a good vantage point, from which they can observe the full track. They assist with several aspects of the race such as strategy and update the driver with real-time information. This communication allows the driver to fully concentrate of the intricacies of driving and completing the race in their best time. The drivers must all complete one 'joker lap' during the race in which they drive a slightly longer version of the track that must be driven strategically. Rallycross racing significantly differs from other racing disciplines that may enjoy greater recognition and more frequent television coverage. For this reason, rallycross is a discipline which is not very well-known despite its thrilling nature. It is crucial to note that each track will possess distinct characteristics and challenging segments which ensures that all races provide the excitement for fans and challenges for drivers. This sport is more readily accessible to amateur drivers compared to other racing disciplines – for example Formula 1 drivers must race in feeder series to even be considered for a race seat. This accessibility is also partially attributed to the fact that the race car can serve as the participant's regular vehicle so there is no need for an expensive race car. Additionally, it is worth noting that the entrance costs for this racing discipline are considerably lower compared to other forms of racing [4].

1.2 eRallycross

In August 2022, the World Rallycross Championship converted from internal combustion engines to electric power units [5]. This marked a significant shift, considering that the rallycross world championship had been in existence for more than five decades, operating according to its customary set of rules and regulations. This means that the racing form has joined other racing series like Formula E in converting to a more sustainable engine type. The substantial acceleration required at the beginning of a rallycross race renders it an ideal racing discipline for the use of an electric car. The new electric racing cars exhibited significantly greater speed compared to their predecessors – this attribute shows the suitability in transitioning to electric. The latest version of the RX1e vehicle achieves a 0-62 mph acceleration in less than two seconds, surpassing the capabilities of a Formula 1 car [5]. This is important as it is crucial to not negatively impact the quality of racing which would result in less exciting races which could ruin the series.

In 2017, a cohort of students from Turku University of Applied Sciences collaborated with Valmet Automotive Group to construct an electric rallycross car. The Mercedes Benz A-class underwent a process of component removal with the aim of eliminating unnecessary parts and recycling them. To construct and integrate a fully electric rallycross vehicle, the typical internal combustion engine was replaced with an electric motor [6].

1.3 The Battery of an Electric Vehicle

Global warming awareness has been a catalyst for the demand for electric and hybrid vehicles with electric cars being a major technological achievement in the 20th century. However, the first electric vehicles did not fully meet the criteria to encourage gasoline-powered car owners to switch to electric. Some examples of disadvantages of these electric vehicles being the long recharging times and these vehicles having short range, making them unreliable. Therefore, these traits did not win over the public so more had to be done to encourage proper integration of electric vehicles into today's society. [7]. Additionally, regular customers, who usually fill their car tank in five minutes, struggle with the long charging time. They may see this as a great inconvenience to their daily life which further deters potential new customers. To integrate electric vehicles into the commercial sector, batteries must be better developed and optimised.

1.3.1 Electric Vehicle Battery Types

The batteries which are implemented into electric vehicles can be divided into two types based on their charging ability. A primary battery can only be used once, but a secondary battery can be recharged. These batteries have differing attributes and are both valuable in certain applications. Based on these descriptions however, the secondary battery is best for electric car batteries as it is not feasible to replace the battery of the vehicle after every use [8]. An electric car battery should have a long lifespan, excellent charging efficiency, and high component safety.

1.3.2 Battery performance Parameters

1.3.2.1 State of Charge Estimation

Estimating State of Charge (SoC) involves calculating the percentage difference between a battery's current charge relative to its charge at maximum capacity [9]. Manufacturer-defined usual capacity is the battery's maximum charge level of 100%. The current state of charge of a battery is its charge relative to its maximum capacity. SoC analysis is crucial for long-term battery health assessments, especially for electric car maintainability since it helps give an idea of the health of the battery to some degree. The SoC of a battery can be calculated directly or estimated using a model with both methods being useful to some extent. Creating a model for finding the SoC may not be the most accurate but may be sufficient for certain applications. The direct estimation approach uses battery voltage and current readings. Direct estimation can be used in many forms one of which is the Ampere-hour (Ah) method [8]. It is important to note that this is not the only way to calculate SoC it is merely one method of formulating this concept. *Equation* 1 illustrates the simplified Ah method calculation.

Equation 1: State of Charge

$$SoC(k) = SoC(k_0) + \int_{k_0}^{k} \eta_c I(t)\ dt / C_n \qquad [10]$$

1.3.2.2 State of Health Estimation

The estimated State of Health (SoH) is another battery characteristic that can indicate the battery's overall condition by revealing its expected performance in its current state. Analysing the battery SoH allows the user to determine when to replace the battery by measuring its remaining capacity [10]. Like the state of charge of the battery, there are numerous methods for calculating the SoH of a battery, *Equation* 2 being one of them.

Equation 2: State of Health

$$SoH(T) = SoH(t_0) + \int_{t=t_0}^{T} \delta_{func}(I, T, SoC, others) d\tau \qquad [11]$$

Through battery health evaluation, battery capacity decline can be used to assess battery ageing. Previous study [10], found that system internal resistance increases as battery capacity diminishes. Batteries with higher internal resistance lose energy and perform poorly which is not optimal for a car battery. Internal resistance in a battery can generate heat energy during energy dissipation, affecting its performance and efficiency [11].

1.3.2.3 State of Power Estimation

The State of Power (SoP) refers to the ratio between the maximum power output of a battery and its nominal power capacity. The peak power is based upon the present condition of the battery, while the nominal power represents the energy capacity of the battery in its pristine and unutilized state. For the power to be classified as peak, it must be sustained for a duration of T seconds while adhering to predefined operational design thresholds for battery voltage, state of charge (SoC), power, and current, without surpassing them [12]. When considering the state of power as a ratio, it can be represented as in *Equation* 3.

Equation 3: State of Power

$$SoP(t) = \frac{P_{max}(t)}{P_{nominal}(t)} \times 100 \qquad [12]$$

The above equation allows for simple analysis of the state of power which is easily understandable and help analyse the health of the battery.

1.4 Battery Management Systems

In uncontrolled environments, car batteries need protection from numerous potential problems, which is where battery management systems (BMS) come in. [13]. The battery management system oversees the battery condition by analysing many aspects of the battery. A better functioning BMS will allow for a clearer understanding of the limits and functions of the battery which can aid in the longevity of a battery being improved and an increased battery efficiency. Thermal stress is a crucial factor that must be taken into consideration which refers to the mechanical stress induced by the rise in temperature experienced by a certain material [14]. High temperatures and extended cold exposure can cause thermal stress in batteries, which can negatively affect performance. When evaluating the utilisation of a battery in an electric vehicle, it is imperative to consider the requisite battery size. The implementation of a sophisticated control circuit will be necessary to enable continuous monitoring and analysis of the battery's state. This is vital as the identification of flaws in the battery system is of utmost importance, as timely detection is crucial to prevent significant issues. It is imperative for users to be informed about the appropriate timing for battery replacement or inspection [13]. The presence of intricate components within an electric car battery necessitates the implementation of a battery management system. This is a safety control system that oversees different components of the battery pack and the battery as a whole [15]. The BMS encompasses a multitude of functions that collectively provide a comprehensive analysis of the battery. The Cell Monitoring Unit (CMU) primarily assesses the voltage and temperature of the cell. The Module Management Unit (MMU) is responsible for the management and control of a collection of cells or CMUs. The Pack Management Unit (PMU) is responsible for overseeing the management of the MMUs and the implementation of battery safety protocols through effective communication with external systems.

1.4.1 The main purposes of Battery Management System

The BMS of a vehicle serves multiple functions, one of which is primarily concerned with the user's safety. The BMS identifies problems within the system and responds appropriately to address the issue. This may encompass a variety of actions, including a notification to the user indicating the presence of an error or malfunction. Nevertheless, in certain instances of heightened severity, the battery may become disconnected by the BMS due to the detection of a malfunction within the battery [13]. Continuous monitoring of the battery's state is crucial to prevent excessive discharge or overcharging as these situations can have very negative impacts on the system. An improperly charged battery can pose a significant danger, as it increases the potential of fire or explosion in the device [16]. It is crucial to monitor not only the overall battery, but also each individual cell this is because the overall strength of the battery is determined by the weakest cell within it. Therefore, if even a single cell is charged improperly, it will have a negative impact on the function and/or safety of the system.

1.4.2 The scope of the Battery Management System

The battery management system plays a crucial role in various domains, and its significance should not be underestimated. The BMS umbrella encompasses four primary categories: safety, performance estimation, control demand, and vulnerability prediction. The safety of the battery is ensured by the BMS, and it can detect various battery conditions that may pose a risk to the system. Over-voltage refers to a condition in which the voltage of the battery exceeds its initial configuration. The maximum permissible voltage value is predetermined during the battery manufacturing process, and the BMS can detect any voltage over this threshold. Similarly, this applies when the battery exhibits an excessively high current value. These metrics are under the safety domain of the BMS. The BMS oversees and supervises the performance indicators such as state of charge, health, and power [17]. The internal resistance of the battery is also assessed which is the resistance that impedes the passage of electrical current within a battery [18]. The control requirement section of the BMS will assess factors such as the remaining usable life and capacity degradation of the battery. The vulnerability prediction section analyses other crucial aspects of a battery. This encompasses the detection of additional heat generated during usage and the BMS's capability to carry out fault diagnosis and prognosis [17].

1.4.3 Types of Battery Management Systems

Battery Management Systems can be categorised using different approaches to facilitate the separation of their functionalities. The classification of these systems can be based on either their function or their topology [19]. Topology refers to the organisation and structure of the BMS in relation to its position. One prominent example of topology is the centralised Battery Management System [20]. A centralised BMS is comprised of a singular system that supervises the entirety of the battery cell modules and battery packs. The system will facilitate the analysis of all cells inside its framework, scrutinise the performance, and acquire measurements to ascertain the safe operation of the battery system. One advantage of employing a centralised BMS is its compact nature, rendering it suitable for integration into smaller products. However, the use of this system in larger products can lead to higher costs due to the requirement for several centralised BMS systems [21]. An alternative topology in the field of BMS is the distributed BMS, which contrasts with the centralised BMS. This type of BMS incorporates a control board that is affixed to each battery module, enabling the analysis of each individual cell [21]. The selection of the battery management system for the product is dependent upon the requirements of the system, and it is imperative to ensure the appropriate system is chosen.

1.5 The Battery Thermal Management System

The Battery Thermal Management System (BTMS) functions as a temperature control mechanism within the battery system of an electric car. The complexity of this system lies in the utilisation of many cooling mechanisms rather than relying solely on a single approach to cool the battery. Examples of these instances include air cooling, liquid cooling, and phase-change material cooling. The air-cooling technique is commonly preferred by engineers for many electric car batteries. This can be attributed in part to the benefits gained from its lightweight nature and its ability to consume little amounts of energy. Nevertheless, the air-cooling system has a lower heat exchange rate, consequently exposing it to significant difficulties in coping with the elevated ambient temperatures experienced during the summer season [22].

1.5.1 The importance of Battery Thermal Management Systems

The integration of a battery system in a vehicle may give rise to notable challenges, despite the evident benefits associated with utilising batteries to mitigate emissions released into the atmosphere. In contrast to the implementation of batteries in devices such as smartphones and laptops, the incorporation of batteries in vehicles necessitates careful consideration of the substantial heat generation. The immense capacity required for electric car batteries is attained through the stacking of numerous battery cells within a pack, contributing to the phenomenon of high heat generation [23]. Another cause of heat generation within the battery is the high-power charging and discharging applications which causes a heat increase due to changes in enthalpy and resistive heating inside the cell [24]. Considering this, it is imperative to have functionalities that can effectively dissipate the heat produced within the battery system, as it has detrimental implications for battery performance. This is why a battery thermal management system is crucial when implementing batteries into vehicles [23].

1.5.2 Battery Thermal Management System design philosophy

When building and selecting a battery thermal management system (BTMS), it is crucial to consider numerous design variables which can drastically change the design of the system. It is imperative to thoroughly consider the primary goals and limitations of the design of the product. This may involve factors such as the spatial dimensions and geometric properties of the designated location for the system, as well as the financial resources available for the building of the system. After careful examination of these characteristics, it is necessary to conduct thermodynamic modelling of the batteries and the battery pack to assess the rate of heat generation and the distribution of cell temperature throughout the battery [25]. The utilisation of thermal models in battery systems enables the simulation of temperature profiles within the battery throughout the processes of charging or discharging [26]. The computation of the temperature of the module in contact with the system is facilitated using energy conservation and heat transfer principles. This process also involves the analytical evaluation of thermophysical features such as heat capacity. The utilisation of Computational Fluid Dynamics (CFD) enables the determination of the heat transfer rate between the fluid of the Battery Thermal Management System (BTMS) and the battery. By consolidating all these empirical findings, it becomes possible to assess the anticipated efficiency of the BTMS, thereby enabling its construction and subsequent experimental validation. It is important to acknowledge that the current design iteration of the BTMS may be too simplistic and can be further optimised to more effectively fulfil the design objectives [25].

1.6 Energy Efficiency

The increase in the energy efficiency of a product is crucial in addressing the escalating global climate change difficulties. Recent years have provided further evidence of the contribution of vehicle emissions to the carbon dioxide problems affecting the climate. The transport sector in its entirety contributed to 28% of the total energy consumption of the world [27]. This statistic illustrates how vital it is to find ways to increase the energy efficiency of the battery within electric vehicles.

1.6.1 Motivations for Increasing Energy Efficiency

To gain a comprehensive understanding of the benefits associated with an improved system efficiency, it is imperative to acquire a firm grasp of the underlying idea of efficiency. Efficiency is commonly described as the achievement of the highest level of performance with minimum input while producing maximum output. Engineers possess the capacity to optimise the efficiency of a given system by the reduction of superfluous inputs, all the while ensuring the attainment of the desired outcome. The quantifiability of the idea of efficiency allows for the examination of whether a system has truly attained improved efficiency following modifications [28]. *Equation* 4 serves as a demonstration of the expression of efficiency [29].

Equation 4: Efficiency expression

$$\eta = \frac{Output}{Input}$$

Equation 4 clarifies that the rationale behind striving for enhanced efficiency can be attributed, in part, to the evident beneficial influence it will exert on the system. Therefore, increased efficiency is not only desirable due to its positive impact on the environment, but it also results in greater system outputs - suggesting that users can obtain a higher level of output relative to the input provided.

1.6.2 Increasing energy efficiency for electric vehicles

When evaluating the integration of electric vehicles into mass manufacturing, it is imperative to ascertain whether these novel propulsion systems can satisfy the dual requirements of reducing emissions while maintaining sufficient power output for practical implementation in vehicles. It was seen that the utilisation of electric motors in cars results in a significant enhancement of engine efficiency in comparison to conventional internal combustion engines [30]. The concept is demonstrated by the observation that electric vehicles exhibit the capacity to effectively convert over 77% of the electrical energy acquired from the grid into propulsive power at the wheels. The electric motor has a notably superior efficiency percentage when compared to the conventional petrol engine, which normally converts approximately 12-30% of the stored energy into mechanical power at the wheels [31].

Enhancing the energy efficiency of a given product yields significant advantages, not just for the engine system in question but also for the environment and in making the engine more cost-effective. One of the advantages associated with this phenomenon is the reduction in greenhouse gas (GHG) emissions, along with a concurrent decrease in water consumption. Enhancing the energy efficiency of the system can yield lasting advantages by reducing the aggregate electricity demand, hence the system becomes more financially viable [32]. An increase in the efficiency will also lead to a longer range of the vehicle which would make the electric car more attractive to buyers [33].

1.7 CSC Supercomputing

The utilisation of high-performance computing is particularly important when carrying out simulations of a system which is of particularly high complexity [34]. The national supercomputers in Finland at the CSC-Tieteen tietotekniikan keskus Oy (Finish IT centre for science) have a unified computing power of 7.5 petaflops per second [35]. A floating-point operation per second (FLOP) gives a measure of the performance of a computer based on the number of floating-point calculations that the computer processor is capable of performing per second [36]. From this, it is clear that the larger FLOP value the more powerful the computer is and the faster it will be able to provide a solution to given simulations.

The two particular supercomputers in Finland are Mahti and Puhti-Al which account for 1.8 petaflops per second with Puhti-Al having 2.7 petaflops per second. The Puhti-Al was designed specifically for the implementation of artificial intelligence software. The Mahti supercomputer is mostly intended for use during medium and heavy intensity simulations that need high computing power [36].

2.0 Literature Review

2.1 The Keller Theory

2.1.1 Background of the Theory

Joseph Keller previously conducted extensive research into pacing strategy, as an application of mathematical principles in real-world contexts. The examination of his work will critically assess two significant aspects: his formulation of the optimal race strategy and theoretical predictions of world records. These concepts can be widely employed as a fundamental basis for initialising the time-optimisation of vehicle control. The Keller theory of competitive running partly relies on Newton's second law (*Equation* 5) as its fundamental principle.

Equation 5: Newton's Second Law

$$\sum F_u = m \times a$$

This law in combination with application of calculus aided Keller in devising the optimum race strategy [37].

After the completion of introductory calculus, four essential physiological parameters became apparent, which were determined using mathematical methods. Physiological parameters are some pertinent aspects of the human body in relation to the locomotor system under analysis. It is crucial to include these parameters when conducting calculations for the system, as they are not within the control of the theorist but rather the runners themselves. As a result, the determination of the most effective race strategy is significantly enhanced through the inclusion of said parameters [38].

The ability to ascertain the four primary characteristics is made feasible through knowledge of the present world record time (T_{WR}) in conjunction with the established race distance (D_{WR}). The four parameters under consideration are the initial energy stored in the runners' body, the rate at which energy is provided by oxygen metabolism, the propulsive force that a runner may exert, and the maximum resistive force opposing the runner [37].

It is apparent that the velocity of a runner will undergo fluctuations during a race, it is improbable for a runner to maintain a constant velocity from the beginning to the midpoint of a long race. One potential variable that may also influence a runner's performance during a race is the stride length, which has the potential to decrease as the runner experiences increasing levels of exhaustion [39]. This is not considered during the formulation of Keller's theory. However, a variable speed (represented as $v(t)$) will be used to minimise the amount of time required. Keller's research findings were essential in establishing the concept of the critical distance in a race. The minimum distance at which a runner should sustain their maximum pace throughout the entirety of a race is titled the critical distance (D_c), which has been shown by Keller's findings to be 291 metres. Races under this distance are commonly referred to as "dashes". It is worth noting that races of greater length necessitate a slightly modified approach to the calculation methodology. Keller theorised that in the context of a long-distance race, it is likely that a runner would commence the race by running at their maximum speed for a duration of approximately one to two seconds. Subsequently, the runner would strive to keep a consistent pace throughout the remaining duration of the race. Finally, the runner is expected to exhibit a minor decrease in speed during the final one to two seconds of the race. *Figure*s 1 and 2 below illustrate the differentiating characteristics between dashes and long-distance races.

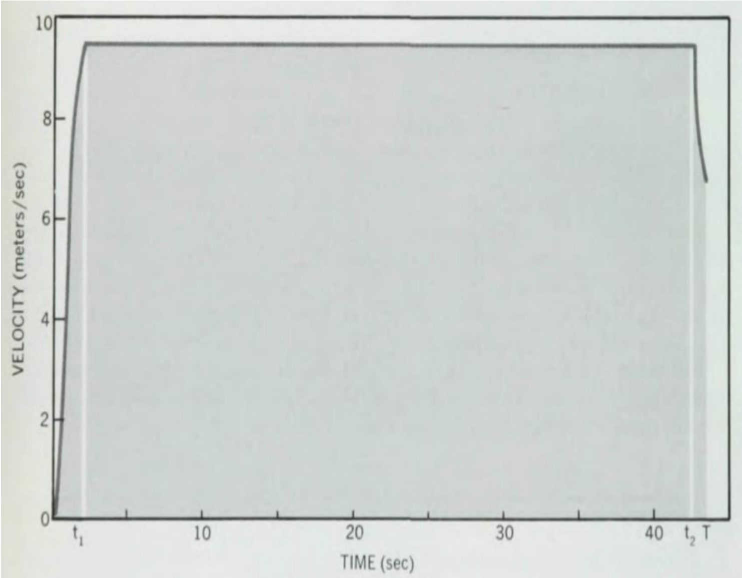

Figure 1: The 400-metre run

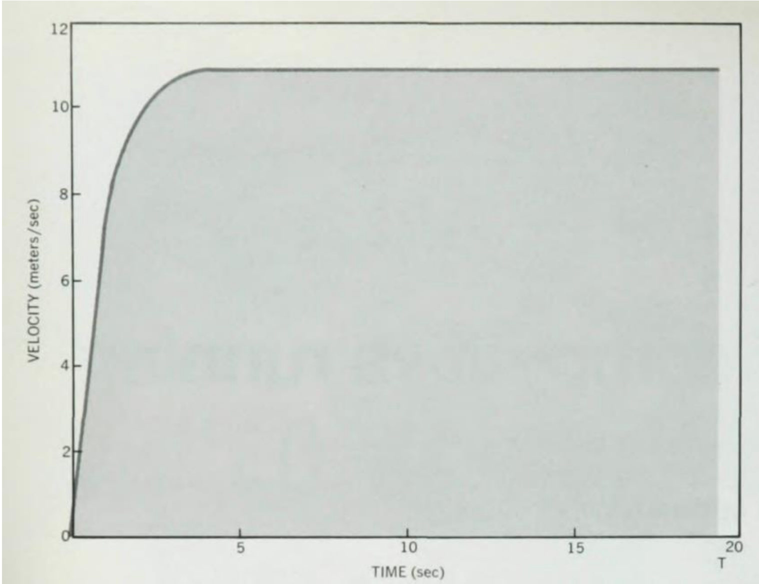

Figure 2: The 220-yard dash

Figure 1 depicts a race of a distance longer than the critical distance, specifically the 400-meter run. During this race, the runner experiences maximum propulsive force for a duration of 1.78 seconds. Following this period, the runner maintains a constant velocity until reaching a point 0.86 seconds prior to the race's conclusion, at which point the supply of oxygen gets depleted, resulting in $E(t)$ being reduced to zero.

Figure 2 showcases the graphical representation of the ideal velocity $v(t)$ as a function of time for the 220-yard sprint. The propulsive force remains at its maximum level throughout the entirety of the race distance. The graphs effectively illustrate the disparities that Keller discerned in his theoretical framework pertaining to the techniques employed in short and long-distance running races.

2.1.1.1 Understanding different pacing strategies

Runners have the option to adopt several pacing techniques during their race with the objective of achieving the fastest possible race completion time. Negative pacing is a strategic approach in which the runner gradually increases their speed throughout the race, culminating in a sprint at the final stage. This strategy may be adopted by a runner aiming to preserve sufficient energy until the end of the race to try and outperform their nearest rivals on the track. Positive pacing refers to the deliberate and progressive reduction in speed throughout the course of a race – this could be used for a runner who wants to gain a large advantage at the beginning of the race. The strategy referred to as the "parabolic-shaped" approach involves maintaining a positive pace throughout the first half of the race and thereafter adopting a negative pace during the second half. The implementation of a variable pacing method is widely regarded as the optimal approach for addressing the vehicle battery issue. This requires adjustments in speed in accordance with different physical factors, such as deviations in height [40]. Variations of weather conditions, such as headwinds impeding forward movement and tailwinds increasing pace, might lead to a fluctuating pacing strategy. A wind is considered "significant" when the runner's pace is approximately equal to the speed of the wind. The presence of substantial wind can result in a decrease in a runner's speed by 12 seconds per mile when facing a headwind and increase by 6 seconds per mile when benefiting from a tailwind [41]. This shows how large of an impact that external factors can either aid or disadvantage a runner, however this type of parameter is not accounted for by Keller.

2.1.1.2 Formulation of the Keller Theory

The theory was introduced by Keller, who employed basic principles of kinematics to derive an equation for determining velocity.

Equation 6: Keller's expression for velocity

$$D = \int_0^T v(t)dt$$

$$\frac{dv}{dt} + \frac{v}{\tau} = f(t)$$

The term $v/_{\tau}$ represents the internal and external resistive force per unit mass and a portion of the total propulsive force per unit mass exerted by the runner $f(t)$ is used to overcome this. The force $f(t)$ is at the control of the runner so can be regarded to as a control variable, and it must be adjusted by the runner throughout the race. With $v(t)$ being the solution of *Equation* 6, the value of T can be minimised through the variation of force [37].

The ability to modify the function $f(t)$ is limited by two parameters, one of which is the presence of a fixed upper limit on the propulsive force (F) that the runner can exert while adhering to the given inequality. The runner can only physically exert their maximum force and cannot exceed this.

Equation 7: Force inequality

$$f(t) \leq F$$

The other constraint on the value of $f(t)$ is that the rate of work done per unit mass (fv) must be equivalent to the rate at which the object consumes energy. At the start of the race, the runner's oxygen supply will initially consist of a specified quantity, which will be supplemented throughout the race by the respiratory and circulatory systems. [37].This oxygen balance is useful in the formulation of the Keller theory.

Equation 8: Oxygen balance

$$\frac{dE}{dt} = \sigma - fv$$

It is evident that the energy equivalence of accessible oxygen for the runner cannot possess a negative value, thus implicitly imposing a second constraint on the fv value.

Equation 9: Expression of restrictions of available oxygen and energy

$$E(t) \geq 0 \quad and \quad E(0) = E_0$$

The combination of the above equations helps to initialise the Keller theory problem so values for $v(t), f(t)\ and\ E(t)$ must be found so that all values satisfy all equations. Keller's research yielded a solution to the problem of determining the rate at which the starting oxygen supply is consumed to complete a race distance, D, in the shortest possible time. The findings indicate that for distances smaller than the critical distance, the following statement holds true [37].

Equation 10: Expression for force for races below critical distance

$$f(t) = F, and\ v\ increases\ monotonically$$

The velocity exhibits a monotonic increase, as evidenced by the strictly ascending nature of *Figures* 1 and 2 when the equation's values are incremented. The value for force exhibits a consistent pattern of either remaining constant or increasing, with no instances of decline observed [42]. However, this approach seems to be beneficial solely for shorter races and fails to consider the intense demands of long-distance events. Keller’s solution to this issue found that for distances $D > D_c$ then $v(t)$ increases for t less than t_1, v is constant between times t and t_1 then v decreases for t greater than t_2 until the end of the race T – these three distinct stages of a long distance run can be visualised using *Figure* 1. These findings must be put through further analysis to develop a formula that can be utilised to accurately formulate predictions for world records [37].

2.1.2 Comparison of The Keller Theory with Physical Observation

An examination of Keller's theoretical records in relation to real-world records is crucial to ascertain the strengths and weaknesses of the theory. This allows for an examination of the effectiveness of which the physiological parameters were extracted and employed in the development of the Keller hypothesis. Although Keller primarily focused on developing a mathematical model that incorporated physiological elements to a certain degree, there was a lack of comprehensive investigation into the specific impact of each variable on a runner across different distances. Because of this, the results obtained may not fully represent the world record times with utmost accuracy.

Table 1 presents a comparison between the outcomes of the Keller theory and the world records for race distances spanning from 50 yards to 10,000 metres. [37].

Table 1: Comparison of world record vs. Keller's results

Distance, D	Time, T (record) min:sec	Time, T (theory) min:sec	Error (per cent)	Average velocity, D/T (theory) m/s	t_1 sec	T-t_2 sec
50 yd	5.10	5.09	-0.2	8.99		
50 m	5.50	5.48	-0.4	9.12		
60 yd	5.90	5.93	0.5	9.26		
60 m	6.50	6.40	-1.5	9.38		
100 yd	9.10	9.29	2.1	9.85		
100 m	9.90	10.07	1.7	9.93		
200 m	19.50	19.25	-1.3	10.39		
220 yd	19.50	19.36	-0.7	10.39		
400 m	44.50	43.27	-2.8	9.24	1.78	0.86
440 yd	44.90	43.62	-2.9	9.22	1.77	0.86
800 m	1:44.3	1:45.95	1.6	7.55	1.07	1.08
880 yd	1:44.9	1:46.69	1.7	7.54	1.06	1.08
1000 m	2:16.2	2:18.16	1.4	7.24	0.98	1.16
1500 m	3:33.1	3:39.44	3.0	6.84	0.88	1.31
1 mile	3:51.1	3:57.28	2.7	6.78	0.87	1.34
2000 m	4:56.2	5:01.14	1.7	6.64	0.84	1.43
3000 m	7:39.6	7:44.96	1.2	6.45	0.80	1.60
2 miles	8:19.8	8:20:82	0.2	6.43	0.80	1.63
3 miles	12:50.4	12:44.89	-0.7	6.31	0.77	1.80
5000 m	13:16.6	13:13.11	-0.4	6.30	0.77	1.82
6 miles	26:47.0	25:57.62	-3.1	6.20	0.75	2.10
10000 m	27.39.4	26:54.10	-2.7	6.20	0.75	2.12

A thorough examination of Table 1 provides valuable insight into the intricacies and accuracies of Keller's theoretical framework, while also underlining its inherent limitations. Some distances yielded a negative error value, indicating that the recorded value is lower than the theoretical record time, as anticipated. Nevertheless, the issue with the credibility of the theory emerges when the error value exhibits a positive outcome, indicating that a runner in a race has surpassed the predicted time. This observation implies that certain assumptions made over the course of the analysis may have oversimplified the situation, hence resulting in these outlying values. The analysis of *Table* 1 reveals that half of the theoretical values, particularly in the longer distance races, exhibit a positive error value.

When conducting a comparison between the Keller theory values and the actual data, it is imperative to thoroughly investigate the discrepancies in the values. The calculation of this error is determined by employing the following formula:

Equation 11: Keller error value calculation

$$Error = \frac{Theortical\ time - Record\ time}{Theortical\ time} \times 100$$

A negative error value occurs when the theoretical value estimated using the Keller method is lower than the actual value. This suggests that, in theory, it is feasible for a runner to exceed the existing world record in terms of speed. Upon analysis of the error numbers, it is observed that the error range for the initial eight occurrences ranges from a minimum of -1.8% to a maximum of 2.1%. While the inaccuracies identified may be of a relatively small scale, the existence of positive values raises some concerns. In the context of extended-distance races, the margin of error falls within the range of 3% to -3.1%. In this case, it was demonstrated that a runner could achieve a higher running speed than the theoretical maximum speed computed by Keller. This observation highlights the inherent limitations of the Keller theory, as it fails to accurately anticipate every individual world record in a theoretical manner. The lack of comprehensive consideration for physiological aspects is apparent, necessitating further investigation to thoroughly examine and address the issue. This implies that the theory is better suited for sprint races, whereas there are certain intricacies that are not accounted for in the calculations for longer distances.

The velocity values obtained by the utilisation of the provided formula are additionally displayed in *Table* 1[37].

Equation 12: Velocity of runner

$$Velocity = \frac{Distance}{Time} \quad (m/s)$$

When examining the velocity numbers over various race distances, it is evident that there is a significant decrease in velocity when the race distances shift from sprints to long-distance races. The observed variations in velocity illustrated in *Figure 3* provide support for the notion that the critical distance value is somewhat accurate.

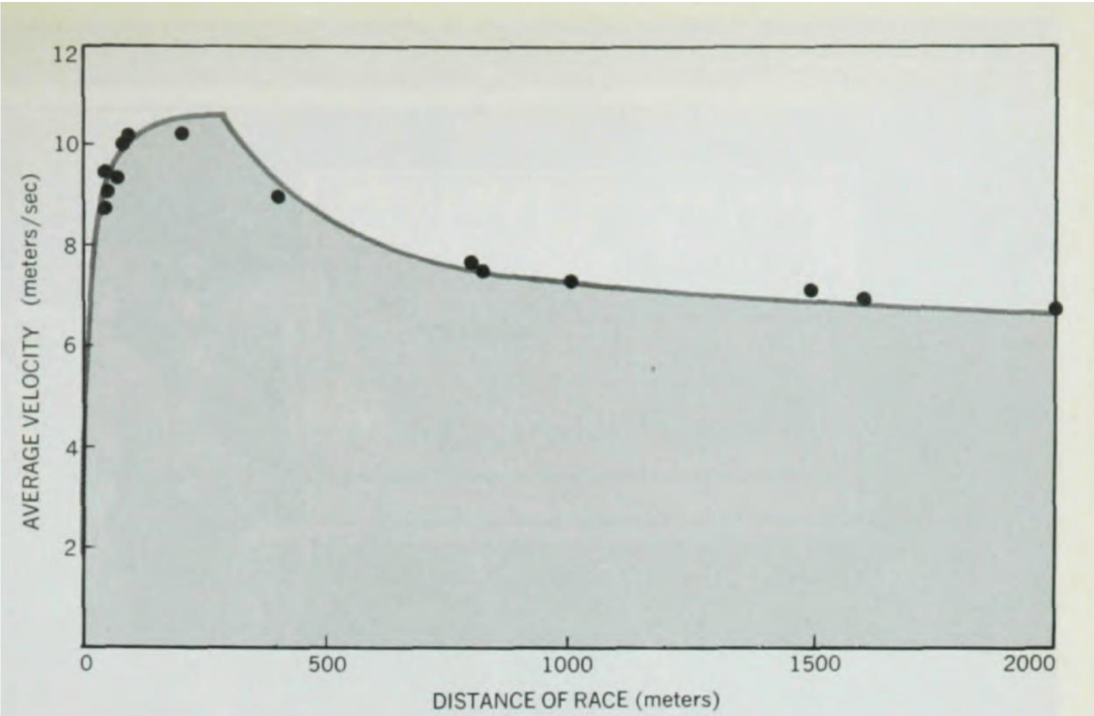

Figure 3: Average velocity for all race distances

2.1.2.1 Determination of the Four Physiological Parameters

Keller utilised the 'least squares fit' approach to aid in ascertaining the four physiological parameters. Through the process of minimising the sum of the squared deviations between the observed data points and the corresponding points on a curve, this approach facilitates the determination of the optimal curve or line that best fits a particular set of recorded outcomes [43].

This indicates that the parameters derived from these are more precise since the points on the line are as near to the actual record value data points as possible. When determining the constants τ and F, the least squares method was applied to the data from the first eight races (short distance sprints), while the 14 lengthier races were used to determine the parameters σ and E_0.

Equation 13: Distance relative to time, damping factor, and force

$$D = F\tau^2\left(\frac{T}{\tau} + e^{-T/\tau} - 1\right), \qquad 0 \leqq T \leqq T_c$$

As an illustration, *Equation* 13 just encompasses the parameters τ and F, which can be selectively determined to minimise the summation of squared relative errors throughout the eight dash races [44]. The Keller theory-determined parameter values are summarised in *Table* 2.

Table 2: Physiological Parameter Values

τ	0.892 sec
F	12.2 m/sec^2
σ	9.93 calories/kg sec
e^0	575 calories/kg
D_c	291 m

2.1.3 Drawbacks of the Keller Theory

Considering the intricacies involved in planning and executing a race, it becomes evident that the Keller theory has been devised in an excessively reductionist fashion. The estimates did not account for several mechanical and physiological characteristics, such as the oscillatory movement of the limbs while running and failed to differentiate between external and internal resistance. Also not taken into consideration were the potential discrepancies in oxygen availability and the potential fluctuations in a runner's oxygen intake throughout the duration of a race. To enhance the accuracy of calculating these theoretical world record times, it is advisable to formulate a comprehensive theory that accounts for all pertinent variables not just a select four. Keller's hypothesis remains relevant to some extent, as it presents suitably accurate findings and demonstrates adaptability to various other sporting events, such as in the context of swimming [37].

2.2 The Douglas-Peucker Method

The Douglas-Peucker algorithm is a technique employed for the purpose of line simplification. The method in question is designed to simplify polylines by lowering the quantity of data points. The purpose of this process is to simplify and condense a multitude of intricate and extensive points while still conveying the same overall information, thereby eliminating superfluous elements. This algorithm is often used to reduce the computation time and intensity when working with large data sets. When simplifying the data, it is expected that the overall shape of the curve would remain largely unchanged. However, the simplified curve will consist solely of the new data points obtained through the technique. The parameter ε is the distance dimension which governs the extent of coarsening, determining the maximum separation between the initial points and the simplified curve [45].

2.2.1 The Algorithm

The original curve C is given as a set of n points which can be expressed as below:

$$C = (P_1, P_2, P_3, \dots, P_n)$$

With the distance dimension of

$$\varepsilon_d > 0$$

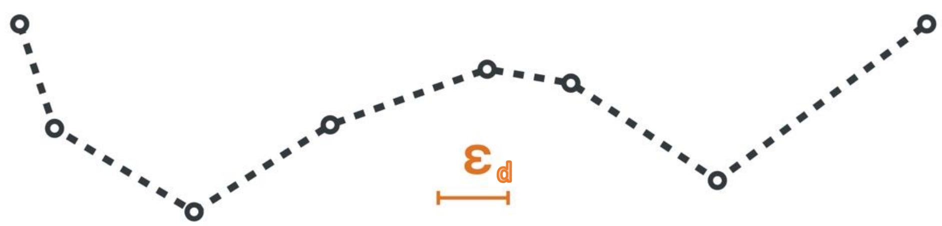

Figure 4: Polyline example

The Douglas-Peucker method utilises a distance threshold to determine the proximity of a point to an edge. The initial and end vertices of the polyline will be connected at the edge, as shown in *Figure 4*. Subsequently, the code will proceed to compute the distance between each vertex and the specified edge. A vertex is classified as a key vertex and included in the simplification process if it is the farthest from all intermediate vertices surrounding it and its distance exceeds the specified tolerance. The procedure facilitates the preservation of crucial polyline points, thereby maintaining the integrity of the original shape, while excluding less significant points from the simplified line's ultimate representation. The process will be iterated until all vertices of the original polyline are contained within the tolerance of the simplification results [46].

2.2.2 Benefits of implementing the Douglas-Peucker Method

One prominent characteristic of this algorithm is its capacity to simplify a very intricate problem by transforming it into a polyline, thereby facilitating easier manipulation and enabling the achievement of desired outcomes. By decreasing the number of points, the path can be simplified, resulting in a decrease in computational complexity and an enhancement in performance, all without compromising the accuracy of the outcomes. One significant benefit associated with employing the algorithm is the flexibility to tailor the approach according to specific requirements or preferences. The error threshold option provides users with the ability to regulate the degree of simplicity based on the unique needs and requirements of the design brief. This implies that the user could modify the algorithm to achieve an optimal trade-off between simplicity and accuracy [47]. The efficiency of the algorithm is another key factor in showing the effectiveness of the Douglas-Peucker Method.

The Douglas-Peucker approach exhibits a diverse range of applications, hence highlighting its extensive utility across various domains. One of the applications of this technology is data visualisation, which entails the simplification of intricate pathways in graphs and the utilisation of interactive visualisation techniques to enhance performance. An additional benefit of this approach is its capacity to streamline trajectory patterns to provide best routes for navigation systems.

2.2.3 Drawbacks of implementing the Douglas-Peucker Method

Despite the numerous advantages associated with the Douglas-Peucker method of line simplification, it is important to acknowledge the existence of certain drawbacks. The process of simplifying the polyline may result in the loss of the essential data that should be collected and utilised. The absence of a designation as a key feature for a location inside a polyline does not automatically indicate that the data associated with that point has any utility or significance. Therefore, it is possible that the Douglas-Peucker Method may not be the most suitable technique for simplification in all instances [48].

2.3 The Mountain Car Problem

2.3.1 Mountain Car Problem Setting

The Mountain Car Problem (MCP) initially presents itself as a very simple task, but with closer examination, it becomes increasingly apparent that it is more intricate and complex in nature. The car is positioned at the lowest point of a sinusoidal valley, and the goal for the car is to ascend and exit the valley. The inherent difficulty of the MCP is highlighted when the vehicle's engine power is insufficient to directly counteract the force of gravity [49]. The process of driving out of the valley involves a reliance on momentum and the strategic use of gravity, achieved by swinging from one side to the other until it reaches the apex of the valley.

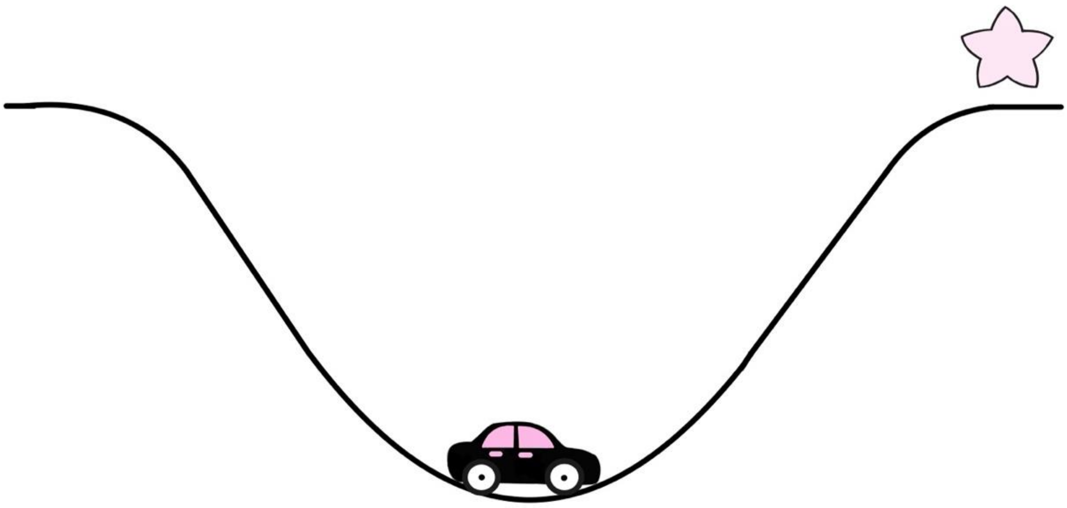

Figure 5: Mountain Car Problem Schematic

Figure 5 serves as a conceptual illustration of the MCP. The primary goal of the problem is to navigate the car towards either end of the valley (an example of the end goal is symbolised by the star sign in *Figure* 5). To initiate its movement, the automobile will first execute a leftward reversal prior to commencing its oscillatory motion. When commencing the problem, it is important to identify and determine the parameters of the vehicle. The current position of the car will be represented by the symbol x, while the symbol $\dot{x}$ will denote its current velocity. The parameters for motion and car velocity at the next time step are $x' and\ \dot{x}'$ respectively [50]. The car's motion can be expressed as follows:

Equation 14: Motion of the vehicle in the Mountain Car Problem

$$x' = x + \Delta t \dot{x}$$

$$\dot{x}' = \dot{x} + \Delta t \left(-9.81\, m \cos(3x) + \frac{F_e}{m} a_{dr} - \mu\, \dot{x} \right)$$

The variable denoted by the letter a_{dr} represents the action performed by the driver. A negative value of a_{dr} implies the vehicle is in reverse motion, whereas a positive value signifies forward motion. A value of zero indicates the vehicle is in a neutral state. This statement implies that the driver has the option to select from three potential courses of action to extricate the vehicle from the valley [49].

2.3.2 Application of the Mountain Car Problem

The mountain car problem provides a clear understanding of the interaction between a vehicle and its environment, as well as the impact of different actions on the vehicle's progress towards its final goal. Understanding the problem necessitates a comprehensive grasp of the car's position and velocity at each state. The simplification of this task is facilitated by the inherent two-dimensionality of the problem, enabling the exclusion of factors such as treating the car as a point mass and ignoring air resistance. Each action performed by the driver of the car, namely forward acceleration, backward acceleration, and no acceleration, will result in a transition to a distinct state within the system. For example, the car will commence its journey at the centre of the valley's lowest point, denoted as position zero and velocity zero, representing its initial state. A new state is achieved only when the driver decides to move the vehicle either forward or backward. The technique has the potential to be iterated multiple times to enable the vehicle to attain the highest point of the valley. The primary aim of the challenge is to ascertain the necessary steps for liberating the vehicle from the mountainous terrain, while also ensuring a comprehensive understanding of these actions at each level [51].

2.3.3 Discretisation of the Mountain Car Problem

The primary aim of discretising the MCP is to determine the set of situations in which both the velocity and position of the car are known prior to its arrival at the summit. The state space of this system is characterised by continuity, indicating the presence of an unlimited number of states. Consequently, the code implemented for the system needs to account for this continuous nature. As a consequence of this, the process of generating and documenting outcomes can present difficulties; so, it becomes vital to streamline this issue by categorising it into distinct segments. The examination of system states will be conducted with respect to the granularity of N, where N is the number of potential values for both location and velocity. This observation suggests that the system can be described by a total of N^2 potential states, hence simplifying its representation. *Table* 3 illustrates the operational procedures of the system [50].

Table 3: Discretized space of the mountain car problem

POS 1, VEL 1	POS 1, VEL 2	POS 1, VEL …	POS 1, VEL N
POS 2, VEL 1	POS 2, VEL 2	POS 2, VEL ….	POS 2, VEL N
POS …, VEL 1	POS…, VEL 2	POS …, VEL …	POS …, VEL N
POS N, VEL 1	POS N, VEL 2	POS N, VEL …	POS N, VEL N

2.3.4 Mountain Car Problem for electric vehicles

The limitations of the energy system are considered static, which implies that these limits remain consistent across all instances [52]. In addition to the principle of energy conservation, which involves the conversion of potential energy to kinetic energy, the vehicle's propulsion power is utilised to overcome the influences of road friction and air resistance, thus addressing the practical aspects of the problem. Furthermore, it is important to acknowledge that the vehicle's battery will be employed during locomotion. This aspect poses a constraint in the problem, as the battery possesses a finite capacity. Consequently, the outcome may fluctuate depending on the extent to which the battery has been utilised at any given moment. Considering the significant ramifications stemming from the battery issue, it becomes imperative to integrate the vehicle control problem with a dynamic energy system model. Based on the review of previous works, it appears that this process has not been previously implemented. By employing Keller's research on optimal running, it is possible to solve the mountain vehicle problem by incorporating dynamic energy limitations. The utilisation of the dynamical energy model in systems such as electric vehicle batteries greatly enhance the realism of the model [49].The limitations of the energy system are considered static, which implies that these limits remain consistent across all instances [52]. In addition to the principle of energy conservation, which involves the conversion of potential energy to kinetic energy, the vehicle's propulsion power is utilised to overcome the influences of road friction and air resistance, thus addressing the practical aspects of the problem. Furthermore, it is important to acknowledge that the vehicle's battery will be employed during locomotion. This aspect poses a constraint in the problem, as the battery possesses a finite capacity. Consequently, the outcome may fluctuate depending on the extent to which the battery has been utilised at any given moment. Considering the significant ramifications stemming from the battery issue, it becomes imperative to integrate the vehicle control problem with a dynamic energy system model. Based on the author's understanding, it appears that this process has not been previously implemented. By employing Keller's research on optimal running, it is possible to solve the mountain vehicle problem by incorporating dynamic energy limitations. The utilisation of the dynamical energy model in systems such as electric vehicle batteries greatly enhances the realism of the model [49].

2.3.4.1 Formulation of the problem

As previously said, the vehicle can be considered as a point mass. The problem of the energy-constrained mountain automobile is described by a nonlinear differential equation, which is presented below.

Equation 15: Differential equation governing the Mountain Car Problem

$$\frac{d}{dt}\,(x, v, E)^T = \left(v, -\frac{v}{\tau} - g\,sin\big(\alpha(x)\big) + f, \sigma - |fv|\right)^T \quad , \qquad t > 0$$

It is important to define the parameters of the valley, while considering its sinusoidal morphology, which necessitates the utilisation of the sine function in *Equation* 15. The track profile for the mountain vehicle problem exhibits characteristics of a smooth function, implying that the function possesses continuous derivatives up to the necessary order across its domain. The classification of a function as smooth depends on the nature of the situation at hand, with the number of continuous derivatives ranging from two to infinity. The limitation of smooth functions across a specific interval is dependent upon the characteristics of the track profile [53]. For this track of the MCP the smooth function is defined as $x \to h(x)\ with\ h(0) = 0\ and\ max_x h(x) = h(x_p)$ for some $x_p > 0$ [49]. The parameter x_p is the point of the change from increasing to decreasing slope on a graph – titled the local maximum for the problem. At this point of the graph the slope of the tangent has a zero value [54]. The Mountain Car Problem is amenable to solution and can be optimised for two unique scenarios: achieving minimal time and minimising energy consumption. The primary goal of the minimal energy model is to optimise the residual energy of the system once it has reached its maximum point, a condition that cannot be achieved if negative energy values are encountered. The equations facilitate the resolution of the two difficulties. *Equation* 16 pertains to the optimisation of time, while *Equation 17* represents the minimisation of energy expenditure.

Equation 16: Expression for minimal time solution to MCP

$$min_f(T)\ such\ that$$

$$x(T) \geq\ x_p\ and\ E(t) \geq 0\ \forall t\ \in [0, T]$$

Equation 17: Expression for minimum energy solution to MCP

$$max_f\big(E(T)\big)\ such\ that$$

$$x(T) \geq\ x_p\ and\ E(t) \geq 0\ \forall t \in [0, T]$$

For this problem to yield any useful results f_{max} must be large enough to ensure the reaching of $x = x_p$. This ensures that the motion is not limited to a single direction, wherein the system functions and moves exclusively in one direction. The utilisation of oscillating movement is crucial for the vehicle to successfully ascend to the peak of the valley. The adoption of unidirectional movement would have a negative impact on resolving the challenge presented by the mountain car problem.

2.3.4.2 Problem Solution and Conclusions

The MCP was solvable by reducing it to parametric optimisation problems – these problems contemplate optimisation based on a parameter and describe how the other variables of the system are affected by alterations to the parameter [55]. Parametric optimisation is a valuable approach for achieving optimal outcomes by efficiently and expeditiously determining the most favourable values for the parameters in relation to one another. It is evident that even in scenarios where minimal energy is required, the system should function at maximum forces. Extensive track swinging is harmful to the system efficiency and incurs a penalty from $\tau > 0$ (energy cost of locomotion). As could be expected, the force profile for the problem of minimum time is much more aggressive than that of the minimum energy profile [49].

2.4 Energy System Models

Fundamentally, energy provides the ability to do work, and thus the capability for movement. There are multiple methods for generating and expending energy, this is due to the wide range of schemes and structures which require energy to function. The term 'energy system' is used to denote specific mechanisms for the production and consumption of energy within a body or system. [56]

2.4.1 Human Energy System

The human energy system is complex and varied, consisting of multiple different types of energy as well as a range of energy generation operations, and expenditure processes. The basis for human energy production is a molecule called adenosine triphosphate (ATP) which is broken down by the body in order to fuel all movement. Energy production methods within the human body can be categorised into two groups, aerobic or anaerobic energies, based upon the processes by which they breakdown and consume the bodies ATP supplies. [56]

Aerobic energy generation is dependent upon the respiratory system and utilises the oxygen amassed within the lungs and is often referred to as the oxidative system. Conversely anaerobic energy production does not utilise oxygen. There are two anaerobic energy systems, the phosphagen systems and the glycolytic system. [56] For all forms of activity, all three of these energy systems are engaged, however the type of activity as well as its duration has a notable impact on the extent to which each energy system is activated. This can be visualised in *Figure* 6, which shows different activity levels and the associated ratio of energy production from each of the three methods, as well as different methods of ATP production.

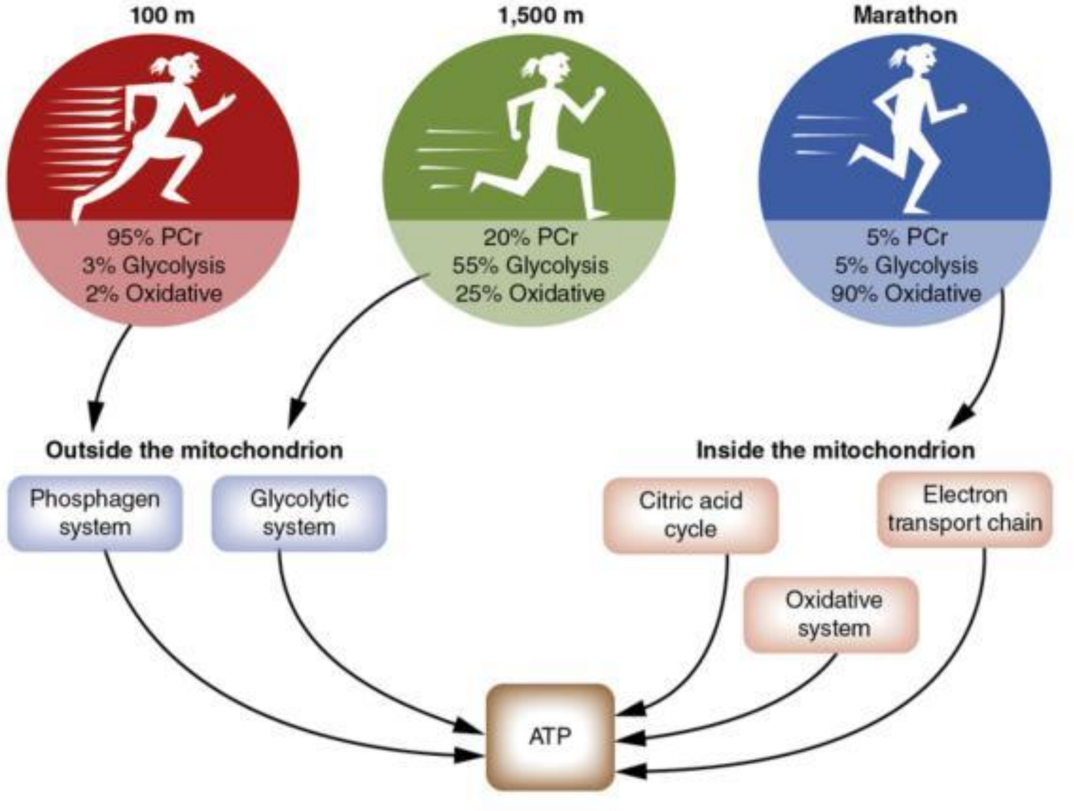

Figure 6 Energy System Contribution Variation with Activity Level [56]

It is evident from *Figure 6* that the phosphagen energy system is the primary energy system implemented for short term activities, such as the 100m sprint depicted above. Short term activities can be categorised as those typically lasting fewer than 30 seconds and involving high intensity movements, such as jumping or sprinting. The phosphagen system, is generally limited to these shorter bursts due to the fact that it utilises the limited supply of phosphagens, such as phosphocreatine (PCr) and ATP stored within the body [56].

The glycolytic system produces ATP by breaking down carbohydrates found in the food we eat, in an absence of oxygen. These carbohydrates, which are stored as muscle glycogen, are firstly broken down to produce pyruvic acid and then lactic acid through the process of glycolysis. This energy system is typically most active during exercise lasting from 30 seconds up to approximately three minutes in duration. For activities of longer duration the vast majority of the required energy tends to be generated aerobically. [56] This is not only due to the limited store of phosphagens and glycogen within the muscles, but also because the sharp decrease in PCr levels as well as the accumulation of the lactic acid produced inevitably leads to a reduction in work output by the athlete due to discomfort. [57]

The aerobic or oxidative energy system is highly involved in longer term activity with low to moderate intensity, such as endurance running, cycling, or swimming. Although the aerobic system has a significantly reduced capability for quickly meeting energy needs when compared to both the phosphagen and glycolytic systems, its ability to maintain energy production long term reaches far beyond the scope of the anaerobic systems. In contrast to the anaerobic systems, the oxidative system is not restricted by the limited ATP storage capacity of the human body, as it uses oxygen in order to breakdown the stores of fats, carbohydrates, glucose, and proteins received from food ingested, and transform them into ATP, generating a near continuous supply without need and thus providing energy for movement [58].The increased cardiopulmonary activity induced by endurance activities, results in a greater concentration of oxygen in the blood, which is being pumped throughout the body at increased rate, this results in prime conditions for aerobic energy production, which all contributes the effectiveness and efficiency of aerobic energy production.

In terms of the overall energy system for long term human locomotion, it can be said that there is a regenerative quality to the human biological energy system, due to the continual production of energy via aerobic systems when engaged in endurance activities. Keller’s Theory implements the Oxygen Balance (*Equation* 8) in order to account for this regenerative factor, where σ is the volumetric (aerobic) recovery rate measured in calories per kilogram per second (cal/kg/s). As can be clearly seen in *Figure* 6 above, the aerobic energy system is of the most consequence to this type of activity, accounting for 90% of all energy generation for long distance activities, making it the most important system to consider during this study.

2.4.2 Electric Vehicle Energy System

2.4.2.1 Equivalent Circuit Modelling

Every electrical appliance, such as a battery, can be broken down into an equivalent circuit model. This model depicts the elements and components that make up the device and often consists of components such as a power supply, resistors, capacitors, and inductors. Using this system, the desired calculations can be carried out as the model has enabled the breakdown of parts to allow this to be done more efficiently. Additionally, the model can be incorporated into a larger circuit to create a system of components. This allows for a larger and more complex system to be modelled through the breakdown into simple component sections.

The lithium-ion battery of the electric vehicle can be constructed using an equivalent circuit model which allows for the analysis of the system. Parameters such as the energy status and peak power can be accurately estimated through the model which ensures the battery is not over charged and is safe [59].

2.4.2.2 State Space System

An essential component of effective battery management involves the anticipation of the battery's dynamic behaviour. The implementation of a mathematical model is beneficial in facilitating the control and analysis of a design problem. A state-space system is a mathematical representation that can be employed for modelling electric car batteries. This representation is utilised to model dynamic systems and encompasses the principles of control theory. State space systems enable the precise depiction of a system's behaviour across a specific time frame, facilitating a comprehensive understanding of the system's overall dynamics while also providing the ability to analyse it through manageable subdivisions [60].

The state space system method was first introduced in Kalman (1960) with subsequent follow-up in Kalman and Busy (1961) [61]. The specific branch of state space system to be implemented within the electric vehicle battery system is the piecewise linear system. A Linear Time-Invariant (LTI) system must satisfy two fundamental properties which are linearity and time invariance [62]. The system can be characterised as a time-invariant model if it is a time-dependent system function that is not explicitly dependent on time. Consequently, the input and output properties of the system remain constant and do not vary over time [63]. The system's linearity can be recognised by the concept of superposition, which states that the output of the system is directly proportional to the input signal. Time invariant systems provide more stability for the system as the outputs are not being altered with variation in time and are simpler to model and analyse than a time variant system [62]. The LTI system contains three primary components: the impulse response function, the input function, and the output function. The impulse response function is a representation of the response of the system to an impulse input. The input signal and output signal represent the input and output function respectively [62].

The comprehensive representation of the electric car battery system can be achieved through the utilisation of a Simulink model. This model allows for an all-encompassing view of the system, enabling the visualisation of the individual blocks that comprise the system. The blocks within the Simulink model symbolise distinct functionalities and enable engineers to visually comprehend the relationships between various aspects. The interactions between the elements of the system are expressed through three elementary subsystems. The three subsystems of integrators, summers and gain elements can be combined to form the electric vehicle battery system [60].

2.5 Optimisation in Engineering

2.5.1 Breakdown of the Engineering Design Process

When engineers engage in the process of product design, it becomes evident that a standardised methodology cannot be universally applied to all products with many design methods capable of producing similar products. Typically, an engineer begins the design process with a summary of the customer's preferences in order of significance to easily identify the problem specifics. Following project definition, designers must investigate the challenge's specifics. This exercise can be done co-operatively or alone, however solo research may yield a less complete result. Poor communication and project management during planning can result in repeated study on the same topics reducing efficiency. Optimisation is a group process that ensures design criteria are satisfied with integrity. Non-negotiable design requirements must be followed during optimising. After research, project needs must be defined, and engineers should then evaluate their study-derived ideas and discuss them with the team. In this step, the technical team will deliberate and determine the best solution for the problem. However, in most cases, this solution may not be ideal [64].

2.5.2 The importance of engineering optimisation

Engineering uses natural principles to create and build practical objects with this study evaluating electric vehicle batteries aiming to optimise system efficiency. Given that the engineering industry has many qualified designers, a design must be carefully considered and optimised for maximum efficiency to be competitive. The design must be analysed throughout the design process, or a company may choose another designer's product. Engineers can use many methods to improve a product's design and features all having different impacts on the system. Optimisation of a design can be achieved by doing things such as minimising product cost or minimising weight while maintaining functionality [65]. Implicit optimisation is generally done by combining experiential knowledge, modelling techniques, and project technical team views. Changing one design framework parameter may affect other features - thus, to ensure the best design, it is essential to carefully monitor all design aspects throughout the process. Some designs are too complex and have too many parts to optimise - such circumstances require additional investigation [65].

The engineering design optimisation phase uses design limitations identified at the project's start to help the design team find the best solution. To achieve the best results, project objectives and constraints must be followed throughout optimisation – however, designing according to these constraints can restrict reliability, efficiency, and durability, among other variables. Optimising a design often involves more than finding the best constraint solution, instead it involves constructing a design that can find a solution that meets all requirements to an extent [66]. In business, a customer's list of demands may include several restrictions that must be carefully considered. Understanding how each limitation affects the user is crucial to optimisation, as it may result in different optimal solutions for the same system based on client preferences. With regards to this specific study, by improving the control and utilisation of the eRallycross vehicles battery, faster track performance may be achieved, increasing the competitiveness of the vehicle, and potentially increasing the chances of winning a given race. Beyond this, better usage of the stored energy may allow the design to be changed in future iterations to be smaller and/or lighter, further increasing the potential for greater racing performance.

2.5.3 Optimisation in MATLAB

MATLAB provides the optimisation toolbox product [67] which provides a number of functions for use in finding parameters for local and global minimums and maximums for specified functions. The toolbox includes solvers for linear programming (LP), mixed-integer linear programming (MILP), nonlinear programming (NLP), quadratic programming (QP), second-order cone programming (SOCP), nonlinear least squares, constrained linear least squares, and nonlinear equations. Due to the Keller equations comprising of multiple multivariable nonlinear functions, *fmincon* was the most appropriate optimisation tool for optimising the equations for a single parameter. *Fmincon* is a nonlinear programming solver, defined by the following equalities and inequalities in *Figure 7*:

$$\min_{x} f(x) \text{ such that } \begin{cases} c(x) \leq 0 \\ ceq(x) = 0 \\ A \cdot x \leq b \\ Aeq \cdot x = beq \\ lb \leq x \leq ub, \end{cases}$$

Figure 7 - Fmincon Definition [75]

Fmincon utilises the interior-point approach [68] by default due to its ability to tackle most problem sizes and densities, alongside being able to recover from infinite or undefined results. The interior-point method functions by initially starting with a point that lies within the 'feasible' region, that is defined by the constraints of the problem [69]. The algorithm then steps towards the optimal solution by generating a number of points within the feasible region (*Figure 8*) [70]. If the objective function deviates to approaching the edge of the feasible region, barrier functions impose a penalty on the function, preventing the function leaving the defined feasible region and ensuring the solution moves efficiently towards the optimal solution. As the function progresses the barrier parameters and penalty term are adjusted until an optimal solution that satisfies both the objective § and the defined solution constraints.

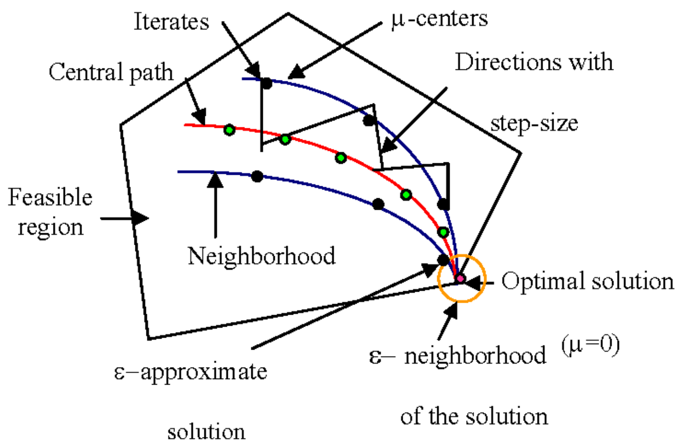

Figure 8 : Graphical representation of interior-point method fmincon uses.

In addition to its wide-ranging applications, *fmincon* utilises the Interior-point method due to its low memory usage as well as its ability to solve large scale problems quickly. Although at the expense of some accuracy in the solution, for most applications this is usually small and can be reduced by altering the *fmincon* function options such as *StepTolerance*, *OptimalityTolerance*, and *ConstraintTolerance* [71].

3.0 Method

The definition of the problem yields two key tasks required to achieve the overarching objective of the project. The first key task was to model and analyse the simple energy system, which in this case was represented by the human runner energy model. Track data with a known profile of varying elevation was given along with the completion time for rounding the track by a human runner. This allows for the construction of a sequence of control actions to minimise the time taken or energy utilised to complete the track layout. The control actions include the propulsive force either as a function of position or time. The two main methods used to aid in the solving of the first task are the Keller Theory and the Douglas-Peucker Method. Conducting this initial analysis allows for a solution to be obtained for this simple human metabolism-based energy system which can then be adapted for use for the second key task. Task two involves the more complex and realistic energy system model of the electric vehicle battery. The results from task one will be reformulated with equations of motion for the eRallycross vehicle in order to solve for the battery problem.

3.1 Solver Selection

When working towards optimisation it was important to consider not only what equations were to be optimised but also how it was solved. It was also imperative that the solvers selected for implementation at each stage are considered carefully so as ensure that the most efficient methods are being employed. This not only aids in improving the accuracy and reliability of the results returned but can also have a significant impact on the computational demands of the code.

Dynamic systems such as those modelled and analysed within the scope of this project, are simulated via the computation of their states at sequential time steps within a specified time span, using a model of said system. This computational process known as 'solving the model', there is not one singular method for solving a model which is suitable for application to the solution of every system. Instead, there are a wide range of numerical integration methods which have been developed in the interest of finding the solution to ordinary differential equations (ODEs) representing the continuous states model of dynamic systems. MATLAB provide a comprehensive selection of fixed, and variable step continuous solvers, which each implement a particular numerical method as the ODE solver scheme.

During the solver selection process, it was important to consider the system of ODEs employed to describe the dynamic system of the runner and subsequently eRallycross car, as well as the end goal and results to be achieved. There are four key characteristics to be taken into consideration during solver selection, these are the dynamics of the system being modelled and the ODE associated, the stability of the solutions, the speed at which the computations are completed, and finally the robustness of the solver. [72]

The numerical solvers furnished in MATLAB can be roughly categorised using just two key properties – the computation step size type and the model states. When categorising solvers by computation step size type there are two options, firstly fixed-step solvers, which calculate the solution to the model using the regular interval time steps with identical step sizes from start to finish for the entire simulation. This step size can either be specified by the model or left to be selected by the solver, in general a smaller tie step will increase the accuracy of the results; however, it will increase the computational demand of the simulations and the time required for completion. The alternative computational time step type is a variable-step solver, which as the name implies, varies the step size throughout the duration of the simulation. Thereby the step size can be decreased at specific points during computation in order to gain a more accurate insight at that point. As a result key events in the simulation such as rapid state changes and zero intercept can be resolved at a high-level accuracy. The step size can then be enlarged across periods of simulation which show more gradual changes where fewer time steps are sufficient for resolution. The calculation of the step size creates an additional task at each step and thus causes an increase in computational demand. However, in spite of this, the implementation of a variable-step solver can lead to a substantial diminution in the total number of steps required for the completion of the simulation, and consequently the overall computational demands for maintaining a specified level of accuracy for complex models with rapid variations and other key events throughout which require extra computation. Furthermore, classifying solver schemes based upon model states also gives two categories; discrete solvers and continuous solvers, the key difference between these two solver types is how the various elements of the system interact with and influence each other throughout the simulation. A discrete solver would predominantly be employed for the solution of purely discrete systems, this is due to the fact that only the next time step is computed for a model, meaning that discrete solvers rely upon each equation within the system of ODEs to amend their singular distinct state. Continuous solvers apply numerical integration as means for calculating the continuous states of a model at the current time step utilising the information obtained from the previous time step as well as the state derivatives, these solvers depend on individual equations within the ODE to find the discrete state as well as the state derivatives. This can be visualised in the diagram shown below in *Figure 9*, which shows how the bank of MATLAB solvers can be classified in terms of the above criteria.

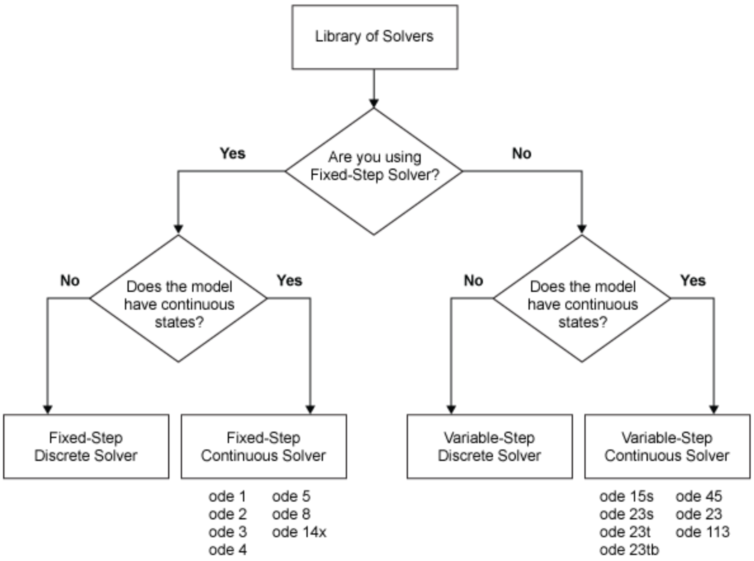

Figure 9 Flow Chart to Aid Solver Selection

This means that it is essential to understand the system being modelled as well as how it is modelled, so as to ensure a suitable solver is selected and employed, as there are multiple solvers which fit within each category, and each will interact differently with a given model. As an initial starting point *Table* 4 can be used a guide in order to find a smaller selection of solve which would be most applicable.

Table 4 Representation of Auto Solver Heuristics

<table>
<tr><td rowspan="2">The system has / The solver type is</td><td rowspan="2">Only discrete states</td><td colspan="3">Continuous states</td></tr>
<tr><td colspan="2">The system is an ordinary differential equation (ODE)</td><td>The system has differential algebraic equations (DAE)</td></tr>
<tr><td>Fixed-Step</td><td>FixedStepDiscrete</td><td colspan="2">ode3</td><td>ode14x</td></tr>
<tr><td rowspan="2">Variable-Step</td><td rowspan="2">VariableStepDiscrete</td><td>The model is stiff</td><td>The model is non-stiff</td><td rowspan="2">ode23t</td></tr>
<tr><td>ode15s</td><td>ode45</td></tr>
</table>

This research was based upon the consequences of the presence of variation in elevation and the determination as to what extent this influences the force output and the resulting velocity changes. Therefore, it was deemed important to have a high level of resolution in the areas where the changes in elevation are prevalent. It was acknowledged however that these changes would not always be sharp and in fact there may be large stretches without significant changes of elevation throughout the course. For this reason, the decision was made to apply a variable-step solver in this case, as it reduces the computation demands required for a solution and lends a level flexibility to the process which was deemed beneficial due to the future application to an unknown track, all without compromising on the resolution of the solutions obtained.

Furthermore, the system of equations modelled to represent the human runner system, takes the form of a non-stiff system of ODEs, this in combination with the decision to employ a variable-step solver led to the solver designated *ode45.* This solver earned its name due to the numerical integration methods it employs. A Runge-Kutta and Dormand-Prince (4,5) pair, makes this solver a fifth-order method which provides a fourth-order approximation of the errors and in addition to this a fourth-order interpolant is used during execution allowing for smoother plots to be obtained as well as the locations of key events in the solution. This makes the *ode45* solver a widely applicable solver which returns robust results with a medium order of accuracy. Other solvers such as *ode23* and *ode113* are also highly suitable for this set of criteria, however they are more rudimentary in their execution, returning results at a lower accuracy and reliability respectively. Alternatively, both *ode78* and *ode89* are variable-step solvers known to return results with a high order of accuracy for non-stiff ODE systems, this of course has the resulting trade off in an increase in complexity generating greater computational demands, making them most beneficial when employed for problems with a high degree of smoothness. Due to this, in combination with the inherent inability to predict the smoothness of the system due to the application for unknown tracks, the decision was made to employ *ode45* as the primary solver during this study.

3.2 Human Locomotive Energy System

3.2.1 The Keller Method – Parameter Derivation

As previously discussed in section 2.1 above there are four physiological constants which are essential to the implementation of Keller's Theory. These four physiological parameters are the maximal propulsive force the runner can exert per unit mass, f_{max}, measured in newtons per kilogram (N/kg), the internal resistive force per unit mass, τ, which is also measured in newtons per kilogram (N/kg), the initial energy stored within the body of the runner per unit mass, e^0, measured in calories per kilogram (cal/kg), and finally the rate of energy recovery from oxygen consumption, s, which has units calories per kilogram per second (cal/kg/s). These parameters are out with the control of the theorist due the nature of them being anatomical and are thus unique to each runner. In order to find the values of these required physiological parameters, using Keller's Theory with the global positioning system (GPS) data provided of a 6 km track in Naantali, Finland, as well as an excel file containing the associated running data, recorded using a Garmin running watch, containing speed and position data at one second time intervals. The aim was to take this data and the equations used in Keller's Theory in order to solve for the desired parameters, this methodology can be seen, in '*A Theory of Competitive Running'* [37] where Keller finds the physiological parameters associated with a collection of world record times for races of different distance.

However, due the optimisation nature of Keller's theory which provides the optimal velocity profile, and the fact that the running data provided cannot be assumed to be the optimal solution due to the nature of the goal of this research. An alternative methodology which instead utilised the procedures laid out by A. Aftalion et al. in '*How to Identify the Physiological Parameters and Run the Optimal Race'* [73], was implemented in order to provide a set of parameters which could be employed as an initial guess in order to find the parameters which most closely replicate the velocity profile extracted from the data set originally provided. An overview of the Parameter Derivation script produced can be seem below in *Figure 10* which showcases a block diagram outlining the key steps taken to obtain the requires physiological parameters.

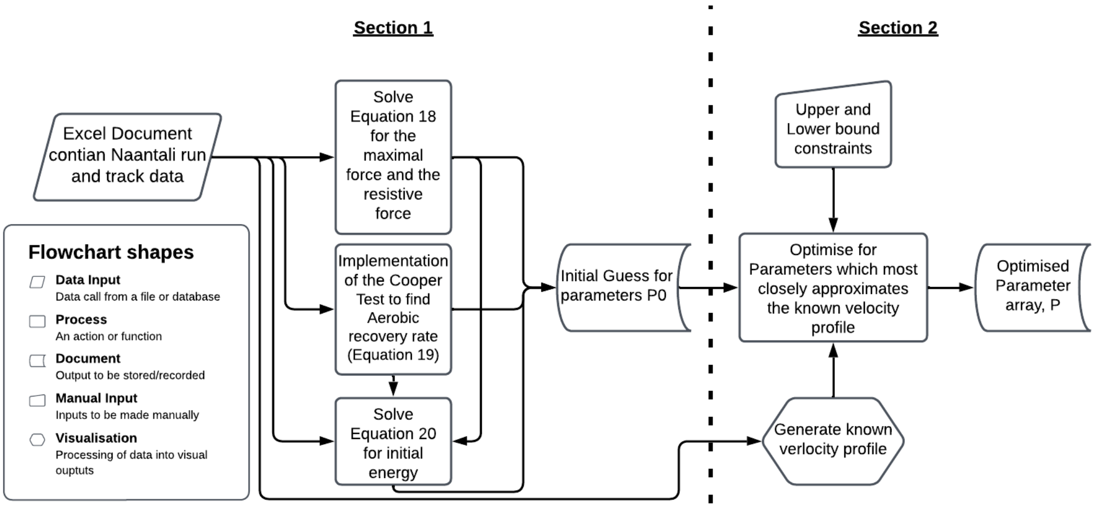

Figure 10: Block Diagram Representation of Keller Parameter Derivation

Prior to implementing Keller's equations in order to identify the necessary parameters a four by one matrix, P, was created in order to store the four physiological constants such that $P = [f_{max}, \tau, \sigma, e^0]$. This variable P is unknown and is the object of the optimisation protocol highlighted in section 2 of *Figure 10* above. However, in order to initialise the optimisation calculation an input matrix P0 must be provided. As previously mentioned, the protocols described by A. Aftalion et al. [73] was referenced in order to find initial values for the four physiological parameters which could then be input as an initial guess $P0$. However, a key difference to note between the experimental data used in this study and those recorded in the original study [73] is that this study was provided only one set of data, for a long distance run (greater than that critical distance, $D_c = 291m$, as above), where the original study conducted multiple runs of varying distances and thus in this study the data for the shorter runs have been approximated by extracting sections of the available data. It is for this reason that the parameter values returned from this method are simply implemented as the initial guess, $P0$, into the optimisation function to be further refined.

With respect to determining initial values for both f_{max} and τ, the methodology involves two sets of data points $(t_1, v(t_1))$ and $(t_2, v(t_2))$ from the initial section of the run during which the runner exerts a high level of force in order to accelerate from rest. These two data sets are then substituted into *Equation* 18 below to form a system of two equations which can be solved simultaneously in pursuance of the two unknowns f_{max} and τ.

Equation 18: Expression for velocity to aid in finding of f_{max} and τ

$$v(t) = f_{max}\, \tau \left(1 - \exp\left(-\frac{t}{\tau}\right)\right)$$

The points selected to applied here were the velocities at $t = 3\, s$ and $t = 5\, s$ which are $v = 3.617\, m/s$ and $v = 3.656\, m/s$ respectively, which gave resulting initial values of $f_{max} = 8.616\, N/kg$ and $\tau = 0.4234\, N/kg$.

It should be noted that due to the nature of this run as a long-distance endurance activity, that the runner may not have enacted a full sprint at the beginning of that race but has instead gradually accelerated to a more maintainable speed. It is for this reason that these values were only employed as initial guesses, to be further refined using optimisation.

It was assumed by Keller that a runner maintains a constant aerobic energy recovery rate, σ, at a value equal to the maximal oxygen uptake, $\dot{V}O2_{max}$. The Cooper Test [74] can be implemented to find an initial value for the aerobic rate, σ. The Cooper Test takes the total distance covered in 12 minutes, d_{12}, to find the maximum volumetric oxygen recovery rate, $\dot{V}O2_{max}$ using *Equation* 19 below.

Equation 19: Maximum Volumetric Oxygen Recovery Rate

$$\dot{V}O2_{max} = (22.351 \cdot d_{12}) - 11.28$$

A value of $\dot{V}O2_{max} = 16.03\, ml/kg/min$, which is equivalent to $\sigma = 4.58\, cal/kg/s$, was found by extracting the distance value at $t = 720\, s$ from the provided data and using *Equation* 19 above.

It is important to note that the value obtained for the aerobic recovery rate using *Equation* 19 above is not to be considered the final value which most accurately represents the runner's aerobic recovery rate. The reason for this is that the Cooper's Test assumes that the distance obtained from the given data at the 12-minute mark represents the maximum distance the runner could cover within that time. Yet, the fact that the run continues for an additional 15 minutes beyond the 12-minute mark suggests that the runner did not exert maximum effort or deplete their energy reserves.

In order to the find value which represents the amount of initial energy the runner has available to them at the beginning of the race, the initial values for the aerobic recovery rate as well as the specific resistive force are required. *Equation* 20 below describes the relationship employed in order to find, the initial value for the initial stored energy of the runner, e^0.

Equation 20: Expression for initial energy value

$$e^0 = \left(\sigma(t_2 - t_1) - \frac{1}{2}(v(t_2)^2 - v(t_1)^2)\right) - \int_{t_1}^{t_2} \frac{v^2}{\tau}\, ds$$

It can be seen that again it is essential for two sets of speed and time data to be known in the interest of determining the initial value for the initial value for the stored energy of the runner. The same values as above were employed and the resulting value for the initial stored energy of the runner was found to be, $e^0 = 304.3\ cal/kg$.

These results were stored as an initial parameter matrix, $P0 = [8.616, 0.4234, 4.580, 304.3]$, and was then carried forward and commissioned as the initial guess for the optimisation routine. This was implemented as a means of refining these parameter values to find those which most closely fit the running data provided.

As mentioned previously, the approach taken in order to establish which set of parameters are optimal, was to determine the set of parameters that best replicated the measured velocity profile of the data provided. This was done by solving Keller's energy equation (*Equation* 8) and velocity equation (*Equation* 6) with the addition of a further term to account for the varying elevation along the path - as seen in *Equation* 21 below - for the known Naantali track data provided. The calculated velocity was then extracted from the solutions to Keller's equations so as to be compared to the measured velocity from the run data provided.

Equation 21: Keller's Velocity Equation for a Track of Varying Elevation

$$\frac{dv}{dt} = f(t) - mgsin(\alpha) - \frac{v}{\tau}$$

The MATLAB optimisation tool *fmincon* [75] was employed in order to determine which value of P produces the velocity profile with the least deviation from the measured velocity. This was achieved utilising the objective function seen in *Equation* 22 below, which takes the absolute error between the measured and calculated velocities at each time step.

Equation 22: Objective Function for Parameter Optimisation

$$Deviation = \sum_{t=0}^{T} |v_{meas}(t) - v_{calc}(t)|$$

In order to reduce the computational demands of the optimisation routine a set of upper and lower bounds were applied to constrain the *fmincon* output matrix P to within a reasonable range of values for each parameter as can be seen in *Table* 5 below. These bounds were based upon the limitations of the human body, the parameters associated with world records found by Keller [37] and encompasses the range of values found by Aftalion et Al. [76].

Table 5 - Upper and Lower Bounds Applied to Parameter Optimisation

$0 < f_{max} \leq 13$	N/kg
$0.6 < \tau < 1.2$	N/kg
$16 \leq \sigma \leq 25$	$cal/kg/s$
$200 \leq e^0 \leq 1000$	cal/kg

3.2.2 The Douglas-Peucker Method

The Douglas-Peucker algorithm was implemented (*Figure* 11) in MATLAB using the *reducepoly* [77] function already present in MATLAB. This function implements the Ramer-Douglas-Peucker algorithm to remove points from a line or object based on the deviation from the curve. An excel file was linked to this function to act as an input file containing the full GPS track data from the baseline Naantali run data provided by Eero Immonen, and outputs two matrices, *P_reduced* and *slope*. These contained the points defining the simplified track profile, and the gradient of each section of the simplified track profile and its corresponding start point, such that the influence of the track gradient on the force required could later be calculated. Alongside this a plot of the simplified profile is generated to visualise the new simplified track. The number of points in the reduced track profile was altered by defining the tolerance used by the *reducepoly* function.

The method was written to work for any length of GPS data, such that any unknown track data could be simplified, when input in the appropriate excel format. The function of the script was then verified by inputting a new set of GPS data of different length and data points, to confirm the implementation of the function.

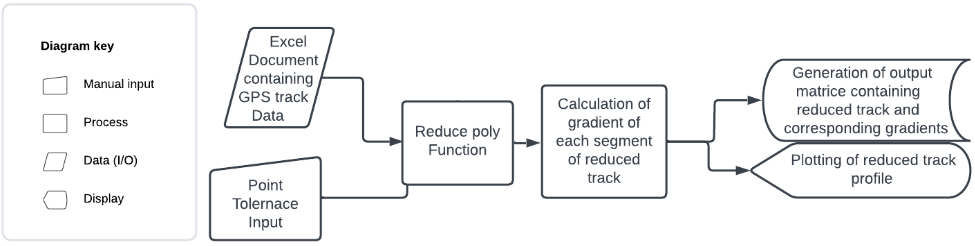

Figure 11 : Douglas-Peucker implementation block diagram

3.2.3 Conversion of Mountain Car Problem Code

The previous work of Eero Immonen and Hashem Haghbayan [78], was used as a foundation for the optimisation routine required to derive the optimum pacing graph for a given runner. The provided MATLAB scripts were designed to compute the optimum force output for the Mountain Car Problem [79] , when the total energy used is constrained. The script does this by calculating the position, velocity, and energy of a unit mass of the mountain car, forming a set of differential equations that are then solved. This routine is implemented via five MATLAB functions, *RUNME(1), Constraints(2), X_V_and_E(3), CalculatePositionVelocityAndEnergyValley(4)* and *nonlcon_pwlinear_valley_simple_NoT(5)* that define an optimisation problem utilising *fmincon* [75] to find sets of parameters which minimise the specified variable, which for the case of this project is, *t*, time for track completion. *Figure 12* illustrates the overall function and integration of each of sub-functions.

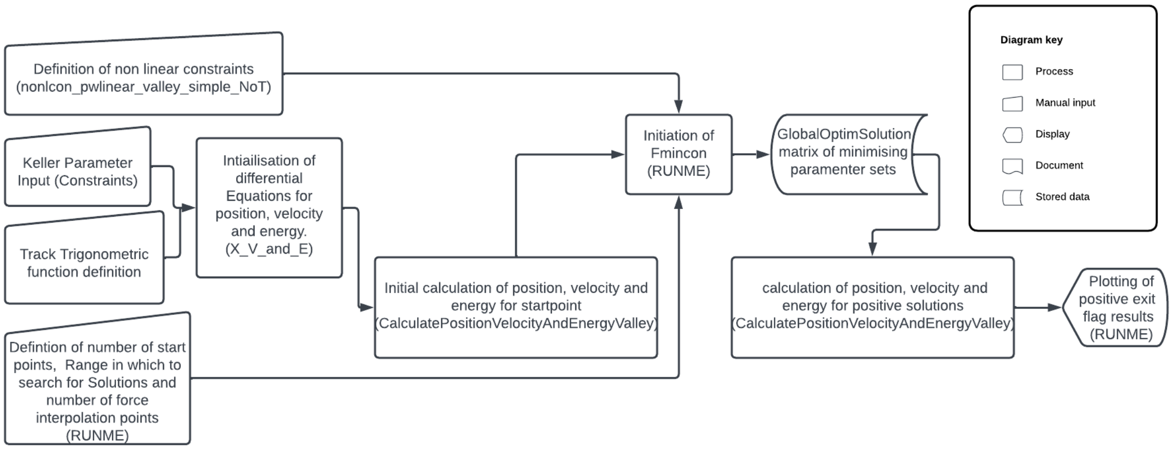

Figure 12: Existing Mountain car problem with constrained energy code structure

The Keller parameters were defined per unit mass in the constraints function (2), and the sine function defining the shape of the valley was defined in function (3), which also contained the initialisation of the differential equations for position energy and velocity of the vehicle, considering the position and gradient of the slope the car is on at any moment in time. Function (4) solves the system of differential equations using *ode45*, which is then utilized by function (4) which defines the function to be optimised, and its inequality constraints, namely reaching the crest of one edge of the valley, and the internal energy of the vehicle being non-negative. Function (1) contains the script for initiation of the minimization problem using *fmincon* and allows the alteration of its various options. Alongside this, the span of the bounds to be searched for an optimal solution, the number of interpolation points for the vehicle force, and the number of start points were defined here. Upon completion of all start point attempts, those attempts with a positive exit flag (optimal force interpolation points within constraints and not exceeding defined iteration and function count limits) parameters were used in function (4) to calculate the values of position energy and velocity of the car throughout its journey, which were then plotted alongside the force outputted by the car in a series of line graphs.

To modify the existing code for a runner on a 2D track, the *Douglas-Peucker* function developed in 3.2.2 was implemented to replace the sinusoidal functional for factoring the impact of the gradient of the track in the differential equation for velocity found in function (3). This was done by evaluating the position of the runner at each timestep, and using this information to correlate the position of the runner with the section of the discretised track they were on and applying the corresponding gradient from the slope matrix to the differential equation for velocity. Due to the nature of most distance running tracks being relatively flat, the small angle assumptions, $\sin(\theta) \approx \theta$ and $\tan(\theta) \approx \theta$, have been applied to simplify code calculating the influence of the gradient on the force required to move the body, to improve computing performance. The boundary criteria for a positive run exit flag in function (5) were also changed to reflect the new track specifications, where a solution must meet the end point of the track specified by the *Douglas Peucker* output, whilst also retaining the constraint of the energy needing to be positive. The final alteration was to change the timespan in which solutions were to be found in function (1), which was replaced with the approximate run completion time found in the Naantali run data provided by Eero Immonen (Appendix A), *Figure 13* displays the modified codes new block diagram.

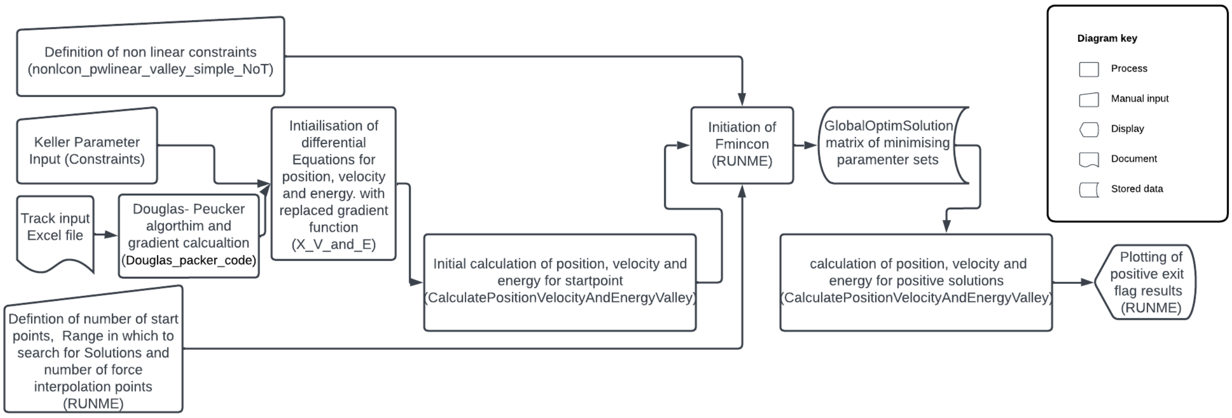

Figure 13 - Modified Mountain car implementation for runner on 2D track block diagram.

3.2.4 Discrete Force Optimisation Strategy

Upon attempting to apply the original optimisation method outlined above to the eRallycross energy system, it became clear that the method was not suitable due to the formatting of the velocity outputs within the model. For this reason, a new optimisation method was developed to use a discrete force strategy of optimisation. This method gave the runner choices for each track segment of which force to select based on the attributes of that segment. The graph obtained by the Douglas-Peucker algorithm, which segments the track, was used in conjunction with the parameters determined through the Keller method to initialise this optimisation method. The maximum propulsive force parameter was extracted with it being used as a fundamental reference for selecting the force values that will make up the force options for the runner. The chosen values were required to be compatible with the Naantali racetrack's extensive length and several changes in elevation. The underlying principle utilised in this optimisation strategy was that when the runner selects a force at the beginning of a track segment, this force will remain constant until the runner reaches a new segment. At this segment change a new force would be selected by the optimisation routine. This implies that the runner's decision-making options during the race are limited to the number of slope variations determined by the Douglas-Peucker method. For the Naantali race, there are six alterations in force corresponding to the six differences in elevation. It is important to highlight that the runner's fastest finishing time would be attained by maintaining a constant exertion of maximal force throughout the entire race. However, when considering the practical use of the system, it is unreasonable to expect that a runner could constantly exert the maximum force value throughout the whole run since the consecutive execution of the segments at maximal force would lead to an excessive expenditure of energy. Therefore, it is crucial for the decision system to encourage the race to be completed efficiently, while also not including excessive energy usage. The optimisation is initialised from the Douglas Peucker code that was previously generated for the Naantali track. A tolerance value of 0.001 was used in this simulation which produced results shown in *Figure* 14 – the tolerance value can be altered to give a different elevation profile. The maximum force of the runner for the simulations was found from the Keller parameter findings (maximum propulsive force = $9.74\ N/kg$) - this resulted in an $f_{\max\_sim}$ value as calculated in *Equation* 23.

Equation 23: Simulation maximum force

$$f_{\max\_sim} = 9.74 \times 75 = 730.5\ N$$

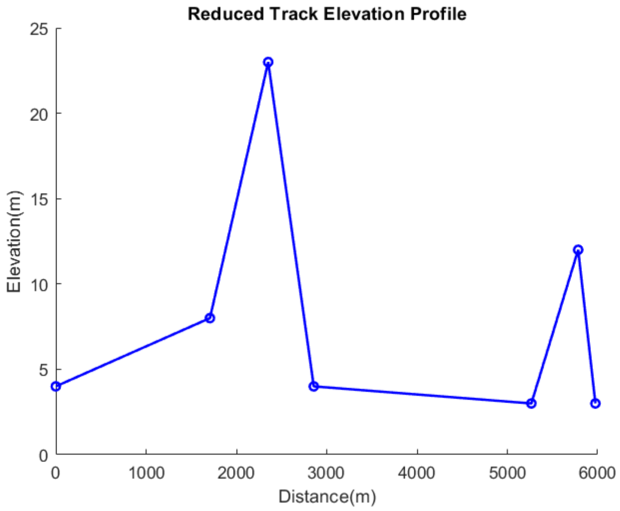

Figure 14: Reduced Track Elevation Profile from DP code

The x coordinate represents the cumulative distance (in metres) of each point on the reduced track elevation profile which were found to be.

$$OverallDistance_N = [\,0, 1707\,, 2352, 2856.5\ \ , 5266\,, 5784\,, 5975\,]$$

In order to implement the distance array into the simulation, the length of each segment was calculated using *diffarray* [80]. This resulted in six differences in lengths that can then be used in order to find the optimal force for each segment.

$$Distances_N = [\,1707\,, 645\,, 504.5\,, 2409.5\,, 518\,, 191\,]$$

The angles of each track segment were also required to allow for the implementation of this discrete force optimisation. These were calculated form the DP code and stored in an excel file which is then initialised within this discrete code. For the Naantali track the angles (in radians) were calculated to be.

$$Angles_N = [\,0.0023\,, 0.0233\,, -0.0377\,, -0.0004\,, 0.0174\,, -0.0471\,]$$

The initial velocity of the runner was set to be zero along with an array of the force values which can be selected by the runner during the simulations. The initial energy was set from the Keller parameter findings and converted into Joules to allow for a streamline inclusion into the force choice simulations. Another key parameter which was extracted from the Keller theory calculated parameters was the σ value which accounted for the runner regenerating energy throughout the course of the run – this ensured the runner was fully capable of completing the race.

A series of *for* loops then allow for a choice of force depending on the value of the angle of slope for that track section. This then means that the final velocity can be calculated along with the time for each segment. The work done by the runner for each segment is calculated using the force choice for that section. As a result, the simulation will then output the velocity, change in energy, and time for each section [81]. In addition to this, the force used for each segment will also be displayed and the total time to run the entire track. In order for the runner to successfully complete the entire race distance, it was crucial to make realistic decisions regarding the force options. Choosing an optimal range of forces allows the runner to complete the race efficiently without depleting their energy supplies. At first, it was impossible to predict the optimal number of force values that the runner can select from. Consequently, a rational approach to determining which technique of force selection would yield the most advantageous race strategy was to simulate two distinct systems, each with a unique set of force choice numbers. One optimisation was executed with two force options, while the other would provide the runner with the flexibility to select from five distinct forces. In order to facilitate a comparison between the two sets of simulations, the full range of forces remained constant - both simulations spanned between the same force range (15-25% of $f_{\max\_sim}$). Consequently, the time required, and energy expended throughout the run may be directly compared.

3.2.4.1 Discrete Strategy for two force choices

Giving the runner two force choices was the first optimisation routine that was initiated for the runner on the Naantali track. Upon analysis of the capabilities of the runner, the chosen force options that were deemed most appropriate for the track profile was 15% and 25% of the maximum force. Having two choices of forces limits the bounds that can be placed on the range of angle values which will cause the selection of each force depending on the track section. As a result, the sensible bound was set that for any angle which is positive (any uphill track sections) the value of $15\%\ f_{\max\_sim}$ would be selected by the runner as seen in *Table* 6. The $25\%\ f_{max\_sim}$ value would therefore be selected for any negative angle values – sections for which the runner would be travelling downhill.

Table 6: Force choices for two force simulation

Track Segment Angle (radians)	Force Choice for Simulation (Newtons)
Angle > 0	109.575
Angle < 0	182.625

3.2.4.2 Discrete Strategy for five force choices

An alternative approach to assess and optimise the system is to provide the runner with the opportunity to select from a range of five different force values. A wider range of forces enables a more precise selection procedure for splitting of angle values, resulting in a smaller variety of angle values per force value. The selected forces for this procedure were $15\%, 17.5\%, 20\%, 22.5\%,$ and 25% with respect to the maximal force value. Angles greater than 0.02 radians will correspond to a chosen force of $15\%\ f_{\max\_sim}$ whereas angles between 0.02 and 0.01 radians will correspond to a force of $17.5\%\ f_{max\_sim}$. $20\%\ f_{max\_sim}$ will be selected for angles ranging from 0.01 to 0, while angles ranging from 0 to -0.02 will result in the selection of $22.5\%\ f_{\max\_sim}$. If the angle value does not meet any of the above specified conditions, the runner will select a force value of $25\%\ f_{\max\_sim}$. These conditions are displayed in *Table* 7.

Table 7: Force choices for five force simulation

Track Segment Angle (radians)	Force Choice for Simulation (Newtons)
Angle > 0.02	109.575
0.02 > Angle > 0.01	127.8375
0.01 > Angle > -0.03	146.1
-0.03 > Angle > -0.04	164.3625
Angle < -0.04	182.625

3.2.4.3 Validity Test with Inversion of Force Choices

To allow for the validation of the force choices given to the runner, the forces were inverted to check if the way in which forces are selected is the optimal method. To do this the forces for both the two-force simulation and the five-force simulations were interchanged as shown in *Table* 8 and *Table* 9.

Table 8: Validity simulation two force choices

Track Segment Angle (radians)	Force Choice for Simulation (Newtons)
Angle > 0	182.635
Angle < 0	109.575

Table 9: Validity simulation five force choices

Track Segment Angle (radians)	Force Choice for Simulation (Newtons)
Angle > 0.02	182.635
0.02 > Angle > 0.01	164.3625
0.01 > Angle > -0.03	146.1
-0.03 > Angle > -0.04	127.8375
Angle < -0.04	109.575

As can be seen from the tables above, the force choice values are maintained, but they are merely rearranged to choose the opposite forces. The validation for the two-force choice will be named Simulation three with the five-force being titled Simulation Four. This yields a comprehensive analysis of which method of force choices gives the faster completion time for the runner while also keeping track of the energy levels.

3.3 Vehicle Dynamic Energy System

An important aspect of the project is the application of the optimisation routine on a vehicle. The aforementioned eRallycross car is an ideal medium for the model to be tested on. This is due to its electric powertrain requiring efficient usage as well as performing to a high level in a race situation.

3.3.1 Optimisation of Vehicle Race Pace Strategy

As previously mentioned, the five-force choice pacing strategy used for the runner, was adapted to be applied to the eRallycross car. Initially the vehicle code also used an array of forces from which to select. The idea being that these forces represented the torque from the electric motor. However, due to the nature of vehicle powertrains, a single output force for a specific sector of the track could not be determined. This is a result of the motors output varying constantly when accelerating, at a constant velocity or coasting.

The code contains an array of velocities, displayed as a percentage of the maximum velocity of the car. The lower velocities were utilised when the car is travelling uphill and the higher velocities when travelling downhill. This was decided after considering the benefits of the car taking advantage of gravity when traversing a negative gradient. Likewise, if the vehicle were to accelerate uphill, the energy demand would be too great and so it is most optimal to allow the car to partially coast until the lower velocity is met. The velocity choice range was 50%, 55%, 60%, 65% and 70% of the maximum velocity. The relatively narrow range was chosen as it minimises significant changes in velocity. This in turn reduces energy expenditure whilst maintaining a high velocity to minimise time.

The same array of distance and angle arrays that were utilised in the running pace strategy code were used in the vehicle code. *For* loops were used in the code to find the correct velocity for each stage of the track. The values were stored in an array which was then used to calculate the estimated time taken to complete the track. This method was implemented for both the Naantali and Holyrood tracks to then be further tested.

3.3.2 eRallycross Simulink Model

TUAS had previously developed a Simulink model of the eRallycross car as part of their prior research as found in Appendix B. The model integrated many components and algorithms to simulate various aspects of the car, including the battery, vehicle dynamics, heat transfer, and energy consumption. The model functioned by extracting data from an Excel file that included the target velocity and track gradient per second. Subsequently, the model employed a proportional-integral-derivative (PID) controller to guarantee that the vehicle attained the desired velocity. The simulation concluded when either the pre-established termination time was reached, or the battery's level of charge decreased to 10%.

The initially developed model was too intricate, encompassing an abundance of data that was not directly relevant to the present work. Consequently, the model's performance was hindered by reduced speeds and increased operational complexity. The thermal cooling feature was eliminated due to its irrelevance in the context of rallycross races, which are of short duration so not needed. Several inconsequential and extraneous calculations were eliminated to simplify the model.

Essential to the model is the battery, whose mathematical representation is in the form of an equivalent circuit model created in MATLAB. The function utilises interpolation to determine new values of resistance, capacitance, and open circuit voltage by considering the state of charge level. State vector was determined by constructing matrices using these newly obtained values. The values are consistently highlighted as the simulation advances to depict the charge level over time. There was also a generation of fluctuating voltage values, which are crucial for the general operation of the model.

The model employs a *Bidirectional DC-DC* module as an intermediary component connecting the battery and the electric motor of the vehicle. This system regulates the transmission of electrical current in order to optimise performance and reliability. For instance, this involves modifying the output voltage levels to align with the motor's needs and ensuring that the battery and motor are compatible in terms of voltage.

Utilising the voltage generated by the bidirectional DC-DC block, along with torque requirement and motor rotational velocity, the '*Mapped Motor'* serves as a key component. This block employs tabulated data of rotational speed and maximum torque to generate an output torque that may be applied to a vehicle dynamics block. The motor is responsible for electrical losses and generates a current that is then fed back into the DC-DC converter.

Outputted torque is multiplied by the quotient of the tyre rolling radius and a transmission relationship coefficient, yielding a propulsive force in Newtons. This force serves as an input to the 'Vehicle Body Total Road Load' block, representing the vehicle dynamics. Predefined parameters, such as vehicle mass and drag coefficient are used to calculate an array of values, like displacement, drag and net force in the x, y, and z directions. Finally, the vehicle body's outputted velocity is integrated to determine the car's displacement.

A new approach had to be taken for implementing the requested velocity with respect to distance into the Simulink. A 'MATLAB function' block was added to the model to control the electric motor. The function used the maximum velocity and the displacement of the car as inputs to find the requested velocity and current gradient of the track. A 'constant' block was used to define the maximum velocity of the car. The displacement was fed back to the function from the output of the vehicle body. The function used 'For' loops to define which value of velocity and gradient was to be met depending on the current value of displacement.

The velocity outputted from the function described above is fed through a 'sum' block to a PID controller. The controller produces a torque command which is sent to the motor. The resultant torque from the motor is fed back to the sum block to calculate the difference between the requested force and actual force. The PID controller continuously and discretely minimises the resultant error using proportional, integral, and derivative terms and adjusts the force demand to suit the instantaneous state.

The *scope* block allows specific signals to be monitored and analysed over time. This block is very useful for tracking results or finding faults in a model. The vehicle model was simulated for both tracks with results recorded for the state of charge, displacement, requested velocity, actual velocity, and gradient. One of the desired outputs from the model was throttle data for the car. Simulating throttle data is vital in motorsport for optimising vehicle performance and refining driver skills. It aids in fine-tuning engine parameters, calibrating throttle response, and simulating race scenarios. This data was crucial for enhancing energy efficiency, diagnosing issues, and integrating with broader vehicle dynamics simulations, contributing to being more competitive on track. Retrieving this data was achieved with the addition of a 'longitudinal driver' block. Generally, the purpose of this block is to act as a controller for a vehicle model, operating similarly to a PID controller. The block uses reference and feedback velocities as inputs and outputs acceleration and deceleration commands to control the model. However, in this application it was simply used to record acceleration and deceleration command outputs. The revised Simulink model can be found in Appendix C.

3.4 CSC Supercomputing Integration.

Due to the computationally intensive nature of optimisation, initial simulations were limited to small numbers of changes of force and possible force outputs. This was needed because of the limited computational power available on personal laptops. As the number of force interpolation points increases, the number of possible combinations also dramatically increases, greatly reducing the speed of the optimisation routine, and quickly becomes impractical to run locally. As such, greater computing power was required, being able to be acquired from CSC-Tieteen tietotekniikan keskus Oy (IT centre for science). The Puhti supercomputer was able to be utilised by using MATLAB parallel server to enable the Multistart function to run the routine in parallel on a cluster. Alongside the increased computing power, offloading the running of the routine allowed simulations to be run for a much longer period (up to three days). This allowed a far greater number of start points to be optimised, increasing the confidence of the results being most optimal solutions.

When running optimisation simulations, the following cluster settings were used: Memory per CPU: 2Gigabytes, queue partition: large, Wall time: 48 hours.

When queuing batch jobs, the maximum number of workers based on the number of available MATLAB parallel server licences were used. Complete processes for usage of MPS with CSC services is detailed in *Appendix D*.

4.0 Results

4.1 The Human Energy System

4.1.1 The Keller Theory – Parameter Derivation

The resulting parameter matrix which was returned by the routine outlined in section 3.2.1 above was P = [9.74, 0.825, 6.29, 305.05] this in turn yields the ideal values for the four key parameters associated with the running data provided to be as follows; $f_{max} = 9.74\ N/kg$, τ = 0.8254 N/kg, σ = 6.29 $cal/kg/s$, and e^0 = 305.5 cal/kg. The associated velocity profile produced by these parameters was plotted and is shown below, in *Figure 15*, where it is compared against the measured velocity profile from the provided data.

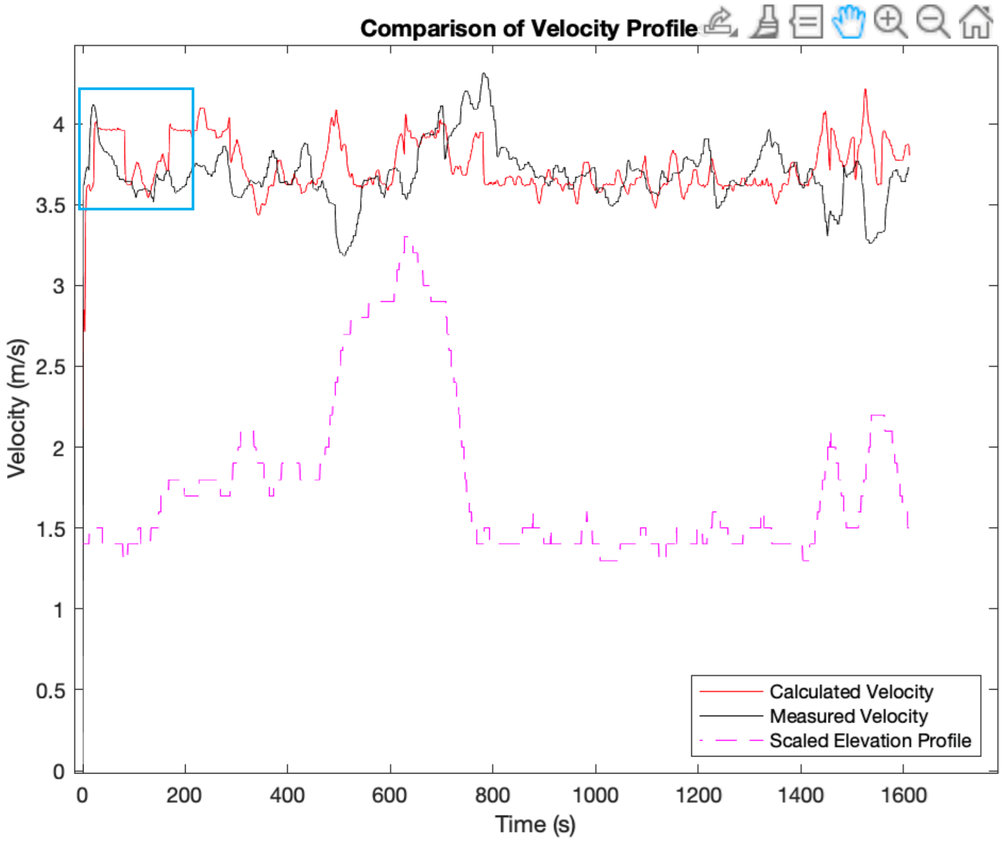

Figure 15: Comparison of Velocity Profiles

It is clear from *Figure 15* above that while the calculated velocity (red) does not perfectly replicate the measure velocity (black) from the data originally provided for this study. The general magnitude of the calculated velocity falls within the same range of amplitudes as can been seen in the profile associated with the measured velocity. It also becomes evident upon closer inspections that variations and divergences between the two velocity profiles occur throughout. Also depicted in the plot above is a scaled profile of the elevation variation throughout the Naantali running course.

4.1.2 Optimum pacing for runner

The *fmincon* optimisation routine was run using Eero Immonen's Keller parameters derived in section 3.2.1, shown in SI units (with the assumption of 75kg bodyweight) in *Figure 16*, with 3 force interpolation points throughout the duration of the track. The time range was set to be between 0 and 1800 seconds, based on the time previously set by Eero of 1657 seconds.

```
tau = 0.8255; %s
sig = 21.7; %m/s^2
Fmax = 9.74; %N = m/s^2
E0 = 1265; %m^2/s^3
```

Figure 16 - Keller parameters used for unit mass.

Figure 17 shows the Reduced track points for the Naantali run GPS data produced by the Douglas-Peucker algorithm and a point tolerance of 0.001.

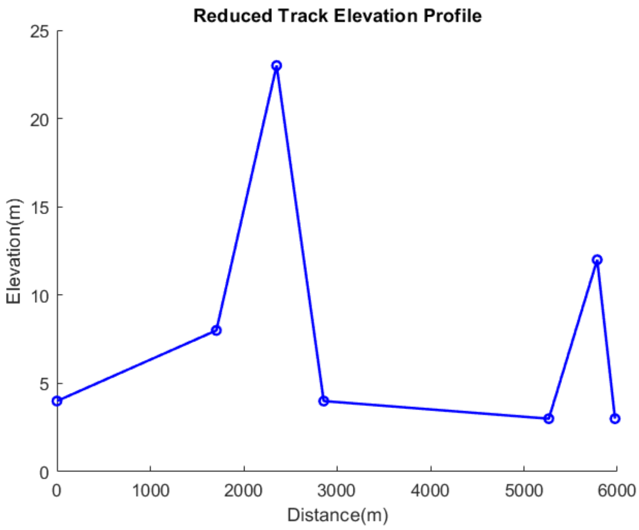

Figure 17 - Reduced track plot for Naantali track, tolerance 0.001

This produced the above optimum solution which satisfied all constraints, shown in *Figure 18*. The minimum running time found was 1546 seconds which equates to 25 minutes and 45 seconds.

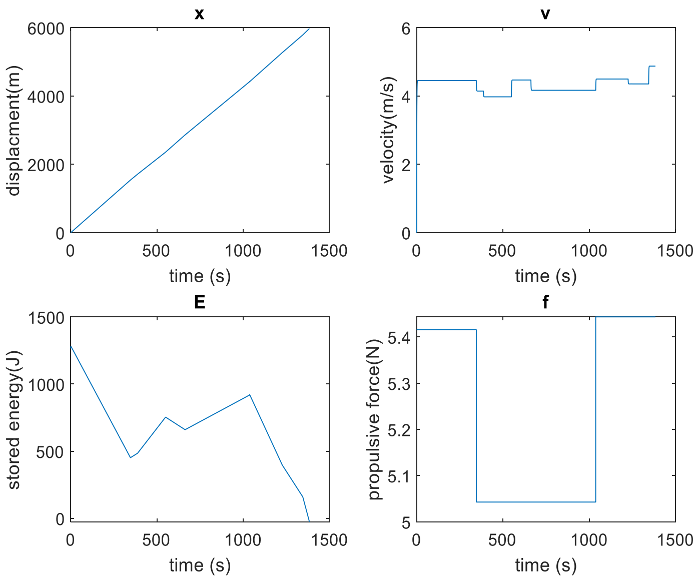

Figure 18 - Optimal Force Graph for Runner on Naantali track,3 interpolation points

The routine was then changed to run with 5 interpolation points on the Naantali track, alongside increasing the iteration count to 4000, and the function evaluation count to 8000 to account for the additional complexity, which produced the following optimum solution in *Figure 19*. No solutions were found for this configuration which satisfied all constraints.

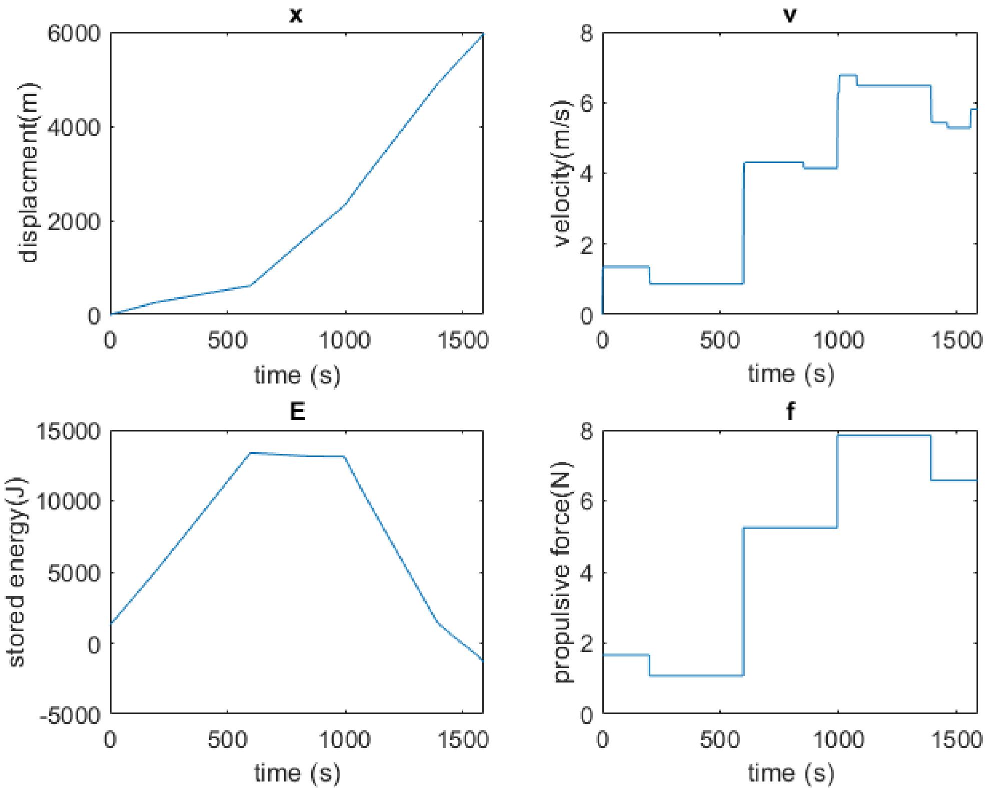

Figure 19 - Optimal Force Graph for Runner on Naantali track,5 interpolation points

The initial configuration of 3 interpolation points and the associated settings was then repeated for an unknown track, the Holyrood parkrun, producing the following reduced track profile in *Figure 20*, and the optimal force graph shown in *Figure 21*.

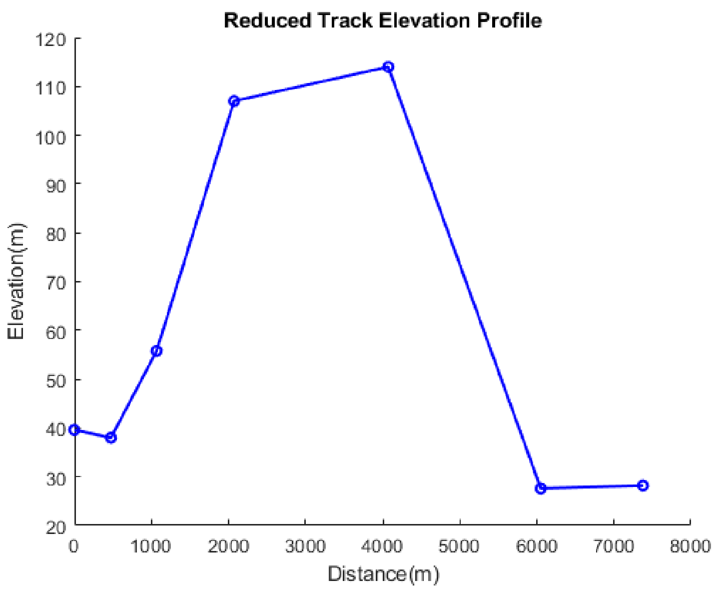

Figure 20 - Reduced track profile for Holyrood parkrun.

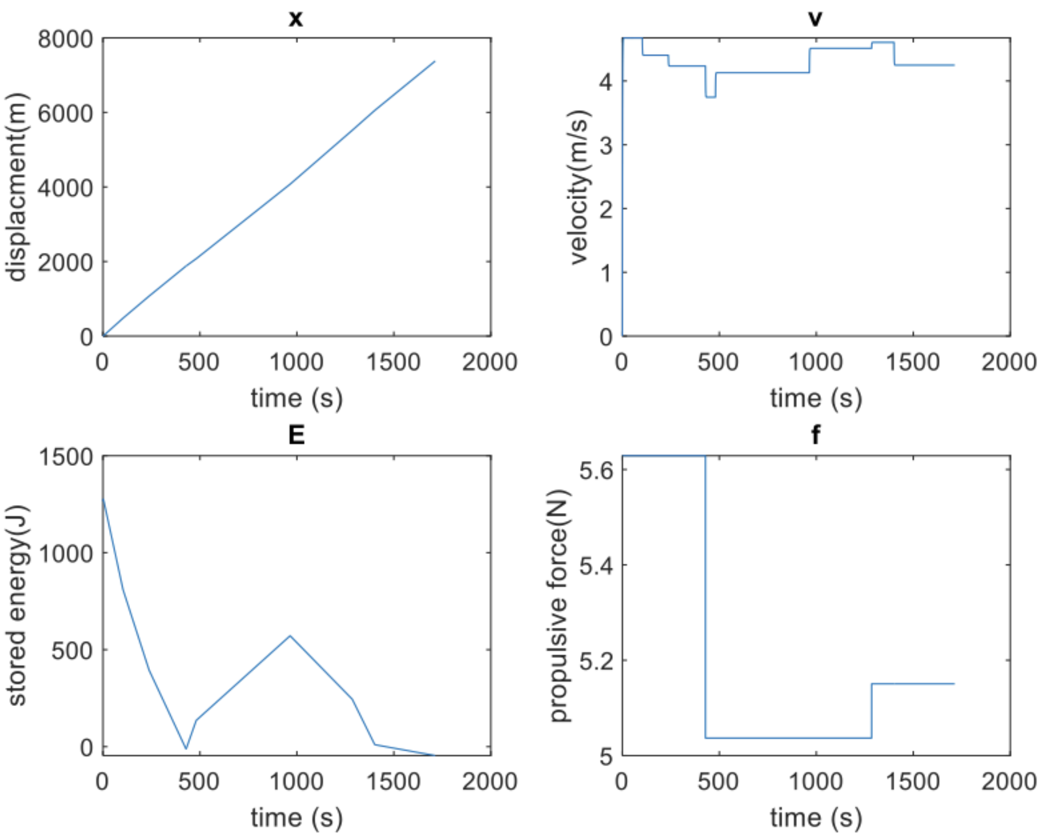

Figure 21: Optimal pacing graph for Holyrood parkrun, 3 interpolation points

The optimal time found for Eero's parameters for the Holyrood Park run was 1713 seconds, or 28 minutes and 33 seconds. The result shown was the shortest time found which satisfied all energy constraints.

4.1.3 Discrete Force Optimisation Strategy

Upon initialising the code required for this runner optimisation, the key parameters of initial energy and sigma values were input with units converted to better streamline the analysis – with $e^0 = 305.5\,cal/kg$ and $\sigma = 6.29\,cal/\,kg/s$. These Keller parameter values were vital to optimise the runner simulations.

4.1.3.1 Results for two force choice

For the six segments of track, the system outputs a velocity, change in energy, and time taken for each segment of the track. For the 'two-force' choice discrete analysis (Simulation One), the choices output the following results shown in *Table* 10.

Table 10: Velocity, Energy and Time per segment for two force simulation

Segment	Velocity (m/s)	Energy (J)	Time (s)
1	2.876	3187044.525	471.0581
2	2.4659	70675.875	261.5304
3	5.6084	92134.3125	89.9546
4	4.8781	44034.9375	493.9373
5	2.5812	56759.85	200.6851
6	5.7935	34881.375	32.9681

From *Table* 10, the runner took 1673 seconds to complete the 5950-meter run, which is approximately 27 minutes and 53 seconds. This simulation yielded a remaining energy of 3407 Joules. Segments of the longest duration are track segments one and four. This was as anticipated because these sections are significantly longer than the others. The runner's maximum velocity during the simulation was approximately 5 m/s, while the minimum velocity was measured as 2.466 m/s for segment two. For this runner simulation, the force value used at each segment was as follows in *Table* 11.

Table 11: Force used at each segment for two force simulation.

Segment	1	2	3	4	5	6
Force Used (N)	109.575	109.575	182.625	182.625	109.575	182.625

Table 11 gives a visual of which force the runner chooses to run at for each segment of the run, three segments being run at the higher force choice of 182.625N with the other half being run at 109.575N.

4.1.3.2 Results for five force choices

The five-force choice simulation of the runner on the Naantali track (Simulation Two) gave the following results for velocity, change in energy, and time taken for each of the six segments, shown in *Table* 12.

Table 12: Velocity, Energy and Time per segment for five force simulation.

Segment	Velocity (m/s)	Energy (J)	Time (s)
1	3.85	249393.7	443.3753
2	2.4659	70675.875	261.5730
3	5.1214	182920.8813	98.5085
4	3.9041	352027.95	617.1638
5	3.0682	66219.825	168.8309
6	5.7935	34881.375	32.9681

The runner's overall race time for these force options was 1623 seconds, equivalent to 27 minutes and 3 seconds. Remaining energy of the runner for this simulation was 5124 Joules which in equivalent to approximately 1124 calories. Each segment selected a force as shown below in *Table 13.*

Table 13: Force used at each Segment for five Force Simulation.

Segment	1	2	3	4	5	6
Force Used (N)	146.1	109.575	164.3625	146.1	127.8375	182.625

Table 13 reveals that, considering the gradient of the Naantali track, the runner selects to utilise the maximum force choice during only segments three and six. The runner chooses the minimum force option in segment two, with the runner selecting one of the three intermediate forces for the three remaining segments.

4.1.3.3 Comparison between force choice options

Having kept the overarching range of force values consistent, with both simulations running between 15% and 25% of the runner's $f_{\max\_sim}$, the results can be directly compared in order to determine which simulation gives the runner the most optimum race strategy. The first element of these simulations that can be compared is the forces for each segment. Figure 22 gives a comparison between the forces for each segment for both the two-force choice simulation and the five-force choices simulation for the runner.

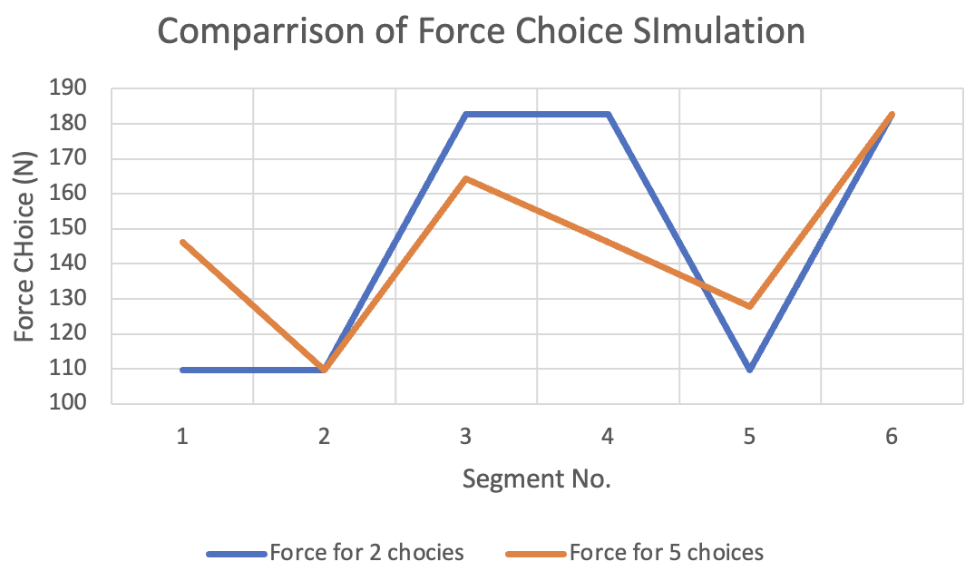

Figure 22: Naantali Track Force Choice Comparison

As can be seen in *Figure 22*, there are two segments of the track in which the runner selects the same force for both force choice simulations. This happens for the minimum force in segment two and maximum force in segment six.

The remaining energy for both force choice simulations can also be analysed to ascertain which force choice simulation yields the optimal method. Table 14 gives the remaining energy, in Joules, for both the two-force and five-force simulations.

Table 14: Remaining energy for both force choice simulations

Force Choice Simulation	Remaining Energy (Joules)
Two force choice	3407
Five force choice	5124

From Table 14, the remaining energy post-run for the five-force choice simulation was larger than that of the two-force simulation. This would suggest the conclusion that the five-force simulation is better than the two-force simulation, but other parameters must be looked at before coming to a finalised conclusion.

Another key value which can be analysed to help conclude which simulation is most optimal is to analyse the time taken to complete the race. It is important to note, that just because one segment is faster it does not mean that overall that simulation is most optimal, it may be quite the opposite, so the total time is the key parameter. The total time for both simulations is shown in *Table 15.*

Table 15: Total time for both force choice simulations

Force Choice Simulation	Time taken
Two force choice	27 minutes 53 seconds
Five force choice	27 minutes 3 seconds

Based on the information provided from both simulations, the runner is able to complete the Naantali race distance 50 seconds quicker when presented with five force options compared to being only given two force choices. This, along with the higher remaining energy, clearly results in a more ideal force pace strategy for the runner but needs to be compared with the validation simulations to ensure this is accurate.

4.1.3.4 Validation of Simulation Force Choices

Upon completion of the simulations for the original five-force and two-force choices the time for every run simulation can be analysed. *Table 16* summarises the time to complete the race for each of the four simulations.

Table 16: Simulation completion time comparison

Runner Simulation	Time to complete the race (s)
Simulation One	1673
Simulation Two	1623
Simulation Three	1624
Simulation Four	1506

When analysing the time taken to complete the race for the four simulations, it is sensible to first analyse the different force choice simulations separately. Firstly, looking into the two-force choice strategy (Simulations One and Three), it can be seen that Simulation Three completes the race 49 seconds faster than the original simulation. Then when comparing Simulations Two and Four which are the five-force choice systems, the validation simulation actually completes the run 116 seconds faster than the original simulation. On the one hand, this would suggest that the validation force choice method is the better method. However, the remaining energy must also be looked into to give full understanding of the system in its entirety.

Another aspect of the four runner simulations that is vital to consider is the remaining energy at the end of the run. *Table 17* provides the four remaining energy values (in Joules) which allows for full analysis of the runner system.

Table 17: Simulation remaining energy comparison

Runner Simulation	Energy Remaining at the end of race (J)
Simulation One	3407
Simulation Two	5124
Simulation Three	-2299
Simulation Four	-83393

For the two-force choice strategy, the original simulation (Simulation One) was the only simulation which completed the race without dipping into negative remaining energy. For this reason, this validates that the original method of force selection for the two-force simulations was correct as it is not allowable for the runner to have a negative remaining energy post-race so Simulation Three can be eliminated from the list potential optimal method. Similarly, for the five-force choice simulations, the original force choice method (Simulation Two) was the only one out of the two that has a positive remaining energy. Again, the runner cannot complete the race with a negative remaining energy value, so this removes Simulation Four as a possible optimal solution.

Upon finalising the analysis of the four runner simulations, it is clear that the optimal force choice strategy is Simulation Two which is the original five-force choice simulation. This simulation selects its force with descending angles selecting higher forces as shown in Table 7. This simulation has the faster completion time out of the two simulations which have a positive remaining energy. Simulation Two also has more remaining energy than Simulation One which further proves that it is the optimal solution that should be carried forward for adaptation for the eRallycross vehicle.

4.2 eRallycross Optimisation

4.2.1 Velocity selection

The code outputs an array of the selected velocities for the six sectors of the track as well as an estimated time taken to complete the track. Running the code for the Naantali track data yields the following results in Table 18.

Table 18: Naantali velocity data for eRallycross car

Segment	1	2	3	4	5	6
Velocity (m/s)	40.8	34	47.6	44.2	37.4	46.9

In addition to the data from Table 18, a time of 143.78 seconds was calculated as the predicted time taken to complete the course. Analysing Table 18 gives an average speed of 42.99m/s or 92.96mph.

The output from the Holyrood data yields the following in Table 19.

Table 19: Holyrood velocity data for eRallycross car

Segment	1	2	3	4	5	6
Velocity (m/s)	43.55	36.85	33.5	40.2	46.9	40.2

The predicted time for this track was 181.87 seconds. Table 19 gives a visual of the velocity of the eRallycross vehicle for each track segment which can be analysed. Upon doing so, the average speed for the car is 40.55 m/s or 90.56 mph.

4.2.2 Simulink Model

The data from the aforementioned MATLAB code was then implemented into the Simulink model to control the electric motor of the vehicle. This was initially conducted with the Naantali velocity and track data.

4.2.2.1 Vehicle Velocity Results

The requested data from the MATLAB function block was monitored alongside the resultant velocity from the vehicle body to identify any differences. The results were as follows in *Figure 23*.

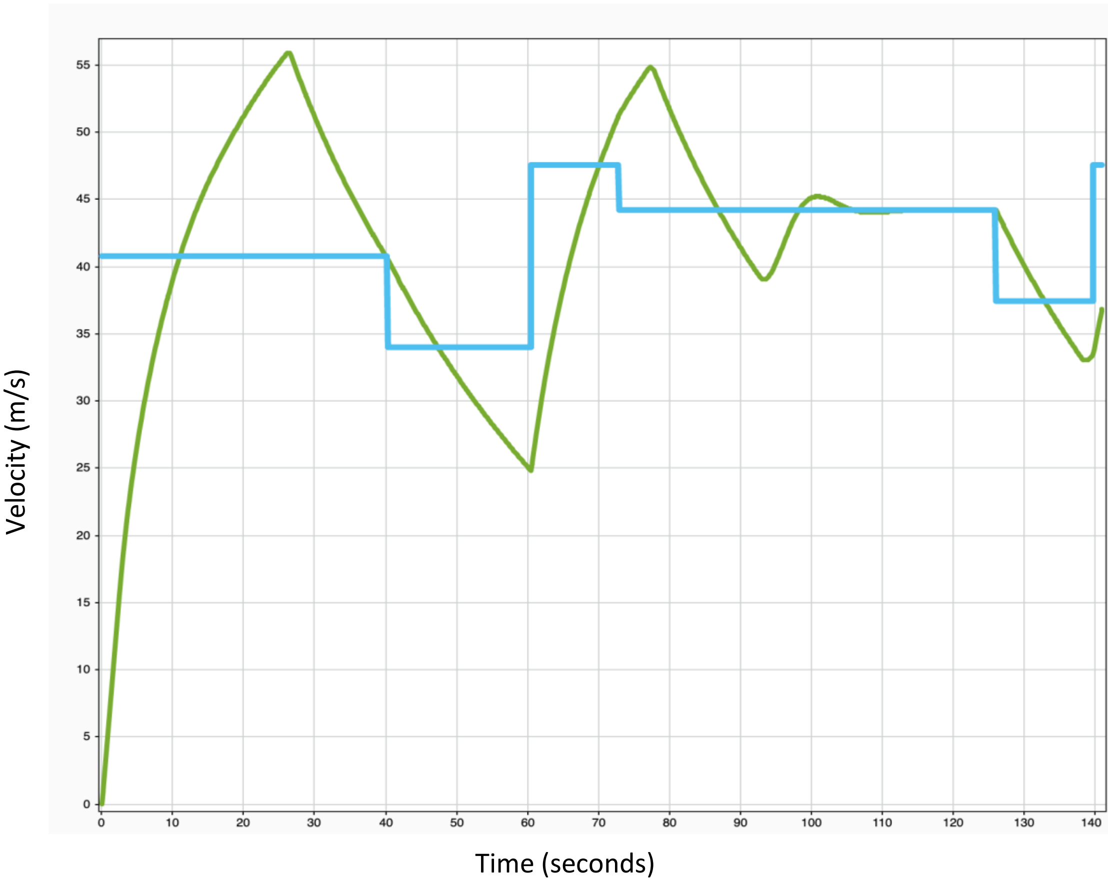

Figure 23: Requested velocity (blue) vs actual velocity (green)

The requested velocity takes the form of a step graph due to the instantaneous change in velocity demand as the vehicle moved between segments of the track. It can be observed that the vehicle responded to the velocity demands however there are significant differences. In the first phase, the initial acceleration is very aggressive, and the car overshoots the velocity request significantly before this is corrected. This result is to be expected as it is unrealistic for the car to achieve significant changes in velocity over such a short period of time.

4.2.2.2 State of Charge Results

The state of charge of the battery was recorded throughout the simulation to observe its behaviour. These results are displayed in *Figure 24*.

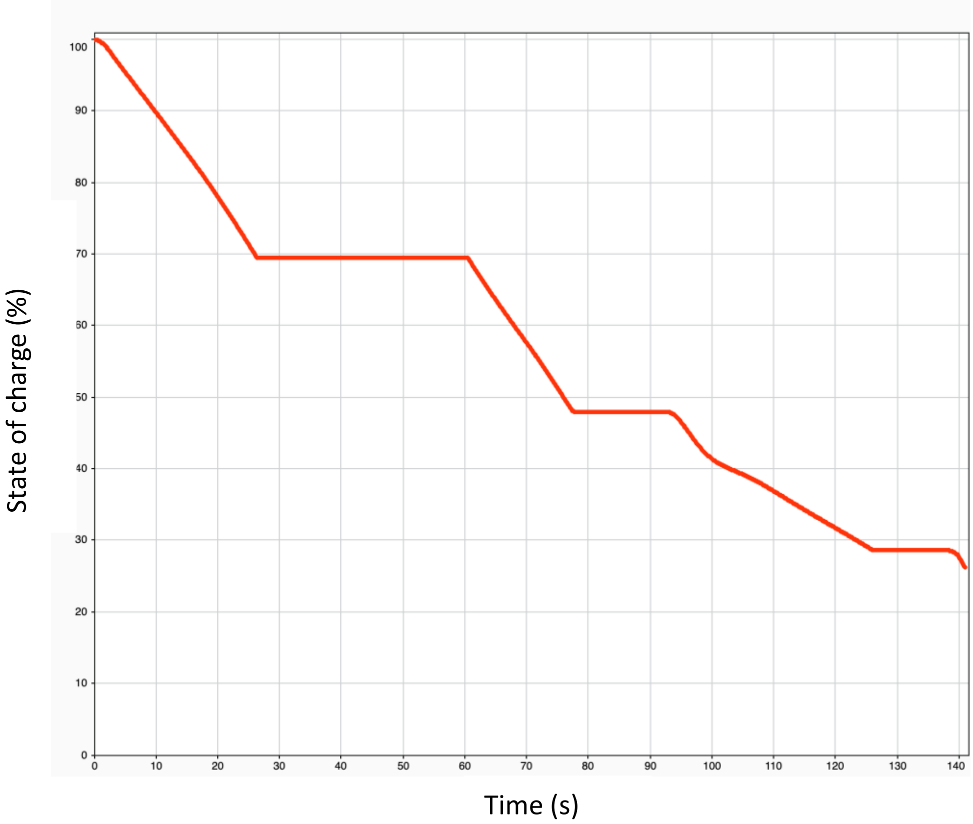

Figure 24: Graph of vehicle battery's state of charge against time

When comparing *Figure 23* and *Figure 24*, multiple correlations can be noted. In *Figure 23*, during the first phase of acceleration lasting approximately 25 seconds, the state of charge decreases significantly. This is repeated between approximately 61 and 77 seconds. This was an anticipated outcome as the vehicle requires a greater force output to accelerate, and therefore a greater energy consumption. Similarly, it can be observed that the flat sections o*f Figure 24*, where the SoC is not decreasing, are a result of deceleration or coasting of the car. When the simulation terminates, it can be seen that there is still approximately 15% of the SoC remaining before the simulation is terminated.

4.2.2.3 Vehicle Throttle Data

The ‘longitudinal driver’ block outputs an acceleration command in the form of a percentage throttle use. This information is displayed in *Figure 25*.

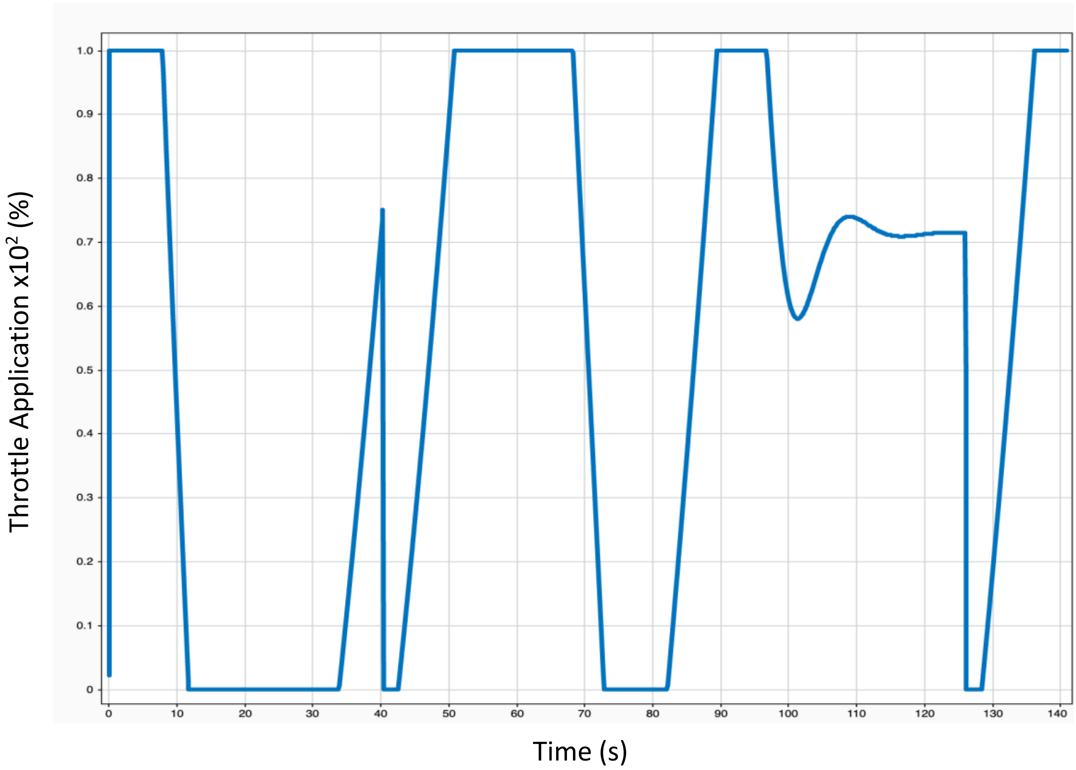

Figure 25: eRallycross throttle data for Naantali track

The throttle data describes how a driver would control the vehicle to traverse the given course. It can be observed that 100% throttle is being used for the first 8 seconds. When compared to *Figure 23*, the driver decompresses the throttle when the actual velocity meets the requested velocity. Likewise, from approximately 100 to 125 seconds, when the requested and actual velocities are similar, the driver uses intermediate throttle positions to control the vehicle.

4.2.2.4 Propulsive Force Graph

Figure 26 is a plot of the propulsive force supplied from the electric motor to the vehicle body. Once again, when compared with the previous graphs, the value of force fluctuates in accordance with the requested and actual velocities. The vehicle accelerates when a significant force is applied therefore conforming to Newton's second law of motion. The force can also be observed to decrease to a constant value as the vehicle nears and reaches the requested velocity. This represents the PID controller taking effect. Similar to the throttle data plot, the state of charge can be seen to deplete as a consequence of the motor generating a propulsive force.

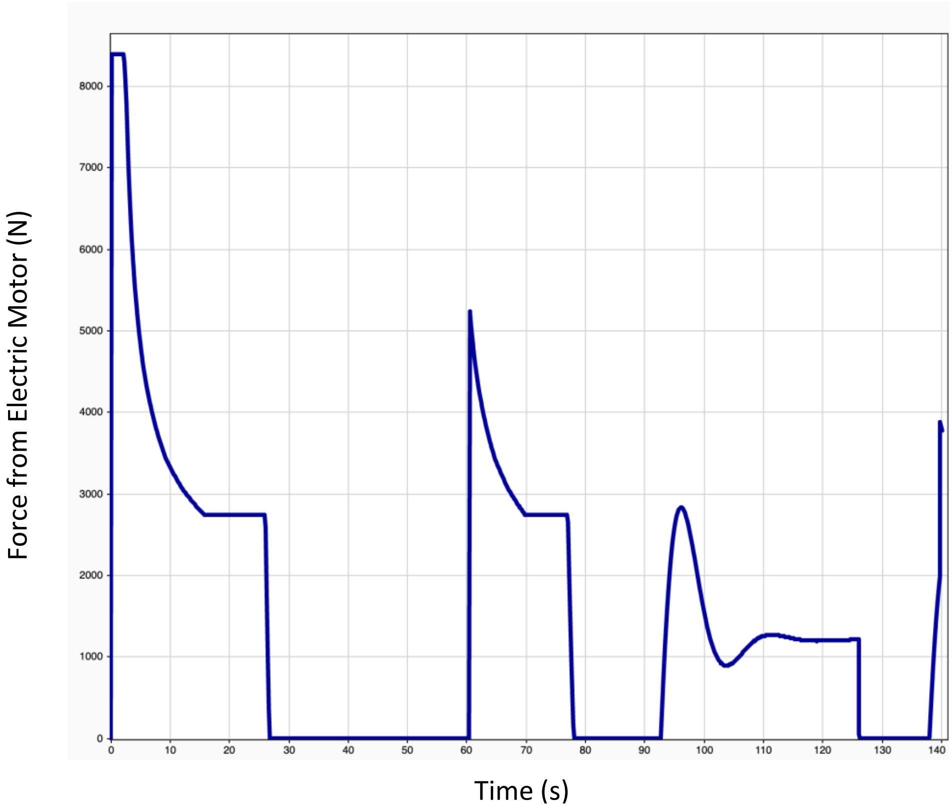

Figure 26: Propulsive force applied to the car from the electric motor for the Naantali track

4.2.2.5 Holyrood Track

The same tests were conducted for the Holyrood track data. In *Figure 28,* comparing the requested velocity (blue) and actual velocity (red) mirrors the results of the Naantali track data by showing clear corelations between the requested and actual velocities.

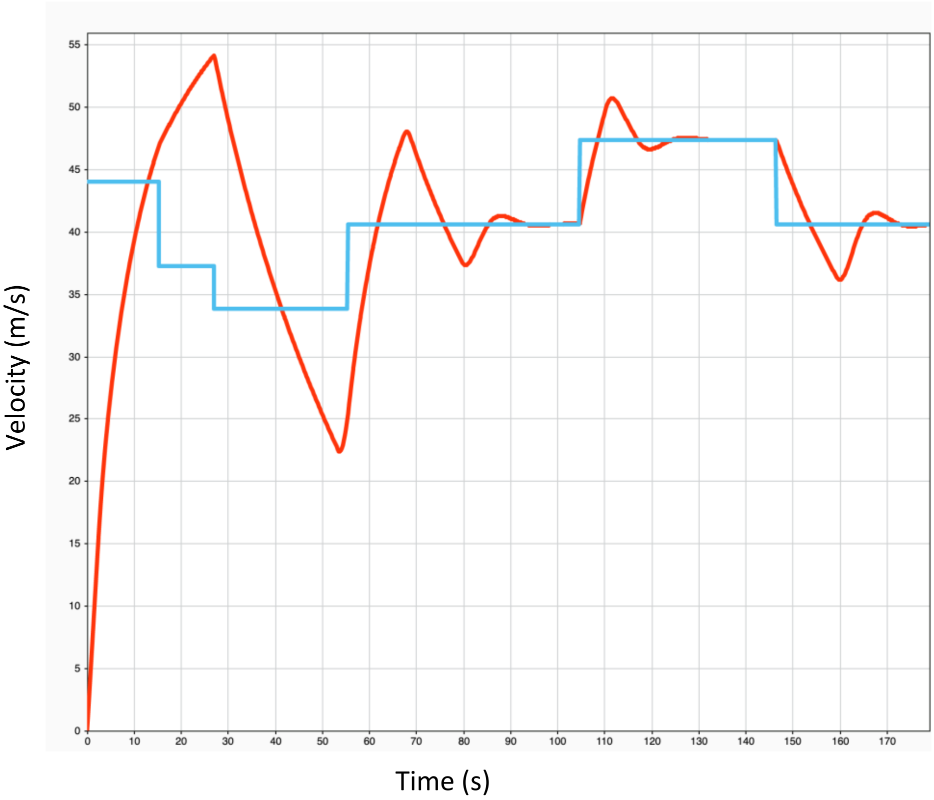

Figure 27: Requested Velocity versus Actual Velocity for Holyrood Track

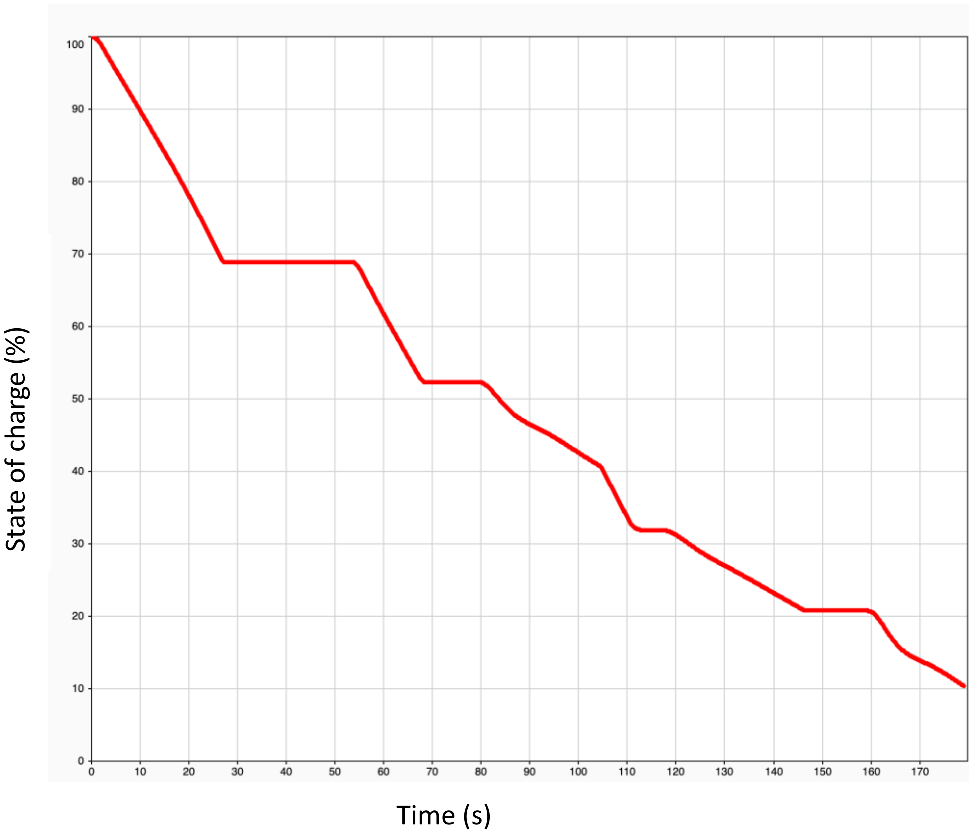

Figure 28: Holyrood State of Charge Data

Figure 27 shows the SoC data for the Holyrood track simulation. Once again, it can be observed that under acceleration, the motor consumes more energy than when the vehicle is coasting or decelerating. *Figure 27* also shows there is significantly less excess energy at the end of the simulation. This is due to a combination of travelling a greater distance and a greater fluctuation in track gradient.

Figure 29 shows the Holyrood throttle data. Once again, the graph mirrors the observations made for the Naantali simulation.

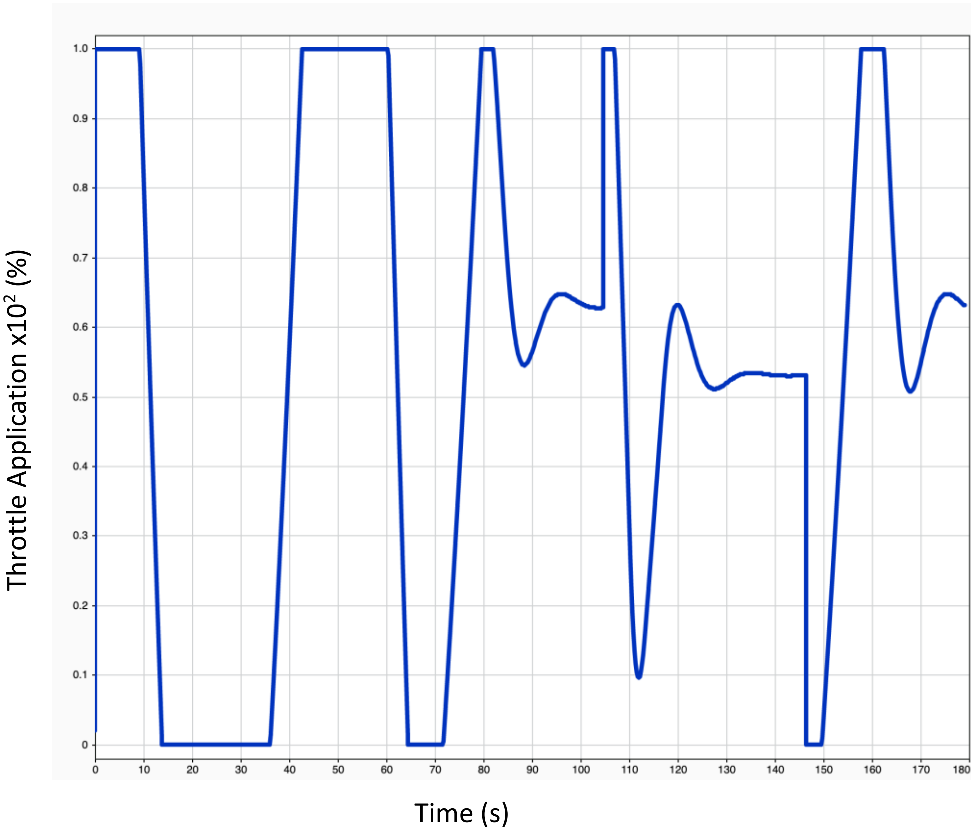

Figure 29: Holyrood Track Throttle Data

Figure 30 shows the propulsive force of the electric motor over time for the Holyrood track. The graph elucidates the same observations made for the Naantali track. This aligns with the concept of minimising substantial velocity changes to decrease energy demand and consumption.

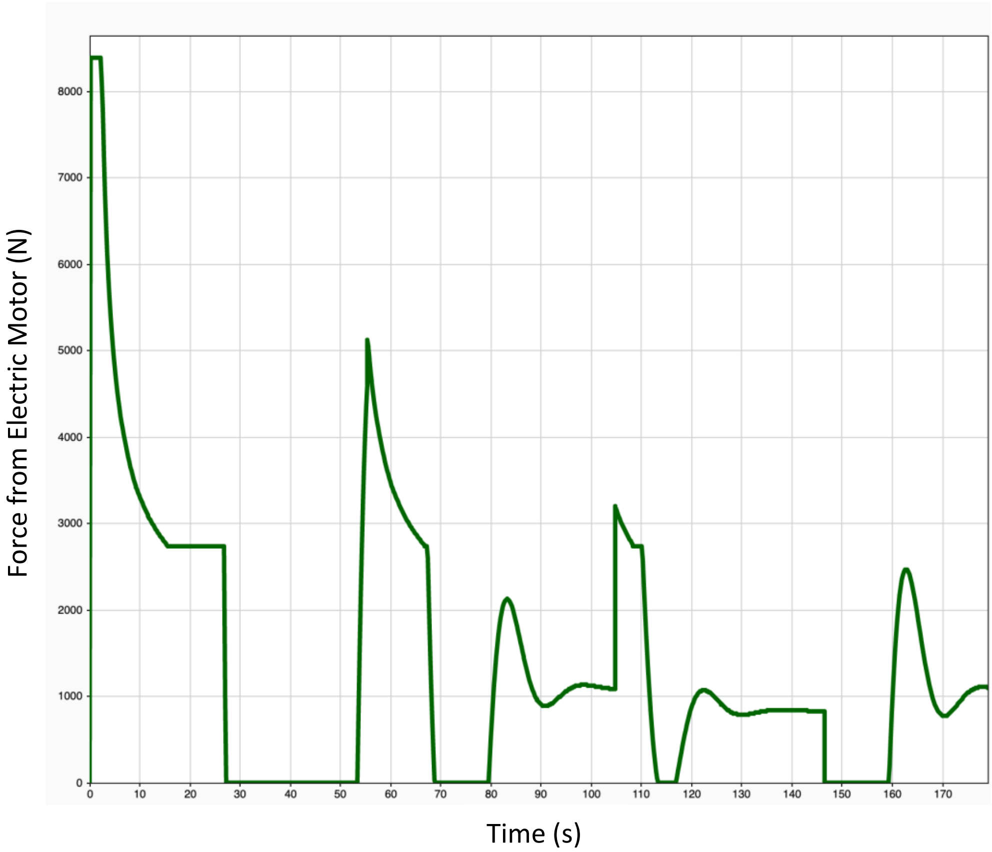

Figure 30: Propulsive force applied to the car from the electric motor for the Holyrood track

5.0 Discussion

5.1 Keller Parameter Derivation

5.1.1 Results

The results obtained from the implementation of Keller's theory, as described previously in section 3.2.1, in pursuance of determining the four key characteristics associated with the running data provided, can be found in section 4.1.1 above.

From *Figure* 15, which compares the velocity calculated using the final ideal Keller parameters returned ($f_{max} = 9.74\ N/kg$, $\tau = 0.8254\ N/kg$, $\sigma = 6.29\ cal/kg/s$, and $e^0 = 305.5\ cal/kg$) with the measured velocity from the provided running data. It can be said that there is a general trend between the two profiles which both appear to have a number of instances of very similar velocity profile shape throughout the period of the race. However there were significant differences between the two velocity profiles that can be observed. After some investigation it was found that these key events more often than not coincided with where the runner's path encountered a change in the local slope angle. In order to visualise this relationship involving the local slope angles and the variations between the measured and calculated velocities, a scaled track profile was added to the plot, this is depicted by the dashed magenta line in the plot (*Figure* 15). With the addition of this scaled elevation profile it becomes easy to decipher that the largest divergence of velocities, which occurs at approximately 500 seconds, is concurrent with the presence of the steepest hill encountered by the runner throughout the course. This divergence is due to the calculated velocity increasing up the hill, where the measured velocity shows a decrease. This can be attributed to the fact that Keller's theory of running, and the equations used in pursuit of the derivation of the calculated velocity, aim to produce the optimal solution for completing the course. However, this theory is unable to account for external factors such as weather conditions and the presence of other competitors on the course. Keller's theory has no method of resolving and simulating human behaviours and decision making, but with these limitations of Keller's method being taken into consideration it was determined that a plausible cause of the velocity divergences, which occur in the presence of slopes and hills throughout the course, could be due the runner's intuitive decision to run slower uphill and recover momentum and speed on the downhill. This opposed the theoretic strategy of increasing force and speed up the hills and recovering energy and momentum on the downhills as is proposed by velocity calculated using Keller's theory of competitive running.

Another way in which the velocity calculated using Keller's methods differs from the velocity data provided, is the abrupt changes in velocity which appear to be almost instantaneous, the most prevalent examples can be seen in the first section of the race and is highlighted within the blue box on *Figure* 15. These abrupt changes in velocity further support the suggestion of limitation to Keller's theory and equations, as it is likely beyond the capabilities of the average runner to be able to change their velocity in such a rapid and immediate manner. Furthermore, even if a person was to be deemed capable of replicating these sharp variations in their velocity, it would not be intuitive to do so, and it is known that the running data provided was obtained from a runner who had not been given the foresight of knowing Keller's theory so did not benefit from the knowledge of the ideal race theory as is presented here. For this reason it was expected for some variations between this measured velocity and the calculated velocity which aims to find the optimal pacing strategy for the given course.

5.1.2 Methods

The methods employed in the pursuit of the results obtained, which are presented (Section 4.1.1) and analysed (Section 5.1.1) above, have been previously delineated in Section 3.2.1 above. The foundation to these methods stem directly from Keller's theory of competitive running which is explored in depth within Section 2.1 above, however there are certain drawbacks and limitations to this theory, as has been discussed in Section 2.1.3 previously. The key limitations which hinder Keller's theory, are primarily based upon the inability to resolve human behaviour and the multitude of potential factors which influence human decision making, in a concise and discernible fashion. This is most evident within the variations and divergences between the two velocity profiles analysed above as a means of validation for the parameter results received. However, as this parameter derivation occurred at an early stage in the project and was only relevant to the sections of the project pertaining to the human system, it was deemed that any variation due the simplicity of Keller's theory would not have a significant enough impact upon the results of the vehicle dynamic system which are a direct answer to the principal aim of this project.

Figure 10 depicts a block diagram which provides a visual representation of the parameter derivation scheme implemented. The processes denoted in section 1 to the left of the dashed line in *Figure 10* - which implement *Equation* 18, *Equation* 19 and, *Equation* 20 in order to find the initial values of maximal propulsive force the runner can exert per unit mass, f_{max} $(\mathrm{N/kg})$, the internal resistive force per unit mass, τ $(\mathrm{N/kg})$, the initial energy stored within the body of the runner per unit mass, e^0 $(\mathrm{cal/kg})$, and finally the rate of energy recovery from oxygen consumption, σ $(cal/kg/s)$, to provide the values which are contained within the initial guess matrix, $P0$. However, upon revisitation and refinement to the optimisation routine – shown to the right of the dashed line in section 2 of *Figure 10*, it was found that small variations in the values presented as an initial starting point for the optimisation, in the form of the matrix, $P0$, tended to have a close to negligible impact upon the final output matrix which stores the final results for the four key characteristics. Furthermore, it was found any notable variation could be mitigated by re-running the optimisation routine and inputting the value previously returned as the initial guess, $P0$. This iterative approach eliminated the variations in parameter output matrices. This means that the processes executed in section 1 become a highly convoluted and computationally expensive method for determining the initial guess, which has been made irrelevant by the iterative process that could be employed in its place, by simply inputting any sensible values within the range between the upper and lower bounds as defined within *Table 5.*

5.2 2D Fmincon Runner Optimisation

5.2.1 Validity of Results

Results from section 4.1.2 show the optimum running time for Eero Immonen's parameters to be 1546 seconds or 25.4 minutes. When compared to the actual time ran by Eero Immonen, of 27 minutes and 31 seconds, they are relatively close, with the optimal time being slightly shorter than the actual time. This would be expected, as it is unlikely that the physical race was run in purely optimal conditions. External factors such as running surface, turning, wind, and other runners may influence pacing at any given moment, alongside maintaining exact pace, and changing pace instantaneously is improbable.

When simulated with a greater number of force interpolation points, such as in *Figure* 19, the plot of energy does not meet the constraints specified in the problem, namely that the stored energy must be greater than or equal to zero, and that the energy may not exceed the maximum capacity. As such the resulting time is invalid, and no optimal solution was able to be found for the given parameters. It is thought that this is due to the function of *fmincon* attempting to use the interpolation points to define a continuous polynomial function, which as the number of points increases, becomes increasingly difficult, and consideration of energy constraints makes this even more difficult, leading to a lack of valid results.

When running the routine for an unknown track, in this case the track from the Holyrood Park run in Edinburgh, UK, using Eero's Parameters, an optimal time of 28 minutes and 33 seconds was found. This result verifies the ability of the optimisation program to find optimal time estimates for tracks of varying length and elevation, beyond the short and relatively flat Naantali track. Alongside this, the resultant time equates to an average pace of approximately 4 minutes per kilometre, which is a good pace for an experienced runner such as Eero.

5.2.2 Possibility of application of method to eRallycross Vehicle

Initially, the problem was to be approached using a similar method to that employed by Eero Immonen e.t al [78] when tackling the mountain car problem with a limited energy system, by building up from a simple human system, to a human system running on a track of varying elevation, then replacing the human energy system with that of the eRallycross vehicle. However, when considering the implementation of the Simulink model to the Keller model for a 2D track, it was realised that the current approach would not be valid due to the nature of the force output during a rallycross race. With the case of a runner, the force output is constant so long as the runner does not stop, as such it can be modelled as a continuous function from a number of interpolation points. Whereas common throttle data for racing drivers is often near-binary, switching between zero throttle when braking and maximum throttle, with occasional usage of force in between these values seen in *Figure* 31, showing throttle data from the University of Strathclyde Motorsport formula student car during track testing [82]. As such it is unlikely a continuous optimisation method such as *fmincon* would be very suitable for the application of a racing vehicle. Thereby, the direction of our research was then changed to develop a method more suitable for the eRallycross application.

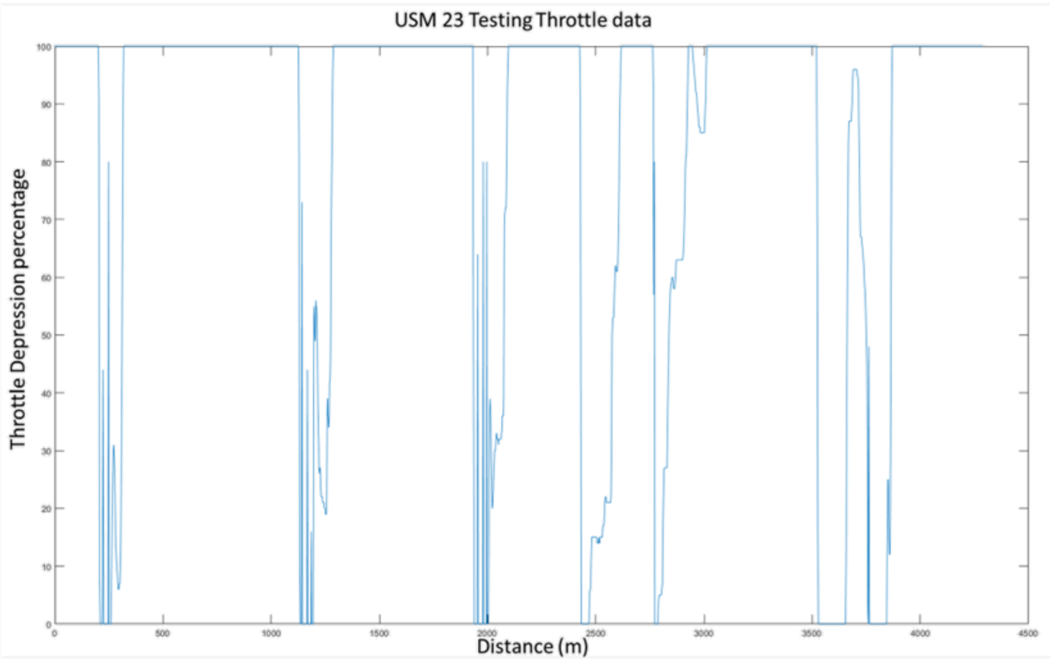

Figure 31: USM electric vehicle throttle usage data

5.3 Discrete Force Strategy Simulation Validity and Reliability

5.3.1 Validity of Methodology and Results

The Naantali run's optimum force strategy, while beneficial for certain applications, is hindered by numerous flaws that significantly undermine the simulations' validity. Several simplifications were taken during the development of this method, each potentially affecting its overall practicality. The main parameter which makes the decision of the force choice is the angle of the segment, which is beneficial to the method as the angle of the slope is critically important in terms of how a runner would pace their race. For example, a runner would apply less force when running uphill (at a negative angle) in order to use the impacts of gravity to aid in a quicker completion time This simplification is easy for a runner to apply as it is intuitive for a runner to behave in this manner of applying more force going downhill and less force uphill. This aids in the validity of the results obtained as it follows a runner's intuition.

One of the criteria of this method which hinders the reliability is that the runner must maintain a uniform velocity throughout the entire portion of each segment, with accuracy to four decimal places. Tracking and maintaining such a high level of accuracy would pose significant challenges for a runner. In addition, the strategy assumes that the runner has the ability to instantaneously alter their speed upon a change in angle of the track. This, however, is not at all reasonable when physically applied to a runner as it is an unrealistic command. A runner cannot accelerate or decelerate immediately to a given velocity when instructed to – this would be done more gradually over a short span of time rather than altering at one specified point on the track. Another serious drawback to this method is that it does not use the length of the segment as a deciding factor when selecting the force value for the segment. This means that when two segments have an identical angle then the same force will be selected, no matter the length of the segment. This ideology is slightly flawed, as a runner may not be able to maintain the same force value when faced with a large steep hill compared to a shorter steep hill – with the runner being capable of applying a higher force to get up a less lengthy hill. This parameter not being fully accounted for further hinders the reliability of the results obtained through this method. This in future work could be remedied by calculating all possible permutations of the runners' pacing options by calculating each possible force choice for each section, forming a decision tree, which could then be searched for the shortest time possible. However, this method would be highly computationally and time intensive, and as such was not feasible in the scope of our work.

For the issue of instantaneous velocity changes within the method, the simulation should be altered in order to account for the acceleration or deceleration of the runner between segments. This should yield more accurate results that would closer match the results found from the mountain car problem simulations as the time taken for these simulations are far quicker than the mountain car due to this simplification.

Taking all of these possible hinderances to the discrete force choice strategy, it is clear that there are certain limitations to using this method which have oversimplified the problem. There is a difference of completion time (over two minutes) between the generated optimum time for the Naantali run using this method when compared to the altered mountain car approach. However, when simplifications are considered, this method is the correct strategy to be carried forward and adapted for use of the eRallycross vehicle.

5.3.2 Pacing strategy integration

In order to address the problem of the overly precise velocity values, the simulation could be modified to incorporate a velocity constraint that is more manageable for the runner. This can be achieved by restricting the degree of accuracy of the velocity output to a specific number of decimal places. Another potential method for improving the runner's compliance to the velocity value is to provide them with the velocity expressed in kilometres per hour, as this is the customary unit displayed on smart watches. This might be particularly beneficial for incorporation into certain applications that might be already utilised by runners as it is a velocity unit that they are more accustomed to and already understand their pacing relative to this rate.

5.4 Electric Vehicle Pacing Strategy

The vehicle pacing optimisation code proved to be a strong method to control the eRallycross car to maximise both performance and efficiency. When implemented in the Simulink model, it can be clearly observed that the vehicle is operating at a very high level of performance whilst ensuring the battery is operating within its limits. The code accounts for vehicle performance efficiency by ensuring the velocity does not fluctuate too significantly over the course of the track. Thereby, reducing power demand and energy consumption. The predicted time taken to complete the track, outputted from the MATLAB script, is very closely replicated by Simulink model. Both sets of track data provide a time within a 3% margin of error. The optimisation could be further improved by increasing the number of velocities for the code to select from. This would further reduce significant surges in energy demand and further refine the optimisation. The code could be enhanced by changing it to a function, which would allow optimisation tools to be utilised to minimise the time taken to complete the track. This would allow for energy considerations by integrating the battery function into the MATLAB code to act as the energy source.

Within the Simulink model, although very accurately and realistically representing the dynamics and energy use of the vehicle, some areas of improvement remain. In *Figure 23* and *Figure 27*, significant differences between the requested and actual velocities can be observed. Although the PID controller works to minimise these differences, further refinement of the controller is required. This enables improvements to the overall efficiency of the system by minimising excess energy use, such as overshooting the requested velocity. It is worth observing that the average velocity of both the simulations is over 90mph. This is significantly greater than the average speed for a car in a rallycross race however this is due to the track not accounting for corners. Therefore the car does not need to aggressively decelerate during the simulation, thus creating a high average velocity.

5.5 Applications of project

Although battery management is important during racing, for the specific application of Rallycross racing, due to the short nature of the track, it is unlikely that all available energy will be used during the race. Due to a buffer of remaining energy being required to account for alternate conditions, such as weather or road surface, and driver actions, mistakes or hinderance by other drivers. In addition to this, drivers speed is most commonly determined by the layout of the track, often accelerating for the entirety of a straight, before braking for corners, with the speeds here limited by the mechanical grip available to the tyres of the vehicle. As such the applicability of this optimisation routine to eRallycross vehicles is limited, however it may be useful for determining battery capacity required during a design phase. An alternate more appropriate usage of this optimisation routine may be for optimising the transit time of other vehicles whose primary object is not racing – for example buses, mining vehicles and haulage. With the coming advent of electric and hybrid powertrain lorries, when traveling on a known route with a constrained finite energy supply, using the developed optimisation routine, the speed of delivery can be minimized whilst meeting the energy constraints. Alternatively, the routine may be reformulated to minimise for energy consumption whilst still meeting a maximum time constraint to ensure results are practical, allowing the energy consumption by transit to be minimised to reduce environmental impact. Similar works may be produced to implement this method of optimisation to improve productivity and/or efficiency for both mining vehicles and public transport, however, may need to account for non-electric power trains and the specific torque curves delivered by them, alongside the necessity to stop in certain locations.

5.6 Future work

Initial steps to increase confidence in the methods used would include validation against practical methods. For the Keller model for a runner on a 2D track, this could potentially be completed by creating a number of tracks using GPS mapping software (e.g. Memory-Map) of varying levels of elevation change and then using the routine to find optimal times for a given runners parameters. Ideally, a cohort of runners with known Keller parameters (found by running a simple track such as a 400m track) would then complete the routes. This data could them be used to validate the accuracy of the optimisation routine for athletes of varying speed, and to understand the accuracy when the change in elevation around the track increases, possibly leading to empirical correction factors to increase the reliably of the optimal time estimates.

With regards to the discrete force method for calculating optimum time for a 2D track completion by the TUAS eRallycross car, initial steps to improve accuracy of the results, would be to carry out calculations for the Naantali track with a higher level of discretisation of the track, as the more times the force can be changed/toggled, the more accurately the solution will respond to the changing gradient of the track, improving the accuracy of the estimated optimal time. In addition to this, evaluating with more discrete force output levels from the motor may also allow faster optimal times to be found, as closer to optimal speeds for each section may be used. This may include again using the computing power of the CSC to calculate for conditions too computationally intensive for personal computers. However, these times may not be replicable in practice, as there is a limit to the fidelity of the percentage of throttle usage a driver is able to accurately and repeatably produce. In addition to this, for optimising battery usage of the car during races, it would be desirable to develop a full car simulation, that takes account of not just motor and battery dynamics, but also the vehicle dynamics and to a degree the aerodynamics of the car, similar to that used by Formula 1 teams, although in a simpler state. This is because factoring in cornering and braking, where traction will limit the speed possible, is essential to accurately model the journey of a race car. To complement this, practical validation comparing physical track times against the estimated optimum times should be carried out to verify the general accuracy of the estimation in time. This should then be repeated following the optimal force profile to test whether or not an improvement in time is found to validate whether or not the routine is able to find a faster method of driving the track.

The integration of regenerative braking technology into the TUAS eRallycross car would greatly enhance the overall efficiency of the system. Regenerative braking uses the braking torque of the electric motor to generate electricity while the vehicle decelerates, converting the kinetic energy of the car into electrical energy, as opposed to heat from the friction braking. Although friction brakes must also be used for a portion of the braking manoeuvres, there are significant improvements to vehicle performance and energy efficiency. The additional energy could either be used to extend the range of the car, or be used to increase the performance, with both these options bringing a competitive edge. A study may then be conducted to provide data as a percentage reduction in lap time for the car, allowing an informed choice to be made on whether it would be worthwhile to implement regenerative braking to the vehicle, or whether the resources would be better spent elsewhere to improve performance. In order for the work from this study to be further developed by the COMEA research group, a MATLAB user guide (Appendix E) was created to allow a streamline handover back to TUAS.

6.0 Conclusions

The extensive research conducted in the pursuit of determining the vehicle control strategy which optimises the performance of the TUAS eRallycross car, with consideration of the energy constraints imposed by the capacity of the battery employed within the vehicle powertrain, as well as the impact elevation variations have upon the rate of energy consumption, has yielded valuable insights, but it is crucial to acknowledge the limitations and consider potential enhancements for practical implementation.

This thesis has delved into the integration of Keller's theory, the Douglas-Peucker method, and the Mountain Car Problem, in order to find the optimal pacing strategy for a runner, on a course of varying elevation with the purpose of later reformulating the optimisation routine to apply to the eRallycross car. The exploration of these methodologies has yielded two innovative methods for optimising the pacing strategy of a runner navigating an unknown track characterized by variations in elevation. These methods utilise both continuous and noncontinuous functions to model force output, offering a comprehensive approach to address the challenges presented by the diverse topography of the track.

Upon reflection, while the discrete force strategy simulation serves as a valuable tool for understanding certain dynamics, its limitations necessitate further refinements. The ongoing pursuit of a model specifically tailored to the unique dynamics of eRallycross applications remains a crucial focus for future research. However, the results obtained from the initial phase of optimising running times and the insights gained from the discrete force strategy simulation contribute valuable groundwork. There is vast adaptability of the optimisation program in estimating optimal times for tracks of varying elevation and its potential applications beyond eRallycross. For example, optimising transit times for electric lorries and minimising energy consumption in public transport—demonstrate the versatility and potential societal impact of this research.

In conclusion, the journey from Keller's theory to discrete force strategy simulation not only deepened our understanding of eRallycross dynamics but also revealed avenues for broader applications in the optimisation of various transportation systems. The ongoing refinement of these models holds promise for advancing electric vehicle technologies, enhancing sustainability, and contributing to the evolution of modern transportation practices.

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8.0 Appendices

Appendix A: Naantali Run Data

Appendix B: Existing Simulink Model for eRallycross Powertrain

Appendix C: Revised Simulink Model

Appendix D: MATLAB Parallel Server CSC Documentation

Appendix E: Project Handover and User Manual for use by COMEA

Appendix F: Reflective Report

Appendix A : Naantali Run Data

time	activity type	enhanced speed	effort pace	step length	enhanced altitude	accumulated power	dist	cad	alt	hr	lon	lat	pwr	speed	speed km/h
0 days 00:00:03	running	1.808	1.808		4		0			140	22.01792222	60.4702714		1.808	6.5088
0 days 00:00:04	running	3.617	3.616		4		0			140	22.01794652	60.47026293		3.617	13.021
0 days 00:00:05	running	3.636	3.636	1140	4		6.5			140	22.01797083	60.47025438		3.636	13.09
0 days 00:00:06	running	3.656	3.655	1140	4		13		4	140	22.01800846	60.47024022		3.656	13.162
0 days 00:00:07	running	3.678	3.677	1140	4	311	17	96	4	141	22.01804627	60.47022605	311	3.678	13.241
0 days 00:00:08	running	3.7	3.699	1150	4	624	21	96	4	142	22.01809539	60.47020753	313	3.7	13.32
0 days 00:00:09	running	3.714	3.713	1150	4	939	26	96	4	142	22.01814459	60.47018901	315	3.714	13.37
0 days 00:00:10	running	3.731	3.73	1160	4	1256	30	96	4	143	22.01819991	60.47016746	317	3.731	13.432
0 days 00:00:11	running	3.731	3.73	1160	4	1574	34	96	4	144	22.01825531	60.47014592	318	3.731	13.432
0 days 00:00:12	running	3.733	3.733	1170	4	1893	38	95	4	146	22.01831298	60.47012262	319	3.733	13.439
0 days 00:00:13	running	3.722	3.722	1170	4	2212	42	95	4	146	22.01837081	60.47009932	319	3.722	13.399
0 days 00:00:14	running	3.711	3.711	1170	4	2531	46	95	4	148	22.01842857	60.47007593	319	3.711	13.36
0 days 00:00:15	running	3.814	3.813	1200	5	2849	51	95	5	149	22.01848648	60.47005263	318	3.814	13.73
0 days 00:00:16	running	3.919	3.919	1240	5	3167	55	95	5	151	22.01854331	60.47002749	318	3.919	14.108
0 days 00:00:17	running	3.975	3.975	1260	5	3493	59	94	5	152	22.01860023	60.47000242	326	3.975	14.31
0 days 00:00:18	running	4.033	4.033	1280	5	3828	63	94	5	153	22.01865756	60.46997619	335	4.033	14.519
0 days 00:00:19	running	4.064	4.063	1290	5	4168	67	94	5	154	22.01871498	60.46995004	340	4.064	14.63
0 days 00:00:20	running	4.097	4.097	1300	5	4513	71	94	5	155	22.01877281	60.46992565	345	4.097	14.749
0 days 00:00:21	running	4.108	4.302	1300	5	4861	75	94	5	155	22.01883056	60.46990134	348	4.108	14.789
0 days 00:00:22	running	4.119	4.511	1310	5	5212	79	94	5	157	22.01888739	60.46987829	351	4.119	14.828
0 days 00:00:23	running	4.117	4.402	1310	5	5581	83	94	5	158	22.01894422	60.46985541	369	4.117	14.821
0 days 00:00:24	running	4.114	4.297	1310	5	5968	87	94	5	159	22.0189987	60.46983294	387	4.114	14.81
0 days 00:00:25	running	4.106	4.291	1300	5	6345	91	94	5	160	22.01905319	60.46981039	377	4.106	14.782
0 days 00:00:26	running	4.097	4.286	1300	5	6713	94	94	5	160	22.01910457	60.46978843	368	4.097	14.749
0 days 00:00:27	running	4.075	4.169	1300	5	7080	98	94	5	160	22.01915612	60.46976656	367	4.075	14.67
0 days 00:00:28	running	4.056	4.055	1300	5	7447	102	93	5	161	22.01920599	60.46974409	367	4.056	14.602
0 days 00:00:29	running	4.031	4.03	1290	5	7804	106	93	5	161	22.01925603	60.4697218	357	4.031	14.512
0 days 00:00:30	running	4.008	4.008	1290	5	8151	109	93	5	161	22.01930833	60.4696995	347	4.008	14.429
0 days 00:00:31	running	3.981	3.98	1280	5	8496	113	93	5	161	22.01936055	60.46967721	345	3.981	14.332
0 days 00:00:32	running	3.956	3.955	1280	5	8839	117	93	5	161	22.01941453	60.46965634	343	3.956	14.242
0 days 00:00:33	running	3.928	3.927	1270	5	9180	121	93	5	162	22.01946842	60.46963538	341	3.928	14.141
0 days 00:00:34	running	3.9	3.899	1260	5	9519	124	93	5	162	22.01952199	60.46961443	339	3.9	14.04
0 days 00:00:35	running	3.886	3.886	1250	5	9855	128	93	5	162	22.01957563	60.46959355	336	3.886	13.99
0 days 00:00:36	running	3.875	3.874	1240	5	10189	132	93	5	162	22.01962919	60.46957126	334	3.875	13.95
0 days 00:00:37	running	3.872	3.872	1240	5	10522	136	93	5	163	22.01968292	60.46954905	333	3.872	13.939
0 days 00:00:38	running	3.869	3.869	1240	5	10854	140	93	5	163	22.01973631	60.46952633	332	3.869	13.928
0 days 00:00:39	running	3.861	3.861	1240	5	11185	144	93	5	164	22.0197897	60.4695037	331	3.861	13.9
0 days 00:00:40	running	3.853	3.852	1240	5	11516	148	93	5	164	22.0198441	60.46948015	331	3.853	13.871
0 days 00:00:41	running	3.847	3.847	1240	4	11846	152	92	4	164	22.0198985	60.46945651	330	3.847	13.849
0 days 00:00:42	running	3.842	3.841	1250	4	12175	156	92	4	164	22.01995399	60.4694322	329	3.842	13.831
0 days 00:00:43	running	3.833	3.833	1250	4	12504	161	92	4	164	22.02000956	60.46940806	329	3.833	13.799
0 days 00:00:44	running	3.828	3.827	1260	4	12833	165	91	4	165	22.02006371	60.46938275	329	3.828	13.781
0 days 00:00:45	running	3.828	3.827	1260	4	13161	169	91	4	165	22.02011777	60.46935752	328	3.828	13.781
0 days 00:00:46	running	3.828	3.827	1260	4	13489	172	91	4	165	22.02017066	60.46933263	328	3.828	13.781
0 days 00:00:47	running	3.828	3.827	1260	4	13817	176	91	4	165	22.02022372	60.46930773	328	3.828	13.781
0 days 00:00:48	running	3.828	3.827	1260	4	14145	180	91	4	165	22.02027493	60.46928292	328	3.828	13.781
0 days 00:00:49	running	3.822	3.822	1250	4	14473	184	91	4	165	22.02032623	60.46925811	328	3.822	13.759
0 days 00:00:50	running	3.817	3.816	1250	4	14801	187	92	4	165	22.02037627	60.46923439	328	3.817	13.741
0 days 00:00:51	running	3.817	3.816	1250	4	15128	191	91	4	165	22.02042639	60.46921084	327	3.817	13.741
0 days 00:00:52	running	3.817	3.816	1250	4	15455	194	91	4	166	22.02047719	60.46918971	327	3.817	13.741
0 days 00:00:53	running	3.808	3.808	1250	4	15782	198	91	4	166	22.02052798	60.46916876	327	3.808	13.709
0 days 00:00:54	running	3.803	3.802	1250	4	16109	202	91	4	166	22.02057978	60.46914864	327	3.803	13.691
0 days 00:00:55	running	3.803	3.802	1250	4	16435	206	91	4	166	22.02063158	60.46912861	326	3.803	13.691
0 days 00:00:56	running	3.803	3.802	1250	4	16760	209	91	4	166	22.02068439	60.46910816	325	3.803	13.691
0 days 00:00:57	running	3.803	3.802	1250	4	17085	213	91	4	167	22.02073728	60.46908762	325	3.803	13.691
0 days 00:00:58	running	3.803	3.802	1250	4	17410	217	91	4	167	22.02079142	60.46906642	325	3.803	13.691
0 days 00:00:59	running	3.789	3.788	1240	4	17735	221	91	4	167	22.02084549	60.46904529	325	3.789	13.64
0 days 00:01:00	running	3.778	3.777	1240	4	18060	225	91	4	167	22.02089846	60.46902325	325	3.778	13.601
0 days 00:01:01	running	3.778	3.777	1240	4	18384	229	91	4	167	22.02095152	60.46900121	324	3.778	13.601
0 days 00:01:02	running	3.778	3.777	1250	4	18708	232	90	4	168	22.02100189	60.46897799	324	3.778	13.601
0 days 00:01:03	running	3.758	3.758	1250	4	19032	236	90	4	168	22.02105227	60.46895494	324	3.758	13.529
0 days 00:01:04	running	3.742	3.741	1260	4	19356	239	89	4	167	22.02109879	60.46893222	324	3.742	13.471
0 days 00:01:05	running	3.742	3.741	1260	4	19678	243	89	4	168	22.02114539	60.46890951	322	3.742	13.471
0 days 00:01:06	running	3.742	3.741	1270	4	19998	246	88	4	168	22.02119216	60.46888713	320	3.742	13.471
0 days 00:01:07	running	3.742	3.741	1270	4	20318	250	88	4	168	22.02123902	60.46886483	320	3.742	13.471
0 days 00:01:08	running	3.742	3.741	1270	4	20638	254	89	4	169	22.02128747	60.46884254	320	3.742	13.471
0 days 00:01:09	running	3.708	3.708	1250	4	20958	258	89	4	169	22.02133608	60.46882032	320	3.708	13.349
0 days 00:01:10	running	3.675	3.674	1230	4	21278	261	90	4	169	22.0213852	60.46879853	320	3.675	13.23
0 days 00:01:11	running	3.675	3.674	1220	4	21595	265	90	4	169	22.0214344	60.46877682	317	3.675	13.23

0 days 00:01:12	running	3.675	3.674	1220	4	21910	268	90	4	169	22.02148461	60.46875486	315	3.675	13.23
0 days 00:01:13	running	3.664	3.663	1210	4	22225	272	90	4	169	22.02153482	60.46873282	315	3.664	13.19
0 days 00:01:14	running	3.656	3.655	1210	4	22540	275	90	4	169	22.02158377	60.46871069	315	3.656	13.162
0 days 00:01:15	running	3.656	3.655	1210	4	22854	279	90	4	169	22.0216328	60.46868864	314	3.656	13.162
0 days 00:01:16	running	3.656	3.655	1210	4	23167	282	90	4	169	22.02168351	60.46866811	313	3.656	13.162
0 days 00:01:17	running	3.656	3.655	1220	4	23480	286	90	4	169	22.0217343	60.46864766	313	3.656	13.162
0 days 00:01:18	running	3.656	3.655	1230	4	23793	289	89	4	170	22.02178443	60.46862821	313	3.656	13.162
0 days 00:01:19	running	3.656	3.655	1230	4	24106	293	89	4	170	22.02183447	60.46860893	313	3.656	13.162
0 days 00:01:20	running	3.656	3.655	1230	4	24419	297	89	4	169	22.02188451	60.46858831	313	3.656	13.162
0 days 00:01:21	running	3.656	3.655	1220	3	24732	301	89	3	170	22.02193446	60.46856769	313	3.656	13.162
0 days 00:01:22	running	3.656	3.655	1220	3	25045	304	90	3	170	22.02198341	60.46854624	313	3.656	13.162
0 days 00:01:23	running	3.647	3.647	1210	3	25358	307	90	3	170	22.02203228	60.46852469	313	3.647	13.129
0 days 00:01:24	running	3.642	3.641	1210	3	25671	310	90	3	170	22.02207897	60.46850424	313	3.642	13.111
0 days 00:01:25	running	3.642	3.641	1210	3	25983	314	90	3	170	22.02212566	60.46848371	312	3.642	13.111
0 days 00:01:26	running	3.642	3.641	1210	3	26295	318	91	3	170	22.02217226	60.46846359	312	3.642	13.111
0 days 00:01:27	running	3.642	3.641	1200	3	26607	322	91	3	170	22.02221903	60.46844356	312	3.642	13.111
0 days 00:01:28	running	3.642	3.641	1200	3	26919	325	91	3	170	22.02226882	60.46842302	312	3.642	13.111
0 days 00:01:29	running	3.642	3.641	1200	3	27231	329	90	3	170	22.02231869	60.46840265	312	3.642	13.111
0 days 00:01:30	running	3.642	3.641	1200	4	27543	332	90	4	171	22.02236932	60.46838245	312	3.642	13.111
0 days 00:01:31	running	3.642	3.641	1200	4	27855	335	90	4	171	22.02242003	60.46836225	312	3.642	13.111
0 days 00:01:32	running	3.642	3.641	1210	4	28167	338	90	4	170	22.02246898	60.46834214	312	3.642	13.111
0 days 00:01:33	running	3.642	3.641	1210	4	28479	341	90	4	171	22.02251801	60.4683221	312	3.642	13.111
0 days 00:01:34	running	3.644	3.644	1220	4	28791	344	89	4	171	22.02256411	60.46830408	312	3.644	13.118
0 days 00:01:35	running	3.644	3.724	1220	4	29103	348	88	4	171	22.02261021	60.46828615	312	3.644	13.118
0 days 00:01:36	running	3.644	3.805	1230	4	29415	351	88	4	171	22.0226543	60.46826871	312	3.644	13.118
0 days 00:01:37	running	3.644	3.805	1230	4	29734	354	88	4	171	22.02269839	60.46825144	319	3.644	13.118
0 days 00:01:38	running	3.644	3.805	1240	4	30060	357	88	4	170	22.0227434	60.46823326	326	3.644	13.118
0 days 00:01:39	running	3.619	3.869	1230	4	30386	361	88	4	171	22.0227885	60.46821498	326	3.619	13.028
0 days 00:01:40	running	3.594	3.933	1220	4	30712	364	89	4	171	22.0228346	60.46819663	326	3.594	12.938
0 days 00:01:41	running	3.594	3.933	1210	4	31043	368	89	4	171	22.0228807	60.46817819	331	3.594	12.938
0 days 00:01:42	running	3.594	3.933	1200	4	31380	372	90	4	171	22.02292755	60.46815765	337	3.594	12.938
0 days 00:01:43	running	3.578	4.011	1180	4	31717	376	91	4	171	22.02297457	60.46813712	337	3.578	12.881
0 days 00:01:44	running	3.564	4.091	1160	4	32054	379	92	4	171	22.02302168	60.46811356	337	3.564	12.83
0 days 00:01:45	running	3.553	4.08	1160	4	32397	383	92	4	171	22.02306887	60.46809001	343	3.553	12.791
0 days 00:01:46	running	3.542	4.069	1160	4	32747	387	92	4	171	22.02311807	60.46806562	350	3.542	12.751
0 days 00:01:47	running	3.558	4.091	1160	4	33096	392	91	4	171	22.02316736	60.46804131	349	3.558	12.809
0 days 00:01:48	running	3.575	4.113	1170	4	33444	396	91	4	171	22.02322117	60.46801608	348	3.575	12.87
0 days 00:01:49	running	3.581	4.022	1170	4	33794	399	91	4	171	22.02327507	60.46799093	350	3.581	12.892
0 days 00:01:50	running	3.586	3.933	1180	5	34146	402	91	5	172	22.02332829	60.46796721	352	3.586	12.91
0 days 00:01:51	running	3.586	3.933	1180	5	34490	406	91	5	172	22.0233816	60.46794349	344	3.586	12.91
0 days 00:01:52	running	3.589	3.933	1180	5	34827	409	91	5	172	22.02343156	60.46792304	337	3.589	12.92
0 days 00:01:53	running	3.589	3.841	1180	5	35164	413	90	5	172	22.0234816	60.46790251	337	3.589	12.92
0 days 00:01:54	running	3.589	3.752	1190	5	35501	416	90	5	172	22.02353172	60.46788272	337	3.589	12.92
0 days 00:01:55	running	3.589	3.669	1180	5	35830	420	90	5	171	22.02358176	60.46786294	329	3.589	12.92
0 days 00:01:56	running	3.589	3.588	1180	4	36152	424	91	4	171	22.02363255	60.46784274	322	3.589	12.92
0 days 00:01:57	running	3.589	3.588	1180	4	36466	428	91	4	172	22.02368352	60.46782254	314	3.589	12.92
0 days 00:01:58	running	3.589	3.588	1180	4	36773	432	91	4	172	22.02373297	60.46780016	307	3.589	12.92
0 days 00:01:59	running	3.592	3.591	1180	4	37080	436	91	4	172	22.02378259	60.4677777	307	3.592	12.931
0 days 00:02:00	running	3.594	3.594	1190	4	37387	440	91	4	172	22.02383439	60.46775239	307	3.594	12.938
0 days 00:02:01	running	3.594	3.516	1190	4	37694	444	90	4	172	22.02388627	60.46772724	307	3.594	12.938
0 days 00:02:02	running	3.594	3.441	1190	4	38001	448	90	4	172	22.02393992	60.46770243	307	3.594	12.938
0 days 00:02:03	running	3.594	3.441	1190	4	38301	452	90	4	171	22.02399348	60.4676777	300	3.594	12.938
0 days 00:02:04	running	3.594	3.441	1190	4	38595	455	90	4	172	22.02404486	60.46765465	294	3.594	12.938
0 days 00:02:05	running	3.594	3.374	1190	4	38889	459	90	4	172	22.02409633	60.4676316	294	3.594	12.938
0 days 00:02:06	running	3.594	3.308	1190	4	39183	462	90	4	173	22.02414561	60.46760973	294	3.594	12.938
0 days 00:02:07	running	3.594	3.308	1190	4	39470	465	90	4	172	22.0241949	60.46758793	287	3.594	12.938
0 days 00:02:08	running	3.594	3.308	1200	4	39751	468	90	4	172	22.02424519	60.46757075	281	3.594	12.938
0 days 00:02:09	running	3.589	3.369	1200	4	40032	472	89	4	173	22.02429556	60.46755365	281	3.589	12.92
0 days 00:02:10	running	3.583	3.433	1200	4	40313	475	89	4	172	22.02435046	60.46755013	281	3.583	12.899
0 days 00:02:11	running	3.583	3.433	1200	4	40600	479	89	4	173	22.02440537	60.46754661	287	3.583	12.899
0 days 00:02:12	running	3.583	3.433	1210	4	40893	482	89	4	172	22.02446161	60.46755524	293	3.583	12.899
0 days 00:02:13	running	3.583	3.508	1210	4	41186	487	88	4	172	22.02451785	60.46756396	293	3.583	12.899
0 days 00:02:14	running	3.583	3.583	1220	4	41479	491	88	4	172	22.02457393	60.46758316	293	3.583	12.899
0 days 00:02:15	running	3.561	3.561	1200	5	41778	495	88	5	173	22.02462992	60.46760235	299	3.561	12.82
0 days 00:02:16	running	3.542	3.541	1190	5	42084	498	89	5	173	22.02468222	60.46762833	306	3.542	12.751
0 days 00:02:17	running	3.542	3.619	1190	5	42388	502	89	5	174	22.02473452	60.4676544	304	3.542	12.751
0 days 00:02:18	running	3.542	3.699	1190	5	42691	506	89	5	173	22.02478356	60.46768131	303	3.542	12.751
0 days 00:02:19	running	3.531	3.777	1180	5	43001	510	89	5	173	22.02483276	60.4677083	310	3.531	12.712
0 days 00:02:20	running	3.519	3.855	1170	5	43318	514	90	5	174	22.02488045	60.46773545	317	3.519	12.668
0 days 00:02:21	running	3.556	3.894	1170	5	43641	518	91	5	173	22.02492831	60.46776253	323	3.556	12.802
0 days 00:02:22	running	3.592	3.933	1180	5	43971	521	91	5	173	22.02497383	60.46778952	330	3.592	12.931

0 days 00:02:23	running	3.614	4.058	1180	5	44304	525	91	5	173	22.02501926	60.46781659	333	3.614	13.01
0 days 00:02:24	running	3.639	4.183	1190	5	44641	528	92	5	174	22.02505966	60.46784383	337	3.639	13.1
0 days 00:02:25	running	3.664	4.211	1200	5	44988	532	91	5	174	22.02510023	60.46787099	347	3.664	13.19
0 days 00:02:26	running	3.689	4.241	1210	5	45346	536	91	5	174	22.02513811	60.46789823	358	3.689	13.28
0 days 00:02:27	running	3.686	4.241	1220	5	45706	540	90	5	173	22.02517608	60.46792556	360	3.686	13.27
0 days 00:02:28	running	3.686	4.241	1240	5	46069	543	89	5	174	22.02521321	60.46795263	363	3.686	13.27
0 days 00:02:29	running	3.669	4.222	1230	5	46432	547	89	5	174	22.02525043	60.4679797	363	3.669	13.208
0 days 00:02:30	running	3.656	4.205	1230	6	46795	550	89	6	174	22.02528706	60.46800661	363	3.656	13.162
0 days 00:02:31	running	3.656	4.205	1230	6	47156	554	88	6	174	22.02532377	60.46803351	361	3.656	13.162
0 days 00:02:32	running	3.656	4.205	1240	6	47516	558	88	6	174	22.02536166	60.46806109	360	3.656	13.162
0 days 00:02:33	running	3.656	4.311	1230	6	47876	562	89	6	173	22.02539963	60.46808875	360	3.656	13.162
0 days 00:02:34	running	3.656	4.419	1230	6	48236	566	89	6	174	22.02544053	60.46811591	360	3.656	13.162
0 days 00:02:35	running	3.653	4.413	1210	7	48604	570	90	7	174	22.02548152	60.46814315	368	3.653	13.151
0 days 00:02:36	running	3.65	4.408	1200	7	48981	573	91	7	175	22.02552502	60.46816846	377	3.65	13.14
0 days 00:02:37	running	3.65	4.299	1190	7	49357	577	91	7	175	22.02556861	60.46819386	376	3.65	13.14
0 days 00:02:38	running	3.65	4.194	1180	7	49733	580	92	7	175	22.0256132	60.46821834	376	3.65	13.14
0 days 00:02:39	running	3.65	4.194	1180	7	50100	584	92	7	175	22.02565779	60.46824281	367	3.65	13.14
0 days 00:02:40	running	3.65	4.194	1180	7	50459	588	92	7	175	22.02570012	60.46826905	359	3.65	13.14
0 days 00:02:41	running	3.669	4.116	1190	7	50818	592	92	7	175	22.02574236	60.4682952	359	3.669	13.208
0 days 00:02:42	running	3.689	4.041	1200	7	51177	595	92	7	175	22.0257836	60.46832219	359	3.689	13.28
0 days 00:02:43	running	3.689	4.041	1210	7	51529	599	91	7	175	22.02582492	60.46834926	352	3.689	13.28
0 days 00:02:44	running	3.689	4.041	1220	7	51875	602	91	7	175	22.02586507	60.4683755	346	3.689	13.28
0 days 00:02:45	running	3.7	4.052	1230	7	52221	606	90	7	175	22.02590539	60.4684019	346	3.7	13.32
0 days 00:02:46	running	3.711	4.063	1240	7	52567	610	90	7	175	22.02594663	60.46842713	346	3.711	13.36
0 days 00:02:47	running	3.711	3.969	1240	7	52914	613	89	7	175	22.02598779	60.46845244	347	3.711	13.36
0 days 00:02:48	running	3.711	3.877	1240	7	53262	616	89	7	176	22.02602961	60.46847641	348	3.711	13.36
0 days 00:02:49	running	3.711	3.877	1240	7	53602	620	89	7	176	22.02607135	60.46850055	340	3.711	13.36
0 days 00:02:50	running	3.711	3.877	1250	8	53934	624	89	8	175	22.0261136	60.4685236	332	3.711	13.36
0 days 00:02:51	running	3.692	3.775	1250	8	54266	628	88	8	175	22.02615593	60.46854674	332	3.692	13.291
0 days 00:02:52	running	3.675	3.674	1250	8	54598	631	88	8	175	22.02619926	60.46857021	332	3.675	13.23
0 days 00:02:53	running	3.675	3.674	1250	8	54921	635	87	8	175	22.02624268	60.46859385	323	3.675	13.23
0 days 00:02:54	running	3.675	3.674	1260	8	55236	638	87	8	176	22.02628786	60.46861832	315	3.675	13.23
0 days 00:02:55	running	3.642	3.641	1240	8	55551	642	87	8	176	22.0263332	60.46864296	315	3.642	13.111
0 days 00:02:56	running	3.611	3.611	1230	8	55866	646	88	8	176	22.0263809	60.46866685	315	3.611	13
0 days 00:02:57	running	3.611	3.611	1230	8	56178	650	87	8	175	22.02642859	60.46869074	312	3.611	13
0 days 00:02:58	running	3.611	3.611	1240	8	56487	653	87	8	175	22.0264824	60.46871203	309	3.611	13
0 days 00:02:59	running	3.611	3.611	1230	8	56796	657	88	8	175	22.02653621	60.46873332	309	3.611	13
0 days 00:03:00	running	3.611	3.611	1220	8	57105	661	88	8	175	22.02659489	60.46875	309	3.611	13
0 days 00:03:01	running	3.592	3.591	1210	8	57414	665	89	8	176	22.02665356	60.46876685	309	3.592	12.931
0 days 00:03:02	running	3.572	3.572	1200	8	57723	668	89	8	176	22.02671399	60.46878311	309	3.572	12.859
0 days 00:03:03	running	3.572	3.572	1200	8	58030	672	89	8	176	22.02677451	60.46879954	307	3.572	12.859
0 days 00:03:04	running	3.572	3.572	1200	8	58336	675	89	8	175	22.026831	60.46881722	306	3.572	12.859
0 days 00:03:05	running	3.578	3.577	1200	8	58642	679	89	8	175	22.02688758	60.46883499	306	3.578	12.881
0 days 00:03:06	running	3.586	3.586	1200	8	58948	682	89	8	176	22.02693536	60.46885511	306	3.586	12.91
0 days 00:03:07	running	3.586	3.586	1200	8	59254	686	89	8	176	22.02698322	60.46887523	306	3.586	12.91
0 days 00:03:08	running	3.586	3.586	1200	8	59561	689	89	8	176	22.0270258	60.46889844	307	3.586	12.91
0 days 00:03:09	running	3.586	3.586	1210	8	59868	693	89	8	176	22.02706846	60.46892166	307	3.586	12.91
0 days 00:03:10	running	3.586	3.586	1220	8	60175	697	88	8	176	22.0271097	60.4689479	307	3.586	12.91
0 days 00:03:11	running	3.592	3.591	1210	8	60482	701	89	8	176	22.02715086	60.46897422	307	3.592	12.931
0 days 00:03:12	running	3.597	3.597	1210	8	60789	705	89	8	175	22.02719243	60.46900162	307	3.597	12.949
0 days 00:03:13	running	3.597	3.597	1210	8	61096	708	89	8	175	22.02723401	60.46902903	307	3.597	12.949
0 days 00:03:14	running	3.597	3.597	1210	8	61404	711	89	8	175	22.02727533	60.4690551	308	3.597	12.949
0 days 00:03:15	running	3.603	3.602	1210	8	61712	715	89	8	175	22.02731665	60.46908125	308	3.603	12.971
0 days 00:03:16	running	3.608	3.608	1220	8	62020	718	89	8	175	22.02735638	60.46910606	308	3.608	12.989
0 days 00:03:17	running	3.608	3.608	1210	8	62328	722	89	8	176	22.0273962	60.46913079	308	3.608	12.989
0 days 00:03:18	running	3.608	3.608	1210	8	62637	726	89	8	176	22.02743509	60.46915585	309	3.608	12.989
0 days 00:03:19	running	3.608	3.608	1200	8	62946	730	90	8	175	22.02747398	60.46918083	309	3.608	12.989
0 days 00:03:20	running	3.608	3.608	1190	8	63255	734	91	8	176	22.02751229	60.46920765	309	3.608	12.989
0 days 00:03:21	running	3.614	3.613	1190	7	63564	738	91	7	176	22.02755067	60.46923439	309	3.614	13.01
0 days 00:03:22	running	3.622	3.622	1190	7	63873	742	91	7	176	22.02759015	60.46926356	309	3.622	13.039
0 days 00:03:23	running	3.622	3.622	1190	7	64182	746	91	7	176	22.0276298	60.46929273	309	3.622	13.039
0 days 00:03:24	running	3.622	3.622	1190	7	64492	750	91	7	175	22.0276702	60.46932274	310	3.622	13.039
0 days 00:03:25	running	3.644	3.644	1200	7	64802	754	91	7	175	22.0277106	60.46935283	310	3.644	13.118
0 days 00:03:26	running	3.669	3.669	1210	7	65112	757	91	7	176	22.0277505	60.46938258	310	3.669	13.208
0 days 00:03:27	running	3.669	3.669	1210	7	65424	761	91	7	176	22.02779048	60.46941242	312	3.669	13.208
0 days 00:03:28	running	3.669	3.669	1210	7	65738	765	91	7	176	22.02782862	60.46944042	314	3.669	13.208
0 days 00:03:29	running	3.669	3.669	1210	7	66052	769	91	7	176	22.02786676	60.4694685	314	3.669	13.208
0 days 00:03:30	running	3.669	3.669	1210	7	66366	772	91	7	176	22.0279054	60.46949683	314	3.669	13.208
0 days 00:03:31	running	3.686	3.608	1220	7	66680	776	90	7	176	22.02794395	60.46952524	314	3.686	13.27
0 days 00:03:32	running	3.703	3.547	1230	7	66994	780	90	7	176	22.02798628	60.46955374	314	3.703	13.331
0 days 00:03:33	running	3.703	3.547	1220	7	67302	784	91	7	176	22.02802869	60.46958232	308	3.703	13.331

Appendix A : Naantali Run Data

0 days 00:03:34	running	3.703	3.547	1220	7	67605	787	91	7	176	22.02807002	60.46960931	303	3.703	13.331
0 days 00:03:35	running	3.717	3.638	1220	7	67908	791	91	7	176	22.02811126	60.46963639	303	3.717	13.381
0 days 00:03:36	running	3.731	3.73	1220	7	68211	795	91	7	176	22.02815132	60.46966262	303	3.731	13.432
0 days 00:03:37	running	3.731	3.73	1220	7	68522	799	91	7	176	22.0281913	60.46968886	311	3.731	13.432
0 days 00:03:38	running	3.731	3.73	1220	7	68841	802	92	7	177	22.02823028	60.46971492	319	3.731	13.432
0 days 00:03:39	running	3.731	3.73	1220	7	69160	806	91	7	176	22.02826942	60.46974099	319	3.731	13.432
0 days 00:03:40	running	3.731	3.73	1220	7	69479	809	91	7	176	22.02830949	60.46976656	319	3.731	13.432
0 days 00:03:41	running	3.742	3.741	1220	7	69798	813	91	7	176	22.02834955	60.46979212	319	3.742	13.471
0 days 00:03:42	running	3.756	3.755	1230	7	70117	816	90	7	176	22.02838928	60.4698166	319	3.756	13.522
0 days 00:03:43	running	3.756	3.936	1240	7	70437	820	90	7	177	22.0284291	60.46984124	320	3.756	13.522
0 days 00:03:44	running	3.756	4.119	1250	7	70759	823	90	7	177	22.02846816	60.46986572	322	3.756	13.522
0 days 00:03:45	running	3.747	4.108	1240	7	71096	827	90	7	177	22.02850739	60.46989019	337	3.747	13.489
0 days 00:03:46	running	3.742	4.097	1240	7	71449	830	91	7	176	22.02854536	60.46991542	353	3.742	13.471
0 days 00:03:47	running	3.742	4.197	1230	7	71801	834	91	7	176	22.02858349	60.46994073	352	3.742	13.471
0 days 00:03:48	running	3.742	4.297	1230	7	72152	837	91	7	176	22.02862171	60.46996554	351	3.742	13.471
0 days 00:03:49	running	3.742	4.297	1230	7	72511	841	91	7	176	22.02866002	60.46999035	359	3.742	13.471
0 days 00:03:50	running	3.742	4.297	1230	8	72878	845	91	8	176	22.02869916	60.47001642	367	3.742	13.471
0 days 00:03:51	running	3.736	4.291	1220	8	73245	849	92	8	176	22.02873839	60.47004249	367	3.736	13.45
0 days 00:03:52	running	3.733	4.286	1210	8	73612	852	92	8	176	22.02877879	60.4700699	367	3.733	13.439
0 days 00:03:53	running	3.733	4.286	1210	8	73978	856	92	8	177	22.02881919	60.47009739	366	3.733	13.439
0 days 00:03:54	running	3.733	4.286	1220	8	74344	859	91	8	177	22.02885926	60.47012438	366	3.733	13.439
0 days 00:03:55	running	3.736	4.291	1230	8	74710	863	91	8	176	22.02889949	60.47015145	366	3.736	13.45
0 days 00:03:56	running	3.739	4.297	1240	8	75076	866	90	8	176	22.02893889	60.47017769	366	3.739	13.46
0 days 00:03:57	running	3.739	4.197	1240	8	75442	870	90	8	176	22.02897836	60.47020401	366	3.739	13.46
0 days 00:03:58	running	3.739	4.097	1250	8	75809	874	90	8	176	22.02901793	60.47023024	367	3.739	13.46
0 days 00:03:59	running	3.739	4.002	1250	8	76168	878	90	8	176	22.02905749	60.47025656	359	3.739	13.46
0 days 00:04:00	running	3.739	3.911	1250	8	76519	881	90	8	176	22.02909831	60.47028305	351	3.739	13.46
0 days 00:04:01	running	3.725	3.811	1240	8	76862	885	90	8	176	22.02913913	60.47030954	343	3.725	13.41
0 days 00:04:02	running	3.711	3.711	1240	8	77197	889	90	8	176	22.02918263	60.47033594	335	3.711	13.36
0 days 00:04:03	running	3.711	3.711	1240	8	77523	893	89	8	176	22.02922605	60.47036234	326	3.711	13.36
0 days 00:04:04	running	3.711	3.711	1240	8	77841	897	89	8	175	22.02927081	60.47038883	318	3.711	13.36
0 days 00:04:05	running	3.7	3.699	1240	8	78159	901	89	8	175	22.02931548	60.4704154	318	3.7	13.32
0 days 00:04:06	running	3.689	3.688	1240	8	78477	905	89	8	175	22.02935915	60.47044155	318	3.689	13.28
0 days 00:04:07	running	3.689	3.688	1230	8	78794	909	89	8	176	22.02940299	60.47046762	317	3.689	13.28
0 days 00:04:08	running	3.689	3.688	1230	8	79110	912	90	8	176	22.02944482	60.47049419	316	3.689	13.28
0 days 00:04:09	running	3.689	3.688	1230	8	79426	916	90	8	176	22.02948656	60.47052093	316	3.689	13.28
0 days 00:04:10	running	3.689	3.688	1230	8	79742	919	90	8	175	22.02952621	60.4705485	316	3.689	13.28
0 days 00:04:11	running	3.683	3.683	1220	8	80058	923	90	8	175	22.02956585	60.47057608	316	3.683	13.259
0 days 00:04:12	running	3.678	3.677	1220	8	80374	927	91	8	175	22.02960491	60.47060399	316	3.678	13.241
0 days 00:04:13	running	3.678	3.677	1210	8	80689	931	91	8	175	22.02964389	60.47063199	315	3.678	13.241
0 days 00:04:14	running	3.678	3.677	1210	8	81004	934	92	8	175	22.02968303	60.47065864	315	3.678	13.241
0 days 00:04:15	running	3.689	3.688	1200	8	81319	938	92	8	175	22.02972209	60.47068521	315	3.689	13.28
0 days 00:04:16	running	3.7	3.699	1200	8	81634	941	93	8	175	22.02976073	60.47071153	315	3.7	13.32
0 days 00:04:17	running	3.7	3.699	1190	8	81950	944	93	8	175	22.02979937	60.47073794	316	3.7	13.32
0 days 00:04:18	running	3.7	3.699	1180	8	82267	947	94	8	175	22.02983642	60.47076283	317	3.7	13.32
0 days 00:04:19	running	3.7	3.622	1170	8	82584	950	94	8	175	22.02987338	60.47078781	317	3.7	13.32
0 days 00:04:20	running	3.7	3.547	1170	8	82901	953	95	8	175	22.02990792	60.47081119	317	3.7	13.32
0 days 00:04:21	running	3.733	3.58	1180	8	83211	957	94	8	175	22.02994237	60.47083475	310	3.733	13.439
0 days 00:04:22	running	3.767	3.613	1200	8	83514	961	94	8	175	22.02997631	60.47085964	303	3.767	13.561
0 days 00:04:23	running	3.767	3.613	1200	8	83819	965	94	8	174	22.03001018	60.47088462	305	3.767	13.561
0 days 00:04:24	running	3.767	3.613	1200	8	84127	968	94	8	175	22.03004597	60.47091161	308	3.767	13.561
0 days 00:04:25	running	3.786	3.633	1220	8	84435	972	93	8	174	22.03008193	60.47093868	308	3.786	13.63
0 days 00:04:26	running	3.808	3.652	1240	8	84743	975	92	8	174	22.03011939	60.47096534	308	3.808	13.709
0 days 00:04:27	running	3.808	3.652	1230	8	85053	979	93	8	175	22.03015703	60.47099191	310	3.808	13.709
0 days 00:04:28	running	3.808	3.652	1220	8	85365	982	93	8	175	22.03019299	60.47101789	312	3.808	13.709
0 days 00:04:29	running	3.808	3.652	1210	8	85677	986	94	8	175	22.03022903	60.47104404	312	3.808	13.709
0 days 00:04:30	running	3.808	3.652	1200	8	85989	990	95	8	174	22.03026482	60.47107179	312	3.808	13.709
0 days 00:04:31	running	3.814	3.736	1200	7	86301	994	95	7	175	22.03030061	60.4710997	312	3.814	13.73
0 days 00:04:32	running	3.819	3.819	1210	7	86613	997	95	7	175	22.03033699	60.47112803	312	3.819	13.748
0 days 00:04:33	running	3.819	3.819	1190	7	86932	###	96	7	175	22.03037336	60.47115636	319	3.819	13.748
0 days 00:04:34	running	3.819	3.819	1180	7	87259	###	97	7	175	22.03041125	60.47118343	327	3.819	13.748
0 days 00:04:35	running	3.839	3.838	1200	7	87586	###	95	7	174	22.03044922	60.47121059	327	3.839	13.82
0 days 00:04:36	running	3.861	3.861	1230	7	87913	###	94	7	175	22.03049021	60.47123683	327	3.861	13.9
0 days 00:04:37	running	3.861	3.861	1240	7	88241	###	93	7	175	22.0305312	60.47126306	328	3.861	13.9
0 days 00:04:38	running	3.861	3.861	1250	7	88571	###	93	7	176	22.03057369	60.47128913	330	3.861	13.9
0 days 00:04:39	running	3.861	3.861	1260	7	88901	###	92	7	175	22.03061619	60.47131528	330	3.861	13.9
0 days 00:04:40	running	3.861	3.861	1270	7	89231	###	91	7	176	22.03065936	60.47134135	330	3.861	13.9
0 days 00:04:41	running	3.844	3.844	1270	7	89561	###	90	7	175	22.03070261	60.47136742	330	3.844	13.838
0 days 00:04:42	running	3.831	3.83	1280	7	89891	###	90	7	176	22.03074351	60.47139206	330	3.831	13.792
0 days 00:04:43	running	3.831	3.916	1280	7	90220	###	90	7	175	22.03078441	60.4714167	329	3.831	13.792
0 days 00:04:44	running	3.831	4.005	1280	7	90548	###	90	7	176	22.03082389	60.47144051	328	3.831	13.792

Appendix A : Naantali Run Data

0 days 00:04:45	running	3.786	4.049	1250	7	90883	###	90	7	175	22.03086337	60.47146431	335	3.786	13.63
0 days 00:04:46	running	3.744	4.097	1230	7	91226	###	91	7	175	22.03090411	60.47148828	343	3.744	13.478
0 days 00:04:47	running	3.733	4.091	1220	7	91573	###	91	7	175	22.03094493	60.47151242	347	3.733	13.439
0 days 00:04:48	running	3.725	4.086	1210	7	91924	###	92	7	176	22.03098742	60.47153581	351	3.725	13.41
0 days 00:04:49	running	3.683	4.133	1200	7	92274	###	91	7	176	22.03103	60.47155936	350	3.683	13.259
0 days 00:04:50	running	3.642	4.183	1190	8	92624	###	91	8	176	22.03107376	60.47158216	350	3.642	13.111
0 days 00:04:51	running	3.625	4.269	1190	8	92978	###	90	8	176	22.03111759	60.47160496	354	3.625	13.05
0 days 00:04:52	running	3.611	4.358	1200	8	93336	###	90	8	175	22.03116118	60.47162784	358	3.611	13
0 days 00:04:53	running	3.589	4.333	1190	8	93700	###	90	8	176	22.03120477	60.47165081	364	3.589	12.92
0 days 00:04:54	running	3.569	4.311	1190	8	94071	###	90	8	176	22.03124668	60.47167503	371	3.569	12.848
0 days 00:04:55	running	3.561	4.416	1180	9	94440	###	90	9	176	22.03128867	60.47169934	369	3.561	12.82
0 days 00:04:56	running	3.556	4.522	1180	9	94807	###	90	9	176	22.03132982	60.4717244	367	3.556	12.802
0 days 00:04:57	running	3.553	4.513	1180	9	95182	###	90	9	175	22.03137098	60.47174955	375	3.553	12.791
0 days 00:04:58	running	3.55	4.508	1180	9	95566	###	90	9	175	22.03141322	60.47177369	384	3.55	12.78
0 days 00:04:59	running	3.55	4.627	1180	9	95949	###	90	9	175	22.03145538	60.471798	383	3.55	12.78
0 days 00:05:00	running	3.55	4.747	1180	9	96331	###	90	9	175	22.03149771	60.47182012	382	3.55	12.78
0 days 00:05:01	running	3.55	4.627	1180	9	96722	###	90	9	175	22.03154013	60.47184225	391	3.55	12.78
0 days 00:05:02	running	3.55	4.508	1180	9	97122	###	90	9	175	22.0315817	60.4718648	400	3.55	12.78
0 days 00:05:03	running	3.544	4.502	1180	9	97513	###	90	9	175	22.03162336	60.47188751	391	3.544	12.758
0 days 00:05:04	running	3.542	4.497	1180	9	97895	###	90	9	176	22.03166535	60.47191174	382	3.542	12.751
0 days 00:05:05	running	3.542	4.386	1170	10	98276	###	90	10	176	22.03170743	60.47193605	381	3.542	12.751
0 days 00:05:06	running	3.542	4.275	1160	10	98657	###	91	10	176	22.03174858	60.47195935	381	3.542	12.751
0 days 00:05:07	running	3.544	4.28	1160	10	99029	###	91	10	175	22.03178991	60.47198273	372	3.544	12.758
0 days 00:05:08	running	3.547	4.286	1160	10	99393	###	91	10	175	22.03183182	60.47200562	364	3.547	12.769
0 days 00:05:09	running	3.547	4.183	1160	10	99757	###	91	10	175	22.03187373	60.4720285	364	3.547	12.769
0 days 00:05:10	running	3.547	4.08	1170	11	100122	###	91	11	176	22.03191631	60.47205239	365	3.547	12.769
0 days 00:05:11	running	3.547	3.983	1170	11	100479	###	91	11	175	22.03195897	60.47207644	357	3.547	12.769
0 days 00:05:12	running	3.547	3.888	1170	11	100828	###	91	11	175	22.03200247	60.47210201	349	3.547	12.769
0 days 00:05:13	running	3.556	3.899	1160	11	101169	###	91	11	175	22.03204606	60.47212766	341	3.556	12.802
0 days 00:05:14	running	3.567	3.911	1160	11	101502	###	92	11	175	22.03209199	60.47215372	333	3.567	12.841
0 days 00:05:15	running	3.567	3.911	1160	11	101836	###	92	11	176	22.03213792	60.47217979	334	3.567	12.841
0 days 00:05:16	running	3.567	3.911	1160	11	102171	###	92	11	176	22.03218461	60.47220561	335	3.567	12.841
0 days 00:05:17	running	3.581	3.83	1170	11	102506	###	91	11	176	22.03223138	60.47223151	335	3.581	12.892
0 days 00:05:18	running	3.594	3.752	1180	11	102841	###	91	11	175	22.03227815	60.47225732	335	3.594	12.938
0 days 00:05:19	running	3.594	3.752	1170	11	103169	###	91	11	175	22.03232501	60.47228322	328	3.594	12.938
0 days 00:05:20	running	3.594	3.752	1170	11	103491	###	92	11	175	22.03237136	60.4723087	322	3.594	12.938
0 days 00:05:21	running	3.594	3.752	1170	11	103813	###	91	11	176	22.03241779	60.47233435	322	3.594	12.938
0 days 00:05:22	running	3.594	3.752	1180	11	104135	###	91	11	176	22.03246239	60.47235975	322	3.594	12.938
0 days 00:05:23	running	3.606	3.686	1180	11	104457	###	91	11	175	22.03250698	60.47238523	322	3.606	12.982
0 days 00:05:24	running	3.619	3.619	1190	11	104779	###	91	11	175	22.03255107	60.47241239	322	3.619	13.028
0 days 00:05:25	running	3.619	3.619	1180	11	105095	###	91	11	175	22.03259532	60.47243963	316	3.619	13.028
0 days 00:05:26	running	3.619	3.619	1180	11	105405	###	92	11	176	22.03263983	60.47246779	310	3.619	13.028
0 days 00:05:27	running	3.633	3.633	1190	11	105715	###	91	11	176	22.03268426	60.47249604	310	3.633	13.079
0 days 00:05:28	running	3.647	3.647	1200	11	106025	###	91	11	175	22.03273027	60.47252261	310	3.647	13.129
0 days 00:05:29	running	3.647	3.647	1200	11	106336	###	90	11	175	22.03277637	60.47254918	311	3.647	13.129
0 days 00:05:30	running	3.647	3.647	1210	11	106648	###	90	11	175	22.03282423	60.47257466	312	3.647	13.129
0 days 00:05:31	running	3.647	3.572	1210	11	106960	###	90	11	176	22.03287201	60.47260014	312	3.647	13.129
0 days 00:05:32	running	3.647	3.5	1220	11	107272	###	90	11	176	22.03292146	60.47262579	312	3.647	13.129
0 days 00:05:33	running	3.642	3.427	1210	11	107577	###	90	11	175	22.03297108	60.47265152	305	3.642	13.111
0 days 00:05:34	running	3.636	3.355	1210	11	107875	###	90	11	175	22.03301953	60.47267742	298	3.636	13.09
0 days 00:05:35	running	3.636	3.294	1210	11	108166	###	90	11	175	22.03306798	60.47270332	291	3.636	13.09
0 days 00:05:36	running	3.636	3.233	1210	10	108451	###	90	10	176	22.03310947	60.47272981	285	3.636	13.09
0 days 00:05:37	running	3.633	3.177	1200	10	108729	###	90	10	176	22.03315113	60.47275638	278	3.633	13.079
0 days 00:05:38	running	3.631	3.122	1200	10	109001	###	91	10	176	22.03318072	60.47278471	272	3.631	13.072
0 days 00:05:39	running	3.631	3.077	1200	10	109267	###	91	10	175	22.03321039	60.47281313	266	3.631	13.072
0 days 00:05:40	running	3.631	3.033	1200	10	109527	###	91	10	175	22.03323117	60.47284288	260	3.631	13.072
0 days 00:05:41	running	3.631	3.033	1190	9	109781	###	91	9	176	22.03325213	60.47287281	254	3.631	13.072
0 days 00:05:42	running	3.631	3.033	1190	9	110030	###	91	9	175	22.0332792	60.47290214	249	3.631	13.072
0 days 00:05:43	running	3.633	3.036	1190	9	110279	###	91	9	175	22.03330628	60.4729314	249	3.633	13.079
0 days 00:05:44	running	3.639	3.041	1200	9	110528	###	91	9	175	22.0333445	60.47295872	249	3.639	13.1
0 days 00:05:45	running	3.639	3.086	1200	9	110777	###	90	9	175	22.03338272	60.47298613	249	3.639	13.1
0 days 00:05:46	running	3.642	3.13	1210	9	111027	###	90	9	175	22.03342941	60.47301069	250	3.642	13.111
0 days 00:05:47	running	3.639	3.18	1210	9	111282	###	89	9	175	22.03347609	60.47303542	255	3.639	13.1
0 days 00:05:48	running	3.636	3.233	1210	9	111543	###	89	9	175	22.03352882	60.47305821	261	3.636	13.09
0 days 00:05:49	running	3.622	3.219	1210	9	111809	###	88	9	174	22.03358145	60.4730811	266	3.622	13.039
0 days 00:05:50	running	3.611	3.208	1220	9	112081	###	88	9	174	22.03363761	60.47310423	272	3.611	13
0 days 00:05:51	running	3.611	3.208	1220	9	112352	###	89	9	174	22.03369369	60.47312728	271	3.611	13
0 days 00:05:52	running	3.611	3.208	1220	9	112622	###	89	9	174	22.03375169	60.47315025	270	3.611	13
0 days 00:05:53	running	3.622	3.219	1210	9	112892	###	90	9	174	22.03380978	60.47317313	270	3.622	13.039
0 days 00:05:54	running	3.636	3.233	1210	9	113162	###	91	9	174	22.03387331	60.47319492	270	3.636	13.09
0 days 00:05:55	running	3.653	3.247	1200	9	113433	###	91	9	174	22.03393693	60.47321672	271	3.653	13.151

0 days 00:05:56	running	3.669	3.261	1200	8	113705	###	92	8	175	22.03400533	60.47323675	272	3.669	13.208
0 days 00:05:57	running	3.669	3.322	1190	8	113978	###	92	8	175	22.03407372	60.4732567	273	3.669	13.208
0 days 00:05:58	running	3.669	3.383	1190	8	114252	###	92	8	175	22.03414262	60.47327438	274	3.669	13.208
0 days 00:05:59	running	3.669	3.45	1190	8	114532	###	92	8	175	22.03421152	60.47329224	280	3.669	13.208
0 days 00:06:00	running	3.669	3.519	1200	8	114819	###	92	8	175	22.03427891	60.47330833	287	3.669	13.208
0 days 00:06:01	running	3.697	3.622	1210	8	115112	###	92	8	174	22.0343463	60.47332451	293	3.697	13.309
0 days 00:06:02	running	3.728	3.727	1220	8	115412	###	92	8	174	22.03441143	60.47333876	300	3.728	13.421
0 days 00:06:03	running	3.728	3.727	1220	8	115721	###	91	8	175	22.03447656	60.47335301	309	3.728	13.421
0 days 00:06:04	running	3.728	3.727	1220	8	116040	###	91	8	176	22.03454001	60.47336709	319	3.728	13.421
0 days 00:06:05	running	3.761	3.761	1230	8	116359	###	92	8	176	22.03460338	60.47338134	319	3.761	13.54
0 days 00:06:06	running	3.794	3.794	1240	7	116678	###	93	7	176	22.03466347	60.47339575	319	3.794	13.658
0 days 00:06:07	running	3.794	3.794	1230	7	116999	###	92	7	175	22.03472357	60.47341025	321	3.794	13.658
0 days 00:06:08	running	3.794	3.794	1220	7	117323	###	92	7	176	22.03478065	60.47342476	324	3.794	13.658
0 days 00:06:09	running	3.794	3.794	1230	7	117647	###	92	7	176	22.0348379	60.47343934	324	3.794	13.658
0 days 00:06:10	running	3.794	3.794	1240	7	117971	###	91	7	176	22.03489356	60.47345325	324	3.794	13.658
0 days 00:06:11	running	3.814	3.813	1250	7	118295	###	90	7	176	22.03494938	60.47346708	324	3.814	13.73
0 days 00:06:12	running	3.836	3.836	1260	7	118619	###	90	7	177	22.03500546	60.47348066	324	3.836	13.81
0 days 00:06:13	running	3.836	3.925	1270	7	118945	###	89	7	177	22.0350617	60.47349416	326	3.836	13.81
0 days 00:06:14	running	3.836	4.013	1290	7	119274	###	88	7	177	22.03511828	60.4735074	329	3.836	13.81
0 days 00:06:15	running	3.811	4.08	1280	8	119610	###	88	8	177	22.03517502	60.47352073	336	3.811	13.72
0 days 00:06:16	running	3.786	4.149	1280	8	119954	###	88	8	177	22.03523269	60.47353213	344	3.786	13.63
0 days 00:06:17	running	3.786	4.149	1280	8	120304	###	88	8	177	22.03529052	60.47354353	350	3.786	13.63
0 days 00:06:18	running	3.786	4.149	1280	8	120660	###	88	8	177	22.03534878	60.47355333	356	3.786	13.63
0 days 00:06:19	running	3.786	4.252	1280	8	121016	###	88	8	178	22.03540712	60.47356322	356	3.786	13.63
0 days 00:06:20	running	3.786	4.355	1280	8	121372	###	88	8	178	22.0354652	60.4735737	356	3.786	13.63
0 days 00:06:21	running	3.739	4.297	1260	8	121736	###	88	8	178	22.03552329	60.47358426	364	3.739	13.46
0 days 00:06:22	running	3.692	4.241	1250	8	122108	###	88	8	178	22.03558121	60.47359575	372	3.692	13.291
0 days 00:06:23	running	3.692	4.241	1240	8	122475	###	88	8	177	22.03563913	60.47360731	367	3.692	13.291
0 days 00:06:24	running	3.692	4.241	1240	8	122838	###	89	8	177	22.03569897	60.47361754	363	3.692	13.291
0 days 00:06:25	running	3.664	4.211	1230	8	123201	###	89	8	178	22.03575899	60.47362785	363	3.664	13.19
0 days 00:06:26	running	3.636	4.183	1230	8	123564	###	89	8	178	22.0358206	60.47363749	363	3.636	13.09
0 days 00:06:27	running	3.636	4.083	1220	8	123924	###	90	8	178	22.03588229	60.47364729	360	3.636	13.09
0 days 00:06:28	running	3.636	3.986	1210	8	124282	###	90	8	177	22.03594565	60.47365702	358	3.636	13.09
0 days 00:06:29	running	3.636	3.986	1210	8	124631	###	90	8	177	22.03600919	60.47366674	349	3.636	13.09
0 days 00:06:30	running	3.636	3.986	1210	9	124972	###	90	9	177	22.03607406	60.47367554	341	3.636	13.09
0 days 00:06:31	running	3.636	3.894	1210	9	125313	###	89	9	178	22.03613911	60.47368443	341	3.636	13.09
0 days 00:06:32	running	3.636	3.805	1210	9	125654	###	89	9	177	22.03620491	60.47369365	341	3.636	13.09
0 days 00:06:33	running	3.636	3.719	1210	9	125987	###	89	9	177	22.0362707	60.47370295	333	3.636	13.09
0 days 00:06:34	running	3.636	3.636	1220	9	126313	###	89	9	178	22.03633751	60.47371184	326	3.636	13.09
0 days 00:06:35	running	3.639	3.638	1230	9	126632	###	88	9	177	22.0364044	60.4737208	319	3.639	13.1
0 days 00:06:36	running	3.644	3.644	1240	9	126944	###	88	9	178	22.03647162	60.47372734	312	3.644	13.118
0 days 00:06:37	running	3.644	3.644	1240	9	127256	###	88	9	177	22.03653876	60.47373396	312	3.644	13.118
0 days 00:06:38	running	3.644	3.644	1240	9	127568	###	88	9	178	22.03660665	60.47373882	312	3.644	13.118
0 days 00:06:39	running	3.644	3.644	1240	9	127880	###	88	9	177	22.03667463	60.47374369	312	3.644	13.118
0 days 00:06:40	running	3.644	3.644	1240	9	128192	###	88	9	177	22.03674219	60.47374972	312	3.644	13.118
0 days 00:06:41	running	3.633	3.633	1230	9	128504	###	88	9	177	22.03680983	60.47375576	312	3.633	13.079
0 days 00:06:42	running	3.622	3.622	1230	9	128816	###	88	9	177	22.03687663	60.47376506	312	3.622	13.039
0 days 00:06:43	running	3.622	3.622	1220	9	129127	###	88	9	177	22.03694335	60.47377436	311	3.622	13.039
0 days 00:06:44	running	3.622	3.622	1220	9	129437	###	89	9	177	22.03701099	60.47378493	310	3.622	13.039
0 days 00:06:45	running	3.622	3.622	1210	9	129747	###	89	9	178	22.03707872	60.47379549	310	3.622	13.039
0 days 00:06:46	running	3.622	3.622	1210	9	130057	###	89	9	178	22.03714787	60.4738068	310	3.622	13.039
0 days 00:06:47	running	3.622	3.702	1210	9	130367	###	89	9	177	22.03721719	60.4738182	310	3.622	13.039
0 days 00:06:48	running	3.622	3.783	1210	9	130677	###	89	9	178	22.03728567	60.47382985	310	3.622	13.039
0 days 00:06:49	running	3.622	3.783	1210	9	130994	###	89	9	178	22.03735432	60.4738415	317	3.622	13.039
0 days 00:06:50	running	3.622	3.783	1210	9	131318	###	90	9	178	22.03742313	60.47385433	324	3.622	13.039
0 days 00:06:51	running	3.639	3.894	1210	9	131642	###	90	9	178	22.03749203	60.47386724	324	3.639	13.1
0 days 00:06:52	running	3.658	4.008	1210	9	131966	###	90	9	178	22.03756202	60.47387964	324	3.658	13.169
0 days 00:06:53	running	3.658	3.916	1210	9	132299	###	90	9	178	22.03763209	60.47389205	333	3.658	13.169
0 days 00:06:54	running	3.658	3.827	1210	9	132642	###	90	9	178	22.03770217	60.47390269	343	3.658	13.169
0 days 00:06:55	running	3.683	3.852	1220	9	132977	###	90	9	178	22.03777232	60.47391342	335	3.683	13.259
0 days 00:06:56	running	3.711	3.877	1230	9	133305	###	90	9	178	22.03784156	60.47392474	328	3.711	13.36
0 days 00:06:57	running	3.711	3.794	1240	9	133635	###	89	9	177	22.03791087	60.47393613	330	3.711	13.36
0 days 00:06:58	running	3.711	3.711	1250	9	133967	###	89	9	177	22.03797936	60.47394921	332	3.711	13.36
0 days 00:06:59	running	3.711	3.711	1240	9	134292	###	89	9	177	22.03804792	60.47396245	325	3.711	13.36
0 days 00:07:00	running	3.711	3.711	1240	9	134610	###	90	9	177	22.0381159	60.47397595	318	3.711	13.36
0 days 00:07:01	running	3.719	3.719	1240	9	134928	###	89	9	177	22.03818387	60.47398944	318	3.719	13.388
0 days 00:07:02	running	3.728	3.727	1250	9	135246	###	89	9	177	22.03824942	60.47400361	318	3.728	13.421
0 days 00:07:03	running	3.728	3.727	1240	9	135564	###	89	9	177	22.03831488	60.47401786	318	3.728	13.421
0 days 00:07:04	running	3.728	3.727	1240	9	135883	###	90	9	177	22.03837532	60.47403295	319	3.728	13.421
0 days 00:07:05	running	3.731	3.655	1230	9	136202	###	90	9	177	22.03843583	60.47404803	319	3.731	13.432
0 days 00:07:06	running	3.736	3.586	1220	8	136521	###	91	8	177	22.03849182	60.47406413	319	3.736	13.45

Appendix A : Naantali Run Data

0 days 00:07:07	running	3.781	3.627	1220	8	136833	###	92	8	177	22.03854782	60.47408022	312	3.781	13.612
0 days 00:07:08	running	3.825	3.672	1230	8	137139	###	93	8	176	22.03860012	60.47409749	306	3.825	13.77
0 days 00:07:09	running	3.836	3.68	1230	8	137448	###	93	8	177	22.03865251	60.47411484	309	3.836	13.81
0 days 00:07:10	running	3.85	3.691	1240	8	137761	###	93	8	177	22.0387038	60.47413336	313	3.85	13.86
0 days 00:07:11	running	3.853	3.694	1230	8	138075	###	93	8	177	22.0387551	60.47415189	314	3.853	13.871
0 days 00:07:12	running	3.856	3.699	1230	8	138390	###	94	8	177	22.03880405	60.47417066	315	3.856	13.882
0 days 00:07:13	running	3.867	3.708	1230	8	138705	###	94	8	177	22.03885317	60.47418944	315	3.867	13.921
0 days 00:07:14	running	3.878	3.719	1230	8	139021	###	95	8	177	22.03890187	60.47420855	316	3.878	13.961
0 days 00:07:15	running	3.878	3.797	1230	8	139337	###	94	8	177	22.03895057	60.47422774	316	3.878	13.961
0 days 00:07:16	running	3.878	3.877	1240	8	139654	###	94	8	177	22.03899876	60.47424752	317	3.878	13.961
0 days 00:07:17	running	3.875	3.874	1240	8	139978	###	93	8	177	22.03904696	60.4742673	324	3.875	13.95
0 days 00:07:18	running	3.875	3.874	1240	8	140310	###	93	8	177	22.03909339	60.47428776	332	3.875	13.95
0 days 00:07:19	running	3.875	3.874	1260	8	140642	###	92	8	177	22.03913991	60.47430821	332	3.875	13.95
0 days 00:07:20	running	3.875	3.874	1290	8	140974	###	90	8	177	22.03918476	60.47432925	332	3.875	13.95
0 days 00:07:21	running	3.839	3.838	1290	8	141306	###	89	8	178	22.03922968	60.4743502	332	3.839	13.82
0 days 00:07:22	running	3.806	3.805	1300	8	141638	###	88	8	178	22.03927327	60.47437283	332	3.806	13.702
0 days 00:07:23	running	3.806	3.805	1300	8	141967	###	88	8	178	22.03931702	60.47439555	329	3.806	13.702
0 days 00:07:24	running	3.806	3.805	1300	8	142293	###	88	8	178	22.03935985	60.4744196	326	3.806	13.702
0 days 00:07:25	running	3.806	3.805	1290	8	142619	###	88	8	178	22.03940277	60.47444374	326	3.806	13.702
0 days 00:07:26	running	3.806	3.805	1280	8	142945	###	89	8	179	22.03944418	60.47446914	326	3.806	13.702
0 days 00:07:27	running	3.736	3.736	1250	8	143271	###	89	8	179	22.03948558	60.47449454	326	3.736	13.45
0 days 00:07:28	running	3.667	3.666	1230	8	143597	###	89	8	178	22.03952607	60.47452111	326	3.667	13.201
0 days 00:07:29	running	3.667	3.666	1230	8	143917	###	89	8	178	22.03956655	60.47454785	320	3.667	13.201
0 days 00:07:30	running	3.667	3.666	1230	8	144231	###	89	8	178	22.03960746	60.47457526	314	3.667	13.201
0 days 00:07:31	running	3.633	3.633	1220	8	144545	###	89	8	179	22.03964836	60.47460266	314	3.633	13.079
0 days 00:07:32	running	3.6	3.6	1210	8	144859	###	89	8	178	22.03969035	60.47462949	314	3.6	12.96
0 days 00:07:33	running	3.6	3.6	1200	8	145170	###	89	8	178	22.03973251	60.47465656	311	3.6	12.96
0 days 00:07:34	running	3.6	3.6	1200	8	145478	###	90	8	178	22.03977618	60.47468263	308	3.6	12.96
0 days 00:07:35	running	3.6	3.6	1200	8	145786	###	90	8	178	22.03981985	60.47470869	308	3.6	12.96
0 days 00:07:36	running	3.6	3.6	1200	8	146094	###	90	8	178	22.03986268	60.47473351	308	3.6	12.96
0 days 00:07:37	running	3.592	3.674	1200	8	146402	###	90	8	178	22.0399056	60.4747584	308	3.592	12.931
0 days 00:07:38	running	3.586	3.752	1200	8	146710	###	90	8	179	22.03994759	60.47478363	308	3.586	12.91
0 days 00:07:39	running	3.586	3.752	1190	8	147025	###	91	8	179	22.03998967	60.47480894	315	3.586	12.91
0 days 00:07:40	running	3.586	3.752	1180	8	147347	###	92	8	179	22.04002982	60.47483434	322	3.586	12.91
0 days 00:07:41	running	3.597	3.763	1170	8	147669	###	92	8	179	22.04006997	60.47485982	322	3.597	12.949
0 days 00:07:42	running	3.611	3.775	1160	8	147991	###	93	8	179	22.0401076	60.47488606	322	3.611	13
0 days 00:07:43	running	3.611	3.775	1160	8	148313	###	92	8	179	22.04014532	60.47491229	322	3.611	13
0 days 00:07:44	running	3.611	3.775	1170	8	148636	###	92	8	179	22.04018011	60.47493735	323	3.611	13
0 days 00:07:45	running	3.611	3.863	1170	9	148959	###	91	9	180	22.04021498	60.47496233	323	3.611	13
0 days 00:07:46	running	3.611	3.952	1180	9	149282	###	91	9	180	22.04024926	60.47498496	323	3.611	13
0 days 00:07:47	running	3.628	3.975	1200	9	149613	###	90	9	180	22.04028362	60.47500759	331	3.628	13.061
0 days 00:07:48	running	3.647	3.997	1220	9	149952	###	89	9	180	22.04031732	60.47502981	339	3.647	13.129
0 days 00:07:49	running	3.647	4.094	1220	9	150292	###	89	9	180	22.0403511	60.47505202	340	3.647	13.129
0 days 00:07:50	running	3.647	4.194	1220	9	150634	###	90	9	180	22.04038513	60.47507574	342	3.647	13.129
0 days 00:07:51	running	3.622	4.163	1210	9	150984	###	90	9	180	22.04041916	60.47509954	350	3.622	13.039
0 days 00:07:52	running	3.6	4.136	1200	9	151343	###	90	9	180	22.04045336	60.47512326	359	3.6	12.96
0 days 00:07:53	running	3.6	4.241	1200	9	151699	###	89	9	180	22.04048756	60.47514698	356	3.6	12.96
0 days 00:07:54	running	3.6	4.347	1200	9	152053	###	89	9	180	22.04052066	60.47517163	354	3.6	12.96
0 days 00:07:55	running	3.6	4.347	1200	10	152415	###	89	10	180	22.04055377	60.47519635	362	3.6	12.96
0 days 00:07:56	running	3.6	4.347	1210	10	152785	###	89	10	181	22.04058353	60.47522158	370	3.6	12.96
0 days 00:07:57	running	3.572	4.427	1200	10	153155	###	89	10	181	22.04061328	60.47524698	370	3.572	12.859
0 days 00:07:58	running	3.547	4.508	1190	10	153525	###	89	10	181	22.04064128	60.47527389	370	3.547	12.769
0 days 00:07:59	running	3.547	4.627	1190	10	153901	###	89	10	181	22.04066928	60.47530096	376	3.547	12.769
0 days 00:08:00	running	3.547	4.747	1190	10	154283	###	89	10	182	22.04069492	60.47532912	382	3.547	12.769
0 days 00:08:01	running	3.531	4.844	1180	10	154674	###	89	10	182	22.04072049	60.47535729	391	3.531	12.712
0 days 00:08:02	running	3.514	4.941	1170	10	155074	###	90	10	182	22.04074069	60.47538411	400	3.514	12.65
0 days 00:08:03	running	3.514	5.075	1170	11	155481	###	90	11	182	22.04076089	60.47541101	407	3.514	12.65
0 days 00:08:04	running	3.514	5.208	1170	11	155895	###	90	11	183	22.0407779	60.47543733	414	3.514	12.65
0 days 00:08:05	running	3.514	5.208	1170	12	156319	###	90	12	182	22.04079492	60.47546365	424	3.514	12.65
0 days 00:08:06	running	3.514	5.208	1170	12	156753	###	90	12	183	22.04081143	60.47548964	434	3.514	12.65
0 days 00:08:07	running	3.511	5.075	1170	12	157187	###	90	12	183	22.04082803	60.47551562	434	3.511	12.64
0 days 00:08:08	running	3.508	4.941	1170	12	157621	###	90	12	183	22.04084521	60.47554186	434	3.508	12.629
0 days 00:08:09	running	3.508	4.941	1170	12	158045	###	89	12	183	22.04086248	60.47556809	424	3.508	12.629
0 days 00:08:10	running	3.508	4.941	1180	13	158459	###	89	13	183	22.04088109	60.47559609	414	3.508	12.629
0 days 00:08:11	running	3.503	5.066	1180	13	158873	###	89	13	183	22.04089969	60.47562425	414	3.503	12.611
0 days 00:08:12	running	3.497	5.191	1180	13	159287	###	88	13	183	22.04091922	60.475653	414	3.497	12.589
0 days 00:08:13	running	3.497	5.191	1180	13	159710	###	88	13	184	22.04093867	60.47568183	423	3.497	12.589
0 days 00:08:14	running	3.497	5.191	1190	13	160143	###	88	13	184	22.04095736	60.47571033	433	3.497	12.589
0 days 00:08:15	running	3.406	4.924	1160	14	160576	###	88	14	184	22.04097622	60.47573883	433	3.406	12.262
0 days 00:08:16	running	3.314	4.661	1130	14	161009	###	88	14	184	22.04099148	60.47576381	433	3.314	11.93
0 days 00:08:17	running	3.3	4.647	1120	14	161421	###	88	14	184	22.0410069	60.47578895	412	3.3	11.88

Appendix A : Naantali Run Data

0 days 00:08:18	running	3.286	4.633	1120	14	161812	###	88	14	184	22.04102098	60.47581351	391	3.286	11.83
0 days 00:08:19	running	3.267	4.488	1110	14	162202	###	87	14	184	22.04103506	60.47583824	390	3.267	11.761
0 days 00:08:20	running	3.247	4.344	1110	15	162591	###	87	15	184	22.04104847	60.47586464	389	3.247	11.689
0 days 00:08:21	running	3.233	4.216	1100	15	162969	###	87	15	184	22.04106197	60.47589105	378	3.233	11.639
0 days 00:08:22	running	3.222	4.088	1100	15	163336	###	87	15	185	22.04107387	60.47591762	367	3.222	11.599
0 days 00:08:23	running	3.211	3.975	1100	15	163693	###	87	15	185	22.04108577	60.47594419	357	3.211	11.56
0 days 00:08:24	running	3.2	3.863	1100	15	164040	###	87	15	185	22.0410965	60.47597126	347	3.2	11.52
0 days 00:08:25	running	3.2	3.963	1100	16	164378	###	86	16	185	22.04110723	60.47599825	338	3.2	11.52
0 days 00:08:26	running	3.2	4.063	1110	16	164707	###	86	16	184	22.04111586	60.4760265	329	3.2	11.52
0 days 00:08:27	running	3.2	4.063	1100	16	165044	###	87	16	184	22.04112466	60.47605483	337	3.2	11.52
0 days 00:08:28	running	3.2	4.063	1090	16	165389	###	88	16	184	22.04112953	60.47608282	345	3.2	11.52
0 days 00:08:29	running	3.192	4.055	1080	16	165734	###	88	16	184	22.04113439	60.4761109	345	3.192	11.491
0 days 00:08:30	running	3.186	4.049	1080	17	166079	###	88	17	185	22.04113548	60.47614032	345	3.186	11.47
0 days 00:08:31	running	3.186	4.049	1070	17	166423	###	88	17	185	22.04113657	60.47616974	344	3.186	11.47
0 days 00:08:32	running	3.186	4.049	1070	17	166767	###	89	17	184	22.04113866	60.47620143	344	3.186	11.47
0 days 00:08:33	running	3.186	3.95	1070	17	167111	###	89	17	184	22.04114093	60.4762332	344	3.186	11.47
0 days 00:08:34	running	3.186	3.852	1070	17	167455	###	89	17	184	22.04114595	60.47626664	344	3.186	11.47
0 days 00:08:35	running	3.2	3.683	1080	17	167791	###	88	17	184	22.04115115	60.4763	336	3.2	11.52
0 days 00:08:36	running	3.214	3.516	1100	17	168119	###	88	17	184	22.04115668	60.47633478	328	3.214	11.57
0 days 00:08:37	running	3.214	3.516	1100	17	168433	###	87	17	184	22.04116222	60.47636965	314	3.214	11.57
0 days 00:08:38	running	3.214	3.516	1100	17	168734	###	87	17	184	22.0411618	60.47640461	301	3.214	11.57
0 days 00:08:39	running	3.225	3.45	1100	17	169035	###	87	17	183	22.04116146	60.47643964	301	3.225	11.61
0 days 00:08:40	running	3.239	3.386	1110	17	169336	###	88	17	183	22.04114486	60.47647216	301	3.239	11.66
0 days 00:08:41	running	3.239	3.386	1110	17	169631	###	88	17	183	22.04112827	60.47650469	295	3.239	11.66
0 days 00:08:42	running	3.239	3.386	1110	17	169921	###	88	17	183	22.04108929	60.476531	290	3.239	11.66
0 days 00:08:43	running	3.239	3.466	1110	17	170211	###	87	17	183	22.04105032	60.47655741	290	3.239	11.66
0 days 00:08:44	running	3.239	3.547	1110	17	170501	###	87	17	182	22.04099307	60.47657618	290	3.239	11.66
0 days 00:08:45	running	3.253	3.483	1110	18	170798	###	87	18	182	22.0409359	60.47659504	297	3.253	11.711
0 days 00:08:46	running	3.267	3.419	1120	18	171102	###	87	18	182	22.04086818	60.4766072	304	3.267	11.761
0 days 00:08:47	running	3.267	3.341	1110	18	171400	###	87	18	182	22.04080062	60.47661943	298	3.267	11.761
0 days 00:08:48	running	3.267	3.266	1110	18	171693	###	88	18	182	22.04072719	60.4766274	293	3.267	11.761
0 days 00:08:49	running	3.286	3.286	1110	18	171979	###	88	18	182	22.04065385	60.47663553	286	3.286	11.83
0 days 00:08:50	running	3.306	3.305	1120	18	172259	###	88	18	182	22.0405811	60.47664441	280	3.306	11.902
0 days 00:08:51	running	3.306	3.305	1110	18	172540	###	89	18	182	22.04050843	60.4766533	281	3.306	11.902
0 days 00:08:52	running	3.306	3.305	1100	18	172823	###	90	18	181	22.04043852	60.47666495	283	3.306	11.902
0 days 00:08:53	running	3.306	3.305	1100	18	173106	###	90	18	182	22.0403687	60.47667651	283	3.306	11.902
0 days 00:08:54	running	3.306	3.305	1100	18	173389	###	90	18	182	22.04030089	60.47668984	283	3.306	11.902
0 days 00:08:55	running	3.342	3.341	1110	18	173672	###	90	18	182	22.04023317	60.47670309	283	3.342	12.031
0 days 00:08:56	running	3.378	3.377	1130	18	173955	###	90	18	181	22.04016661	60.47671725	283	3.378	12.161
0 days 00:08:57	running	3.378	3.377	1130	18	174241	###	90	18	181	22.04009998	60.47673142	286	3.378	12.161
0 days 00:08:58	running	3.378	3.377	1130	18	174530	###	90	18	182	22.04003351	60.47674399	289	3.378	12.161
0 days 00:08:59	running	3.411	3.411	1140	18	174819	###	89	18	182	22.03996696	60.47675665	289	3.411	12.28
0 days 00:09:00	running	3.444	3.444	1150	18	175108	###	89	18	181	22.03990149	60.47676796	289	3.444	12.398
0 days 00:09:01	running	3.444	3.444	1150	18	175399	###	89	18	181	22.03983603	60.47677919	291	3.444	12.398
0 days 00:09:02	running	3.444	3.444	1160	18	175693	###	89	18	181	22.03977149	60.47678984	294	3.444	12.398
0 days 00:09:03	running	3.458	3.458	1160	18	175987	###	89	18	181	22.03970712	60.4768004	294	3.458	12.449
0 days 00:09:04	running	3.475	3.475	1170	18	176281	###	89	18	181	22.03964417	60.47681071	294	3.475	12.51
0 days 00:09:05	running	3.539	3.538	1190	18	176577	###	89	18	181	22.0395813	60.47682102	296	3.539	12.74
0 days 00:09:06	running	3.603	3.602	1210	18	176875	###	89	18	181	22.03952045	60.476833	298	3.603	12.971
0 days 00:09:07	running	3.614	3.613	1210	18	177178	###	89	18	181	22.03945968	60.47684516	303	3.614	13.01
0 days 00:09:08	running	3.625	3.625	1210	18	177486	###	90	18	181	22.03939917	60.47685773	308	3.625	13.05
0 days 00:09:09	running	3.636	3.636	1210	18	177795	###	90	18	181	22.03933882	60.4768703	309	3.636	13.09
0 days 00:09:10	running	3.647	3.647	1220	18	178106	###	90	18	181	22.03927838	60.47688363	311	3.647	13.129
0 days 00:09:11	running	3.65	3.65	1220	18	178417	###	90	18	182	22.03921812	60.47689704	311	3.65	13.14
0 days 00:09:12	running	3.653	3.652	1220	18	178729	###	90	18	181	22.0391581	60.4769123	312	3.653	13.151
0 days 00:09:13	running	3.65	3.65	1220	18	179041	###	89	18	182	22.03909809	60.47692772	312	3.65	13.14
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0 days 00:09:16	running	3.65	3.816	1220	18	179977	###	90	18	183	22.03891712	60.47697399	312	3.65	13.14
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0 days 00:09:20	running	3.653	3.816	1210	19	181277	###	90	19	183	22.03867723	60.47703124	327	3.653	13.151
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0 days 00:09:23	running	3.658	3.738	1220	19	182258	###	89	19	183	22.0385044	60.47707658	327	3.658	13.169
0 days 00:09:24	running	3.664	3.663	1230	19	182585	###	89	19	183	22.0384469	60.47709159	327	3.664	13.19
0 days 00:09:25	running	3.664	3.663	1230	19	182905	###	89	19	183	22.03838948	60.47710659	320	3.664	13.19
0 days 00:09:26	running	3.664	3.663	1230	19	183218	###	90	19	183	22.03833282	60.47712201	313	3.664	13.19
0 days 00:09:27	running	3.664	3.744	1220	19	183531	###	90	19	183	22.03827616	60.47713752	313	3.664	13.19
0 days 00:09:28	running	3.664	3.827	1210	19	183844	###	91	19	182	22.03821899	60.47715386	313	3.664	13.19

0 days 00:09:29	running	3.661	3.827	1210	19	184164	###	91	19	183	22.03816183	60.47717012	320	3.661	13.18
0 days 00:09:30	running	3.661	3.827	1210	19	184492	###	91	19	183	22.03810609	60.47718773	328	3.661	13.18
0 days 00:09:31	running	3.661	3.916	1210	19	184820	###	91	19	183	22.03805043	60.47720541	328	3.661	13.18
0 days 00:09:32	running	3.661	4.008	1210	19	185148	###	91	19	184	22.03800081	60.47722301	328	3.661	13.18
0 days 00:09:33	running	3.667	4.019	1210	19	185483	###	90	19	183	22.03795128	60.4772407	335	3.667	13.201
0 days 00:09:34	running	3.675	4.03	1220	19	185826	###	90	19	182	22.03791129	60.47725076	343	3.675	13.23
0 days 00:09:35	running	3.675	4.03	1230	19	186170	###	89	19	182	22.03787131	60.47726082	344	3.675	13.23
0 days 00:09:36	running	3.675	4.03	1250	19	186515	###	88	19	181	22.03783368	60.47726786	345	3.675	13.23
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0 days 00:09:38	running	3.675	3.847	1250	19	187205	###	89	19	181	22.03775707	60.47728839	345	3.675	13.23
0 days 00:09:39	running	3.644	3.73	1230	19	187542	###	89	19	181	22.03771801	60.47730189	337	3.644	13.118
0 days 00:09:40	running	3.617	3.616	1220	19	187872	###	89	19	181	22.0376792	60.47732293	330	3.617	13.021
0 days 00:09:41	running	3.617	3.616	1210	19	188192	###	90	19	181	22.03764039	60.47734405	320	3.617	13.021
0 days 00:09:42	running	3.617	3.616	1210	19	188502	###	90	19	181	22.03760301	60.47736978	310	3.617	13.021
0 days 00:09:43	running	3.592	3.591	1190	19	188812	###	90	19	180	22.03756562	60.47739568	310	3.592	12.931
0 days 00:09:44	running	3.569	3.569	1180	19	189122	###	89	19	180	22.03752606	60.47742183	310	3.569	12.848
0 days 00:09:45	running	3.569	3.569	1190	19	189430	###	89	19	180	22.03748667	60.4774479	308	3.569	12.848
0 days 00:09:46	running	3.569	3.569	1200	19	189736	###	89	19	180	22.0374461	60.47747556	306	3.569	12.848
0 days 00:09:47	running	3.569	3.569	1200	19	190042	###	89	19	180	22.03740561	60.47750322	306	3.569	12.848
0 days 00:09:48	running	3.569	3.569	1200	19	190348	###	89	19	180	22.03736052	60.47752954	306	3.569	12.848
0 days 00:09:49	running	3.558	3.558	1190	19	190654	###	89	19	180	22.03731551	60.47755586	306	3.558	12.809
0 days 00:09:50	running	3.547	3.547	1190	19	190960	###	90	19	180	22.0372658	60.47757958	306	3.547	12.769
0 days 00:09:51	running	3.561	3.561	1190	19	191265	###	90	19	180	22.03721618	60.47760355	305	3.561	12.82
0 days 00:09:52	running	3.575	3.574	1190	19	191569	###	90	19	180	22.03716178	60.4776256	304	3.575	12.87
0 days 00:09:53	running	3.597	3.522	1190	19	191874	###	90	19	180	22.03710739	60.47764773	305	3.597	12.949
0 days 00:09:54	running	3.619	3.469	1200	19	192180	###	90	19	181	22.03705089	60.47766776	306	3.619	13.028
0 days 00:09:55	running	3.642	3.566	1200	19	192481	###	90	19	181	22.0369944	60.47768779	301	3.642	13.111
0 days 00:09:56	running	3.664	3.663	1210	19	192777	###	91	19	181	22.03693681	60.47770732	296	3.664	13.19
0 days 00:09:57	running	3.681	3.68	1210	19	193081	###	91	19	181	22.03687923	60.47772693	304	3.681	13.252
0 days 00:09:58	running	3.697	3.697	1220	19	193394	###	91	19	181	22.03682349	60.47774705	313	3.697	13.309
0 days 00:09:59	running	3.706	3.705	1220	19	193709	###	91	19	181	22.03676792	60.47776708	315	3.706	13.342
0 days 00:10:00	running	3.714	3.713	1220	19	194026	###	91	19	181	22.03671511	60.47778703	317	3.714	13.37
0 days 00:10:01	running	3.714	3.713	1220	19	194343	###	91	19	181	22.03666231	60.47780698	317	3.714	13.37
0 days 00:10:02	running	3.714	3.713	1230	19	194661	###	91	19	181	22.0366121	60.47782718	318	3.714	13.37
0 days 00:10:03	running	3.714	3.794	1230	19	194979	###	91	19	182	22.03656198	60.47784738	318	3.714	13.37
0 days 00:10:04	running	3.714	3.877	1230	19	195297	###	91	19	182	22.03651252	60.47786775	318	3.714	13.37
0 days 00:10:05	running	3.717	3.975	1220	19	195622	###	91	19	182	22.03646298	60.47788803	325	3.717	13.381
0 days 00:10:06	running	3.719	4.075	1220	19	195954	###	91	19	182	22.03641093	60.47790631	332	3.719	13.388
0 days 00:10:07	running	3.719	4.174	1220	19	196294	###	91	19	182	22.0363588	60.47792466	340	3.719	13.388
0 days 00:10:08	running	3.719	4.275	1220	19	196643	###	91	19	182	22.03630742	60.47794302	349	3.719	13.388
0 days 00:10:09	running	3.719	4.383	1220	19	197000	###	91	19	183	22.03625612	60.47796146	357	3.719	13.388
0 days 00:10:10	running	3.719	4.491	1230	20	197365	###	91	20	183	22.03620901	60.47798275	365	3.719	13.388
0 days 00:10:11	running	3.722	4.613	1230	20	197739	###	91	20	183	22.03616191	60.47800404	374	3.722	13.399
0 days 00:10:12	running	3.725	4.736	1230	20	198122	###	91	20	183	22.0361122	60.47802533	383	3.725	13.41
0 days 00:10:13	running	3.725	4.736	1230	20	198514	###	90	20	182	22.0360625	60.4780467	392	3.725	13.41
0 days 00:10:14	running	3.725	4.736	1240	20	198916	###	90	20	183	22.03600919	60.47806749	402	3.725	13.41
0 days 00:10:15	running	3.714	4.847	1240	21	199318	###	90	21	183	22.03595596	60.47808836	402	3.714	13.37
0 days 00:10:16	running	3.706	4.961	1240	21	199720	###	89	21	183	22.03590618	60.47810932	402	3.706	13.342
0 days 00:10:17	running	3.706	4.961	1250	21	200130	###	89	21	183	22.03585647	60.47813044	410	3.706	13.342
0 days 00:10:18	running	3.706	4.961	1260	21	200548	###	88	21	183	22.03582177	60.47815542	418	3.706	13.342
0 days 00:10:19	running	3.706	4.961	1260	21	200966	###	88	21	183	22.03578707	60.4781804	418	3.706	13.342
0 days 00:10:20	running	3.706	4.961	1270	22	201384	###	87	22	183	22.03577802	60.47821065	418	3.706	13.342
0 days 00:10:21	running	3.669	4.913	1260	22	201802	###	87	22	183	22.03576896	60.47824091	418	3.669	13.208
0 days 00:10:22	running	3.636	4.866	1250	22	202220	###	87	22	183	22.03578866	60.47827184	418	3.636	13.09
0 days 00:10:23	running	3.636	4.744	1250	22	202634	###	87	22	183	22.03580853	60.47830286	414	3.636	13.09
0 days 00:10:24	running	3.636	4.622	1250	22	203045	###	87	22	183	22.03584616	60.47833244	411	3.636	13.09
0 days 00:10:25	running	3.6	4.461	1230	22	203446	###	87	22	183	22.03588396	60.47836212	401	3.6	12.96
0 days 00:10:26	running	3.564	4.299	1220	22	203838	###	87	22	183	22.03592788	60.47838869	392	3.564	12.83
0 days 00:10:27	running	3.564	4.194	1220	22	204217	###	87	22	183	22.03597181	60.47841542	379	3.564	12.83
0 days 00:10:28	running	3.564	4.091	1220	22	204583	###	87	22	183	22.03601941	60.47843956	366	3.564	12.83
0 days 00:10:29	running	3.564	3.994	1220	22	204941	###	87	22	183	22.03606702	60.4784637	358	3.564	12.83
0 days 00:10:30	running	3.564	3.899	1220	23	205291	###	88	23	183	22.03611732	60.47848835	350	3.564	12.83
0 days 00:10:31	running	3.547	3.716	1200	23	205633	###	88	23	183	22.03616769	60.47851291	342	3.547	12.769
0 days 00:10:32	running	3.533	3.533	1190	23	205967	###	89	23	184	22.0362127	60.47854216	334	3.533	12.719
0 days 00:10:33	running	3.533	3.533	1180	23	206285	###	89	23	184	22.03625771	60.47857133	318	3.533	12.719
0 days 00:10:34	running	3.533	3.533	1180	23	206587	###	90	23	184	22.03628889	60.4786093	302	3.533	12.719
0 days 00:10:35	running	3.55	3.549	1180	23	206889	###	90	23	184	22.03632016	60.47864735	302	3.55	12.78
0 days 00:10:36	running	3.569	3.569	1190	23	207191	###	90	23	184	22.03632561	60.4786875	302	3.569	12.848
0 days 00:10:37	running	3.569	3.569	1190	23	207495	###	90	23	184	22.03633097	60.47872773	304	3.569	12.848
0 days 00:10:38	running	3.569	3.569	1190	23	207801	###	90	23	183	22.03630348	60.47876034	306	3.569	12.848
0 days 00:10:39	running	3.569	3.494	1190	23	208107	###	89	23	183	22.03627598	60.47879303	306	3.569	12.848

Appendix A : Naantali Run Data

0 days 00:10:40	running	3.569	3.422	1200	23	208413	###	89	23	184	22.03622636	60.478817	306	3.569	12.848
0 days 00:10:41	running	3.597	3.45	1200	23	208712	###	89	23	184	22.03617683	60.47884106	299	3.597	12.949
0 days 00:10:42	running	3.628	3.48	1210	23	209004	###	90	23	184	22.0361179	60.47886	292	3.628	13.061
0 days 00:10:43	running	3.628	3.48	1210	23	209298	###	90	23	185	22.03605906	60.47887911	294	3.628	13.061
0 days 00:10:44	running	3.628	3.48	1210	23	209595	###	90	23	184	22.03599821	60.47889713	297	3.628	13.061
0 days 00:10:45	running	3.644	3.494	1210	23	209892	###	90	23	184	22.03593727	60.47891515	297	3.644	13.118
0 days 00:10:46	running	3.664	3.508	1220	22	210189	###	90	22	184	22.03587743	60.47893443	297	3.664	13.19
0 days 00:10:47	running	3.664	3.508	1210	22	210487	###	90	22	184	22.03581758	60.47895371	298	3.664	13.19
0 days 00:10:48	running	3.664	3.508	1210	22	210786	###	91	22	184	22.03575446	60.47897156	299	3.664	13.19
0 days 00:10:49	running	3.664	3.508	1200	22	211085	###	91	22	184	22.03569151	60.47898933	299	3.664	13.19
0 days 00:10:50	running	3.664	3.508	1200	22	211384	###	91	22	183	22.03562756	60.47900794	299	3.664	13.19
0 days 00:10:51	running	3.683	3.458	1200	22	211683	###	91	22	184	22.03556377	60.47902655	299	3.683	13.259
0 days 00:10:52	running	3.703	3.411	1210	22	211982	###	91	22	183	22.03550166	60.479047	299	3.703	13.331
0 days 00:10:53	running	3.703	3.411	1210	22	212276	###	91	22	183	22.03543955	60.47906754	294	3.703	13.331
0 days 00:10:54	running	3.703	3.411	1220	22	212565	###	91	22	184	22.03537937	60.47908849	289	3.703	13.331
0 days 00:10:55	running	3.772	3.475	1240	22	212854	###	91	22	184	22.03531919	60.47910961	289	3.772	13.579
0 days 00:10:56	running	3.844	3.538	1270	21	213143	###	91	21	184	22.03525825	60.47912956	289	3.844	13.838
0 days 00:10:57	running	3.85	3.547	1270	21	213437	###	91	21	184	22.0351974	60.47914951	294	3.85	13.86
0 days 00:10:58	running	3.856	3.558	1270	21	213737	###	91	21	184	22.03513596	60.47916971	300	3.856	13.882
0 days 00:10:59	running	3.869	3.638	1270	21	214038	###	91	21	184	22.03507469	60.47918991	301	3.869	13.928
0 days 00:11:00	running	3.883	3.719	1280	21	214340	###	91	21	184	22.03501266	60.4792102	302	3.883	13.979
0 days 00:11:01	running	3.892	3.727	1280	21	214649	###	91	21	185	22.03495081	60.47923065	309	3.892	14.011
0 days 00:11:02	running	3.903	3.738	1290	21	214966	###	91	21	185	22.03488819	60.47925144	317	3.903	14.051
0 days 00:11:03	running	3.914	3.83	1290	21	215284	###	91	21	185	22.03482558	60.47927231	318	3.914	14.09
0 days 00:11:04	running	3.925	3.925	1290	21	215603	###	91	21	185	22.03476381	60.47929301	319	3.925	14.13
0 days 00:11:05	running	3.925	3.844	1290	21	215930	###	91	21	184	22.03470203	60.47931371	327	3.925	14.13
0 days 00:11:06	running	3.928	3.766	1290	20	216266	###	91	20	185	22.03464252	60.47933509	336	3.928	14.141
0 days 00:11:07	running	3.928	3.766	1290	20	216594	###	91	20	185	22.03458301	60.47935654	328	3.928	14.141
0 days 00:11:08	running	3.928	3.766	1290	20	216915	###	91	20	184	22.03452643	60.4793775	321	3.928	14.141
0 days 00:11:09	running	3.931	3.772	1290	20	217236	###	91	20	184	22.03446985	60.47939862	321	3.931	14.152
0 days 00:11:10	running	3.936	3.777	1290	20	217557	###	91	20	184	22.03441311	60.47941765	321	3.936	14.17
0 days 00:11:11	running	3.936	3.777	1290	20	217878	###	91	20	184	22.03435636	60.47943676	321	3.936	14.17
0 days 00:11:12	running	3.936	3.777	1290	20	218200	###	91	20	185	22.03429962	60.47945646	322	3.936	14.17
0 days 00:11:13	running	3.936	3.777	1290	20	218522	###	91	20	184	22.03424279	60.47947615	322	3.936	14.17
0 days 00:11:14	running	3.936	3.777	1290	20	218844	###	91	20	184	22.03418872	60.47949878	322	3.936	14.17
0 days 00:11:15	running	3.939	3.777	1290	20	219166	###	91	20	184	22.03413466	60.4795215	322	3.939	14.18
0 days 00:11:16	running	3.942	3.777	1300	20	219488	###	90	20	184	22.03408269	60.47954564	322	3.942	14.191
0 days 00:11:17	running	3.942	3.858	1300	20	219810	###	90	20	184	22.03403081	60.4795697	322	3.942	14.191
0 days 00:11:18	running	3.942	3.941	1300	20	220132	###	91	20	183	22.03398119	60.47959375	322	3.942	14.191
0 days 00:11:19	running	3.936	3.936	1290	20	220461	###	91	20	183	22.03393157	60.47961772	329	3.936	14.17
0 days 00:11:20	running	3.931	3.93	1290	20	220798	###	91	20	183	22.03388295	60.4796401	337	3.931	14.152
0 days 00:11:21	running	3.931	3.93	1290	19	221134	###	91	19	183	22.03383442	60.47966248	336	3.931	14.152
0 days 00:11:22	running	3.931	3.93	1290	19	221470	###	91	19	183	22.03378463	60.47968369	336	3.931	14.152
0 days 00:11:23	running	3.931	3.847	1280	19	221806	###	92	19	183	22.03373476	60.47970506	336	3.931	14.152
0 days 00:11:24	running	3.931	3.766	1280	19	222142	###	93	19	183	22.03368212	60.47972652	336	3.931	14.152
0 days 00:11:25	running	3.931	3.766	1270	19	222470	###	93	19	183	22.0336294	60.47974815	328	3.931	14.152
0 days 00:11:26	running	3.933	3.766	1270	19	222791	###	92	19	183	22.0335786	60.47977371	321	3.933	14.159
0 days 00:11:27	running	3.933	3.766	1270	19	223112	###	93	19	183	22.03352789	60.47979936	321	3.933	14.159
0 days 00:11:28	running	3.933	3.766	1280	19	223433	###	94	19	183	22.0334792	60.47982618	321	3.933	14.159
0 days 00:11:29	running	3.953	3.869	1260	19	223754	###	94	19	183	22.03343058	60.47985326	321	3.953	14.231
0 days 00:11:30	running	3.972	3.972	1250	19	224075	###	95	19	183	22.03337937	60.47987689	321	3.972	14.299
0 days 00:11:31	running	3.972	3.972	1240	19	224405	###	96	19	183	22.03332815	60.4799007	330	3.972	14.299
0 days 00:11:32	running	3.972	3.972	1240	19	224745	###	97	19	184	22.03327568	60.47992065	340	3.972	14.299
0 days 00:11:33	running	3.972	3.972	1230	19	225085	###	97	19	184	22.03322321	60.47994051	340	3.972	14.299
0 days 00:11:34	running	3.972	3.972	1230	19	225425	###	97	19	184	22.03316848	60.4799592	340	3.972	14.299
0 days 00:11:35	running	4.022	4.213	1240	19	225765	###	96	19	184	22.03311383	60.47997789	340	4.022	14.479
0 days 00:11:36	running	4.072	4.458	1260	19	226105	###	95	19	184	22.0330549	60.47999449	340	4.072	14.659
0 days 00:11:37	running	4.072	4.355	1270	19	226466	###	93	19	184	22.03299606	60.48001109	361	4.072	14.659
0 days 00:11:38	running	4.072	4.255	1290	19	226848	###	92	19	183	22.0329342	60.48002341	382	4.072	14.659
0 days 00:11:39	running	4.089	4.275	1320	19	227221	###	91	19	184	22.03287243	60.48003581	373	4.089	14.72
0 days 00:11:40	running	4.108	4.297	1350	19	227586	###	90	19	183	22.03280579	60.48003984	365	4.108	14.789
0 days 00:11:41	running	4.108	4.297	1350	19	227952	###	90	19	183	22.03273916	60.48004394	366	4.108	14.789
0 days 00:11:42	running	4.108	4.297	1360	19	228320	###	89	19	183	22.03266892	60.48004495	368	4.108	14.789
0 days 00:11:43	running	4.108	4.202	1370	19	228688	###	88	19	183	22.03259868	60.48004604	368	4.108	14.789
0 days 00:11:44	running	4.108	4.108	1390	19	229056	###	88	19	183	22.03252768	60.48004931	368	4.108	14.789
0 days 00:11:45	running	4.036	4.036	1370	19	229416	###	88	19	183	22.03245677	60.48005266	360	4.036	14.53
0 days 00:11:46	running	3.967	3.966	1350	19	229768	###	88	19	183	22.03238636	60.48006188	352	3.967	14.281
0 days 00:11:47	running	3.872	3.872	1310	19	230114	###	88	19	183	22.03231595	60.48007119	346	3.872	13.939
0 days 00:11:48	running	3.778	3.777	1280	19	230454	###	88	19	183	22.03224412	60.48008443	340	3.778	13.601
0 days 00:11:49	running	3.783	3.705	1280	19	230786	###	89	19	184	22.0321722	60.48009759	332	3.783	13.619
0 days 00:11:50	running	3.792	3.633	1280	19	231110	###	89	19	184	22.03209761	60.48011242	324	3.792	13.651

0 days 00:11:51	running	3.817	3.586	1280	18	231427	###	89	18	184	22.03202301	60.48012726	317	3.817	13.741
0 days 00:11:52	running	3.844	3.538	1290	18	231737	###	90	18	183	22.03194858	60.48014352	310	3.844	13.838
0 days 00:11:53	running	3.869	3.441	1290	17	232042	###	90	17	183	22.03187423	60.48015978	305	3.869	13.928
0 days 00:11:54	running	3.894	3.344	1290	17	232342	###	90	17	183	22.03180181	60.48017663	300	3.894	14.018
0 days 00:11:55	running	3.908	3.308	1290	17	232631	###	90	17	184	22.03172939	60.48019356	289	3.908	14.069
0 days 00:11:56	running	3.922	3.274	1300	16	232910	###	90	16	184	22.03165881	60.48020991	279	3.922	14.119
0 days 00:11:57	running	3.922	3.202	1290	16	233184	###	90	16	183	22.03158815	60.48022642	274	3.922	14.119
0 days 00:11:58	running	3.922	3.13	1290	16	233453	###	91	16	183	22.03151976	60.48024142	269	3.922	14.119
0 days 00:11:59	running	3.922	3.105	1290	16	233711	###	90	16	183	22.03145136	60.48025651	258	3.922	14.119
0 days 00:12:00	running	3.922	3.083	1300	16	233959	###	90	16	183	22.03138573	60.48027051	248	3.922	14.119
0 days 00:12:01	running	3.936	3.094	1300	15	234202	###	90	15	183	22.0313201	60.4802845	243	3.936	14.17
0 days 00:12:02	running	3.95	3.108	1310	15	234441	###	90	15	183	22.03125422	60.48029775	239	3.95	14.22
0 days 00:12:03	running	3.95	3.13	1310	15	234680	###	90	15	183	22.03118842	60.48031099	239	3.95	14.22
0 days 00:12:04	running	3.95	3.155	1310	15	234920	###	90	15	183	22.0311212	60.48032566	240	3.95	14.22
0 days 00:12:05	running	3.961	3.194	1310	15	235165	###	90	15	182	22.03105406	60.48034033	245	3.961	14.26
0 days 00:12:06	running	3.972	3.236	1310	14	235415	###	91	14	182	22.03098675	60.48035684	250	3.972	14.299
0 days 00:12:07	running	3.972	3.236	1300	14	235670	###	91	14	182	22.03091953	60.48037344	255	3.972	14.299
0 days 00:12:08	running	3.972	3.236	1300	14	235931	###	91	14	183	22.03085097	60.48039062	261	3.972	14.299
0 days 00:12:09	running	3.972	3.236	1300	14	236192	###	91	14	182	22.03078249	60.4804078	261	3.972	14.299
0 days 00:12:10	running	3.972	3.236	1310	14	236453	###	91	14	182	22.03071359	60.48042482	261	3.972	14.299
0 days 00:12:11	running	3.983	3.211	1310	13	236714	###	90	13	182	22.03064477	60.48044192	261	3.983	14.339
0 days 00:12:12	running	3.994	3.188	1320	13	236975	###	90	13	182	22.03057671	60.4804591	261	3.994	14.378
0 days 00:12:13	running	3.994	3.219	1320	13	237231	###	90	13	182	22.03050873	60.48047628	256	3.994	14.378
0 days 00:12:14	running	3.994	3.252	1320	13	237483	###	90	13	182	22.03043908	60.48049313	252	3.994	14.378
0 days 00:12:15	running	3.997	3.255	1320	13	237740	###	90	13	182	22.03036959	60.48050989	257	3.997	14.389
0 days 00:12:16	running	4	3.261	1330	12	238003	###	90	12	182	22.03029759	60.48052582	263	4	14.4
0 days 00:12:17	running	4	3.227	1330	12	238266	###	90	12	182	22.03022559	60.48054183	263	4	14.4
0 days 00:12:18	running	4.003	3.194	1330	11	238529	###	90	11	182	22.03015225	60.48055742	263	4.003	14.411
0 days 00:12:19	running	4.056	3.213	1340	11	238787	###	90	11	182	22.03007899	60.48057309	258	4.056	14.602
0 days 00:12:20	running	4.108	3.233	1350	11	239040	###	91	11	182	22.03000733	60.4805891	253	4.108	14.789
0 days 00:12:21	running	4.119	3.241	1350	10	239291	###	91	10	181	22.02993558	60.4806052	251	4.119	14.828
0 days 00:12:22	running	4.133	3.249	1360	10	239541	###	91	10	181	22.02986693	60.48062146	250	4.133	14.879
0 days 00:12:23	running	4.15	3.263	1360	10	239791	###	91	10	181	22.02979828	60.48063772	250	4.15	14.94
0 days 00:12:24	running	4.169	3.28	1360	10	240042	###	92	10	181	22.02973131	60.4806539	251	4.169	15.008
0 days 00:12:25	running	4.181	3.288	1360	10	240294	###	92	10	181	22.02966426	60.48067016	252	4.181	15.052
0 days 00:12:26	running	4.192	3.297	1370	9	240548	###	92	9	181	22.02959578	60.48068264	254	4.192	15.091
0 days 00:12:27	running	4.194	3.3	1370	9	240802	###	91	9	181	22.0295273	60.48069522	254	4.194	15.098
0 days 00:12:28	running	4.2	3.305	1380	8	241057	###	91	8	181	22.02945731	60.48070134	255	4.2	15.12
0 days 00:12:29	running	4.2	3.363	1380	8	241312	###	91	8	181	22.0293874	60.48070754	255	4.2	15.12
0 days 00:12:30	running	4.2	3.422	1380	8	241568	###	91	8	181	22.02932077	60.4807041	256	4.2	15.12
0 days 00:12:31	running	4.2	3.463	1380	7	241834	###	91	7	181	22.0292543	60.48070075	266	4.2	15.12
0 days 00:12:32	running	4.2	3.508	1390	7	242111	###	90	7	181	22.02920132	60.48068541	277	4.2	15.12
0 days 00:12:33	running	4.189	3.5	1380	7	242393	###	90	7	181	22.02914827	60.48067024	282	4.189	15.08
0 days 00:12:34	running	4.178	3.491	1380	7	242681	###	91	7	181	22.02910895	60.4806456	288	4.178	15.041
0 days 00:12:35	running	4.178	3.541	1380	7	242968	###	91	7	181	22.02906973	60.48062104	287	4.178	15.041
0 days 00:12:36	running	4.178	3.594	1380	6	243255	###	91	6	181	22.02903662	60.48058919	287	4.178	15.041
0 days 00:12:37	running	4.15	3.627	1370	6	243548	###	90	6	181	22.02900359	60.4805575	293	4.15	14.94
0 days 00:12:38	running	4.122	3.661	1370	6	243847	###	90	6	181	22.0289725	60.4805218	299	4.122	14.839
0 days 00:12:39	running	4.122	3.727	1360	6	244150	###	90	6	181	22.0289414	60.48048609	303	4.122	14.839
0 days 00:12:40	running	4.122	3.797	1360	6	244458	###	91	6	181	22.0289124	60.48045055	308	4.122	14.839
0 days 00:12:41	running	4.122	3.872	1360	5	244773	###	91	5	181	22.02888348	60.48041493	315	4.122	14.839
0 days 00:12:42	running	4.122	3.95	1360	5	245095	###	91	5	180	22.02885649	60.48038023	322	4.122	14.839
0 days 00:12:43	running	4.106	3.936	1350	5	245424	###	91	5	181	22.02882959	60.48034561	329	4.106	14.782
0 days 00:12:44	running	4.092	3.922	1340	5	245761	###	91	5	180	22.02880461	60.48031082	337	4.092	14.731
0 days 00:12:45	running	4.092	4.005	1340	5	246096	###	91	5	181	22.02877963	60.48027612	335	4.092	14.731
0 days 00:12:46	running	4.092	4.091	1340	5	246430	###	91	5	181	22.02875859	60.48024176	334	4.092	14.731
0 days 00:12:47	running	4.092	4.005	1340	5	246772	###	91	5	181	22.02873755	60.48020739	342	4.092	14.731
0 days 00:12:48	running	4.092	3.922	1340	5	247122	###	92	5	181	22.02872138	60.48017319	350	4.092	14.731
0 days 00:12:49	running	4.092	3.922	1330	5	247464	###	92	5	181	22.0287052	60.48013916	342	4.092	14.731
0 days 00:12:50	running	4.092	3.922	1330	5	247798	###	93	5	181	22.02869388	60.48010354	334	4.092	14.731
0 days 00:12:51	running	4.092	3.922	1320	4	248132	###	94	4	181	22.02868265	60.48006792	334	4.092	14.731
0 days 00:12:52	running	4.092	3.922	1310	4	248466	###	95	4	181	22.02867536	60.48003095	334	4.092	14.731
0 days 00:12:53	running	4.114	4.027	1300	4	248800	###	95	4	181	22.02866807	60.47999399	334	4.114	14.81
0 days 00:12:54	running	4.136	4.136	1300	4	249134	###	95	4	181	22.02866429	60.47995694	334	4.136	14.89
0 days 00:12:55	running	4.136	4.136	1300	4	249478	###	95	4	181	22.02866061	60.47991981	344	4.136	14.89
0 days 00:12:56	running	4.136	4.136	1310	4	249832	###	95	4	182	22.02865943	60.47988402	354	4.136	14.89
0 days 00:12:57	running	4.172	4.172	1310	4	250186	###	95	4	182	22.02865826	60.47984823	354	4.172	15.019
0 days 00:12:58	running	4.211	4.211	1320	4	250540	###	95	4	181	22.02865801	60.47981319	354	4.211	15.16
0 days 00:12:59	running	4.231	4.23	1310	4	250897	###	97	4	181	22.02865776	60.47977832	357	4.231	15.232
0 days 00:13:00	running	4.25	4.25	1300	4	251257	###	98	4	181	22.02865826	60.47974329	360	4.25	15.3
0 days 00:13:01	running	4.278	4.277	1290	4	251619	###	99	4	182	22.02865876	60.47970833	362	4.278	15.401

0 days 00:13:02	running	4.308	4.308	1290	4	251983	###	100	4	182	22.02865709	60.47967355	364	4.308	15.509
0 days 00:13:03	running	4.311	4.311	1290	4	252349	###	99	4	182	22.02865541	60.47963876	366	4.311	15.52
0 days 00:13:04	running	4.314	4.313	1300	4	252718	###	99	4	182	22.02864912	60.47960431	369	4.314	15.53
0 days 00:13:05	running	4.311	4.311	1300	5	253087	###	99	5	182	22.02864275	60.47957003	369	4.311	15.52
0 days 00:13:06	running	4.308	4.308	1310	5	253456	###	98	5	182	22.02863119	60.47953575	369	4.308	15.509
0 days 00:13:07	running	4.297	4.297	1320	5	253825	###	97	5	182	22.0286197	60.47950155	369	4.297	15.469
0 days 00:13:08	running	4.286	4.286	1330	5	254194	###	97	5	182	22.02860361	60.47946685	369	4.286	15.43
0 days 00:13:09	running	4.286	4.286	1340	5	254562	###	96	5	182	22.0285876	60.47943223	368	4.286	15.43
0 days 00:13:10	running	4.286	4.286	1350	5	254929	###	95	5	182	22.02856807	60.47939904	367	4.286	15.43
0 days 00:13:11	running	4.286	4.286	1350	5	255296	###	95	5	182	22.02854862	60.47936585	367	4.286	15.43
0 days 00:13:12	running	4.286	4.286	1350	5	255663	###	95	5	182	22.02852851	60.47933366	367	4.286	15.43
0 days 00:13:13	running	4.247	4.247	1340	5	256030	###	95	5	182	22.02850848	60.47930156	367	4.247	15.289
0 days 00:13:14	running	4.211	4.211	1330	5	256397	###	95	5	182	22.02849037	60.47926879	367	4.211	15.16
0 days 00:13:15	running	4.211	4.211	1320	5	256760	###	95	5	182	22.02847227	60.47923626	363	4.211	15.16
0 days 00:13:16	running	4.211	4.211	1320	4	257120	###	95	4	183	22.02846179	60.4792024	360	4.211	15.16
0 days 00:13:17	running	4.158	4.158	1300	4	257480	###	95	4	183	22.02845139	60.47916871	360	4.158	14.969
0 days 00:13:18	running	4.108	4.108	1290	4	257840	###	95	4	182	22.02845232	60.47913459	360	4.108	14.789
0 days 00:13:19	running	4.108	4.108	1290	4	258196	###	94	4	182	22.02845315	60.47910064	356	4.108	14.789
0 days 00:13:20	running	4.108	4.108	1300	4	258548	###	94	4	182	22.02846589	60.47906695	352	4.108	14.789
0 days 00:13:21	running	4.108	4.108	1300	4	258900	###	93	4	182	22.02847855	60.47903325	352	4.108	14.789
0 days 00:13:22	running	4.108	4.108	1300	4	259252	###	93	4	182	22.02850278	60.47900031	352	4.108	14.789
0 days 00:13:23	running	4.067	4.066	1300	4	259604	###	92	4	182	22.02852708	60.47896754	352	4.067	14.641
0 days 00:13:24	running	4.025	4.024	1300	4	259956	###	92	4	182	22.02855139	60.47893468	352	4.025	14.49
0 days 00:13:25	running	4.025	4.024	1310	4	260304	###	91	4	182	22.02858031	60.47890233	348	4.025	14.49
0 days 00:13:26	running	4.025	4.024	1320	4	260649	###	90	4	182	22.02860923	60.47886989	345	4.025	14.49
0 days 00:13:27	running	3.972	3.972	1310	4	260994	###	90	4	182	22.02863806	60.47883762	345	3.972	14.299
0 days 00:13:28	running	3.919	3.919	1300	4	261339	###	91	4	182	22.02866706	60.47880543	345	3.919	14.108
0 days 00:13:29	running	3.858	3.858	1270	4	261679	###	91	4	182	22.02869531	60.47877392	340	3.858	13.889
0 days 00:13:30	running	3.8	3.8	1250	4	262014	###	92	4	182	22.02872355	60.47874249	335	3.8	13.68
0 days 00:13:31	running	3.797	3.797	1240	4	262344	###	92	4	182	22.02874887	60.47871072	330	3.797	13.669
0 days 00:13:32	running	3.797	3.797	1230	4	262669	###	92	4	182	22.02877427	60.47867903	325	3.797	13.669
0 days 00:13:33	running	3.806	3.805	1230	4	262994	###	92	4	182	22.02879597	60.4786476	325	3.806	13.702
0 days 00:13:34	running	3.814	3.813	1230	4	263319	###	93	4	182	22.02881768	60.47861625	325	3.814	13.73
0 days 00:13:35	running	3.828	3.827	1230	4	263644	###	93	4	182	22.02883738	60.47858574	325	3.828	13.781
0 days 00:13:36	running	3.842	3.841	1230	4	263970	###	93	4	182	22.02885716	60.47855523	326	3.842	13.831
0 days 00:13:37	running	3.847	3.847	1230	4	264297	###	93	4	181	22.02887611	60.47852581	327	3.847	13.849
0 days 00:13:38	running	3.853	3.852	1240	4	264626	###	93	4	182	22.02889496	60.47849639	329	3.853	13.871
0 days 00:13:39	running	3.853	3.852	1240	4	264955	###	93	4	182	22.02891307	60.47846639	329	3.853	13.871
0 days 00:13:40	running	3.853	3.852	1240	4	265284	###	93	4	183	22.02893126	60.47843646	329	3.853	13.871
0 days 00:13:41	running	3.853	3.852	1240	4	265613	###	93	4	182	22.02894819	60.47840335	329	3.853	13.871
0 days 00:13:42	running	3.853	3.852	1240	4	265942	###	93	4	182	22.02896512	60.47837025	329	3.853	13.871
0 days 00:13:43	running	3.85	3.938	1230	4	266271	###	93	4	182	22.02898188	60.47833546	329	3.85	13.86
0 days 00:13:44	running	3.85	4.024	1230	4	266600	###	94	4	183	22.02899882	60.47830059	329	3.85	13.86
0 days 00:13:45	running	3.85	4.024	1230	4	266937	###	93	4	183	22.02901801	60.4782674	337	3.85	13.86
0 days 00:13:46	running	3.85	4.024	1240	4	267282	###	93	4	183	22.02903729	60.47823421	345	3.85	13.86
0 days 00:13:47	running	3.85	4.024	1250	4	267627	###	92	4	183	22.02906193	60.47820303	345	3.85	13.86
0 days 00:13:48	running	3.85	4.024	1260	4	267972	###	91	4	183	22.02908649	60.47817185	345	3.85	13.86
0 days 00:13:49	running	3.839	4.013	1260	4	268317	###	91	4	183	22.02911616	60.47814209	345	3.839	13.82
0 days 00:13:50	running	3.828	4.005	1270	4	268662	###	90	4	184	22.029146	60.47811242	345	3.828	13.781
0 days 00:13:51	running	3.828	4.005	1270	4	269006	###	90	4	184	22.02917869	60.47808308	344	3.828	13.781
0 days 00:13:52	running	3.828	4.005	1270	4	269349	###	90	4	184	22.02921147	60.47805383	343	3.828	13.781
0 days 00:13:53	running	3.803	3.977	1250	4	269692	###	91	4	184	22.029246	60.47802432	343	3.803	13.691
0 days 00:13:54	running	3.778	3.952	1230	4	270035	###	92	4	184	22.02928062	60.47799482	343	3.778	13.601
0 days 00:13:55	running	3.778	3.952	1220	4	270376	###	92	4	184	22.02931523	60.47796506	341	3.778	13.601
0 days 00:13:56	running	3.778	3.952	1210	4	270715	###	93	4	184	22.02934977	60.47793522	339	3.778	13.601
0 days 00:13:57	running	3.778	3.952	1210	4	271054	###	93	4	184	22.0293822	60.47790564	339	3.778	13.601
0 days 00:13:58	running	3.778	3.952	1210	4	271393	###	94	4	184	22.02941473	60.47787605	339	3.778	13.601
0 days 00:13:59	running	3.783	3.872	1210	4	271732	###	93	4	184	22.02944918	60.47784596	339	3.783	13.619
0 days 00:14:00	running	3.792	3.791	1220	4	272071	###	93	4	184	22.02948371	60.47781578	339	3.792	13.651
0 days 00:14:01	running	3.792	3.791	1230	4	272402	###	92	4	184	22.02952201	60.47778561	331	3.792	13.651
0 days 00:14:02	running	3.792	3.791	1240	4	272726	###	91	4	184	22.02956032	60.47775543	324	3.792	13.651
0 days 00:14:03	running	3.789	3.788	1250	4	273050	###	90	4	184	22.02960047	60.4777266	324	3.789	13.64
0 days 00:14:04	running	3.786	3.786	1260	4	273374	###	90	4	184	22.0296407	60.47769793	324	3.786	13.63
0 days 00:14:05	running	3.786	3.874	1250	4	273698	###	90	4	184	22.02967993	60.47767094	324	3.786	13.63
0 days 00:14:06	running	3.786	3.963	1250	4	274022	###	91	4	184	22.02971907	60.47764395	324	3.786	13.63
0 days 00:14:07	running	3.786	3.963	1250	4	274354	###	90	4	184	22.0297578	60.47761889	332	3.786	13.63
0 days 00:14:08	running	3.786	3.963	1260	4	274694	###	90	4	184	22.02979661	60.47759391	340	3.786	13.63
0 days 00:14:09	running	3.767	3.941	1250	4	275034	###	90	4	185	22.02983709	60.47757195	340	3.767	13.561
0 days 00:14:10	running	3.747	3.919	1240	4	275374	###	91	4	185	22.02987766	60.47754999	340	3.747	13.489
0 days 00:14:11	running	3.747	3.919	1240	4	275712	###	91	4	184	22.0299168	60.47752736	338	3.747	13.489
0 days 00:14:12	running	3.747	3.919	1240	4	276048	###	91	4	185	22.02995586	60.47750473	336	3.747	13.489

0 days 00:14:13	running	3.731	3.897	1230	4	276384	###	91	4	184	22.0299945	60.47747824	336	3.731	13.432
0 days 00:14:14	running	3.714	3.877	1220	4	276720	###	91	4	184	22.03003323	60.47745184	336	3.714	13.37
0 days 00:14:15	running	3.714	3.794	1210	4	277054	###	92	4	184	22.03007597	60.47742284	334	3.714	13.37
0 days 00:14:16	running	3.714	3.713	1210	4	277386	###	92	4	185	22.03011889	60.47739392	332	3.714	13.37
0 days 00:14:17	running	3.714	3.713	1210	4	277711	###	92	4	184	22.03016558	60.47736676	325	3.714	13.37
0 days 00:14:18	running	3.714	3.713	1210	4	278029	###	92	4	185	22.03021226	60.47733961	318	3.714	13.37
0 days 00:14:19	running	3.717	3.716	1210	4	278347	###	92	4	185	22.03025912	60.47731304	318	3.717	13.381
0 days 00:14:20	running	3.722	3.722	1210	5	278665	###	92	5	185	22.03030597	60.47728655	318	3.722	13.399
0 days 00:14:21	running	3.722	3.722	1210	5	278983	###	92	5	185	22.03035308	60.47726182	318	3.722	13.399
0 days 00:14:22	running	3.722	3.722	1210	5	279301	###	92	5	185	22.03040019	60.47723726	318	3.722	13.399
0 days 00:14:23	running	3.733	3.733	1210	5	279619	###	92	5	185	22.03044897	60.47721438	318	3.733	13.439
0 days 00:14:24	running	3.747	3.747	1220	5	279937	###	92	5	185	22.03049775	60.47719175	318	3.747	13.489
0 days 00:14:25	running	3.747	3.747	1220	5	280256	###	92	5	184	22.03054645	60.47716828	319	3.747	13.489
0 days 00:14:26	running	3.747	3.747	1220	5	280577	###	92	5	184	22.03059532	60.47714506	321	3.747	13.489
0 days 00:14:27	running	3.747	3.747	1220	5	280898	###	91	5	184	22.03064376	60.47712143	321	3.747	13.489
0 days 00:14:28	running	3.747	3.747	1220	5	281219	###	91	5	184	22.0306923	60.47709796	321	3.747	13.489
0 days 00:14:29	running	3.753	3.752	1230	5	281540	###	91	5	184	22.03073907	60.47707465	321	3.753	13.511
0 days 00:14:30	running	3.761	3.761	1240	5	281861	###	91	5	184	22.03078601	60.47705144	321	3.761	13.54
0 days 00:14:31	running	3.761	3.761	1240	5	282182	###	91	5	185	22.03083353	60.47702931	321	3.761	13.54
0 days 00:14:32	running	3.761	3.761	1240	5	282504	###	91	5	184	22.03088106	60.47700735	322	3.761	13.54
0 days 00:14:33	running	3.747	3.836	1240	5	282826	###	91	5	184	22.03093261	60.4769874	322	3.747	13.489
0 days 00:14:34	running	3.736	3.911	1240	5	283148	###	91	5	184	22.03098407	60.47696753	322	3.736	13.45
0 days 00:14:35	running	3.736	3.911	1230	5	283476	###	91	5	184	22.03103998	60.47694909	328	3.736	13.45
0 days 00:14:36	running	3.736	3.911	1230	5	283811	###	91	5	184	22.03109597	60.47693082	335	3.736	13.45
0 days 00:14:37	running	3.736	3.822	1230	5	284146	###	91	5	184	22.03115297	60.47691263	335	3.736	13.45
0 days 00:14:38	running	3.736	3.736	1230	5	284481	###	91	5	184	22.03120996	60.47689453	335	3.736	13.45
0 days 00:14:39	running	3.722	3.722	1230	5	284808	###	90	5	184	22.03126595	60.47687726	327	3.722	13.399
0 days 00:14:40	running	3.708	3.708	1240	6	285128	###	90	6	184	22.03132203	60.47685991	320	3.708	13.349
0 days 00:14:41	running	3.708	3.708	1240	5	285447	###	90	5	183	22.03137768	60.47684331	319	3.708	13.349
0 days 00:14:42	running	3.708	3.708	1240	5	285765	###	90	5	183	22.03143342	60.4768268	318	3.708	13.349
0 days 00:14:43	running	3.689	3.613	1230	5	286083	###	90	5	183	22.03149118	60.47681021	318	3.689	13.28
0 days 00:14:44	running	3.669	3.519	1220	5	286401	###	90	5	183	22.03154901	60.47679361	318	3.669	13.208
0 days 00:14:45	running	3.669	3.45	1220	5	286710	###	90	5	183	22.03160978	60.47677903	309	3.669	13.208
0 days 00:14:46	running	3.669	3.383	1220	5	287010	###	91	5	183	22.03167072	60.47676444	300	3.669	13.208
0 days 00:14:47	running	3.669	3.322	1210	5	287303	###	91	5	183	22.03173358	60.47675229	293	3.669	13.208
0 days 00:14:48	running	3.669	3.261	1200	5	287590	###	91	5	183	22.03179661	60.47674022	287	3.669	13.208
0 days 00:14:49	running	3.667	3.255	1200	5	287870	###	91	5	184	22.03186082	60.47672966	280	3.667	13.201
0 days 00:14:50	running	3.664	3.252	1200	5	288144	###	91	5	183	22.03192511	60.47671909	274	3.664	13.19
0 days 00:14:51	running	3.664	3.311	1200	5	288418	###	91	5	183	22.03198873	60.47670954	274	3.664	13.19
0 days 00:14:52	running	3.664	3.372	1200	5	288692	###	91	5	183	22.03205243	60.4766999	274	3.664	13.19
0 days 00:14:53	running	3.669	3.45	1200	5	288972	###	91	5	183	22.03211722	60.4766906	280	3.669	13.208
0 days 00:14:54	running	3.678	3.527	1210	5	289258	###	91	5	184	22.03218201	60.47668129	286	3.678	13.241
0 days 00:14:55	running	3.678	3.602	1210	5	289551	###	90	5	184	22.0322453	60.47667199	293	3.678	13.241
0 days 00:14:56	running	3.678	3.677	1210	5	289852	###	90	5	184	22.03230858	60.47666285	301	3.678	13.241
0 days 00:14:57	running	3.678	3.677	1220	5	290160	###	89	5	183	22.03237119	60.47665246	308	3.678	13.241
0 days 00:14:58	running	3.678	3.677	1240	5	290475	###	89	5	183	22.0324338	60.47664215	315	3.678	13.241
0 days 00:14:59	running	3.672	3.672	1230	5	290790	###	89	5	183	22.03249767	60.47663083	315	3.672	13.219
0 days 00:15:00	running	3.669	3.669	1230	5	291105	###	90	5	183	22.03256171	60.47661952	315	3.669	13.208
0 days 00:15:01	running	3.669	3.752	1230	4	291419	###	89	4	183	22.03262256	60.4766072	314	3.669	13.208
0 days 00:15:02	running	3.669	3.836	1230	4	291733	###	88	4	183	22.0326835	60.47659496	314	3.669	13.208
0 days 00:15:03	running	3.65	3.813	1230	4	292054	###	89	4	183	22.03274502	60.47658188	321	3.65	13.14
0 days 00:15:04	running	3.633	3.794	1230	4	292383	###	89	4	183	22.03280663	60.47656889	329	3.633	13.079
0 days 00:15:05	running	3.633	3.883	1220	4	292710	###	89	4	183	22.03287126	60.4765559	327	3.633	13.079
0 days 00:15:06	running	3.633	3.975	1220	4	293035	###	90	4	183	22.03293596	60.47654291	325	3.633	13.079
0 days 00:15:07	running	3.633	3.975	1220	4	293368	###	89	4	183	22.03300218	60.47652941	333	3.633	13.079
0 days 00:15:08	running	3.633	3.975	1220	4	293709	###	89	4	183	22.0330684	60.47651592	341	3.633	13.079
0 days 00:15:09	running	3.622	3.963	1210	4	294050	###	90	4	183	22.03313403	60.476502	341	3.622	13.039
0 days 00:15:10	running	3.614	3.952	1210	4	294391	###	91	4	183	22.03319957	60.47648826	341	3.614	13.01
0 days 00:15:11	running	3.614	3.863	1190	4	294731	###	91	4	183	22.03326521	60.4764756	340	3.614	13.01
0 days 00:15:12	running	3.614	3.775	1180	4	295070	###	92	4	183	22.03333092	60.47646303	339	3.614	13.01
0 days 00:15:13	running	3.628	3.788	1180	4	295401	###	92	4	183	22.03339186	60.47645339	331	3.628	13.061
0 days 00:15:14	running	3.642	3.805	1190	4	295724	###	92	4	183	22.03345288	60.47644383	323	3.642	13.111
0 days 00:15:15	running	3.642	3.805	1170	5	296048	###	93	5	183	22.03351457	60.4764352	324	3.642	13.111
0 days 00:15:16	running	3.642	3.805	1160	4	296374	###	94	4	183	22.03357626	60.47642665	326	3.642	13.111
0 days 00:15:17	running	3.642	3.805	1170	4	296700	###	93	4	184	22.03363837	60.47641818	326	3.642	13.111
0 days 00:15:18	running	3.642	3.805	1180	4	297026	###	93	4	184	22.03370056	60.47640989	326	3.642	13.111
0 days 00:15:19	running	3.681	3.847	1190	4	297352	###	93	4	184	22.0337651	60.47640033	326	3.681	13.252
0 days 00:15:20	running	3.722	3.888	1200	4	297678	###	93	4	184	22.03382956	60.47639069	326	3.722	13.399
0 days 00:15:21	running	3.722	3.888	1210	4	298007	###	92	4	184	22.03389376	60.47637946	329	3.722	13.399
0 days 00:15:22	running	3.722	3.888	1230	4	298340	###	91	4	184	22.03395797	60.47636823	333	3.722	13.399
0 days 00:15:23	running	3.733	3.899	1230	4	298673	###	90	4	184	22.03401815	60.47635482	333	3.733	13.439

Appendix A : Naantali Run Data

0 days 00:15:24	running	3.744	3.911	1240	4	299006	###	90	4	184	22.0340785	60.47634141	333	3.744	13.478
0 days 00:15:25	running	3.744	3.827	1250	4	299340	###	90	4	184	22.03414002	60.47632699	334	3.744	13.478
0 days 00:15:26	running	3.744	3.744	1260	4	299675	###	89	4	183	22.03420163	60.47631266	335	3.744	13.478
0 days 00:15:27	running	3.744	3.744	1250	4	300002	###	89	4	183	22.0342629	60.47629816	327	3.744	13.478
0 days 00:15:28	running	3.744	3.744	1250	4	300322	###	90	4	183	22.03432417	60.47628365	320	3.744	13.478
0 days 00:15:29	running	3.722	3.722	1240	4	300642	###	90	4	183	22.0343867	60.4762689	320	3.722	13.399
0 days 00:15:30	running	3.7	3.699	1230	4	300962	###	90	4	183	22.03444932	60.47625432	320	3.7	13.32
0 days 00:15:31	running	3.7	3.699	1220	4	301280	###	91	4	183	22.03450866	60.47624032	318	3.7	13.32
0 days 00:15:32	running	3.7	3.699	1210	4	301597	###	92	4	183	22.03456817	60.47622641	317	3.7	13.32
0 days 00:15:33	running	3.7	3.622	1200	4	301914	###	92	4	183	22.03462886	60.47621015	317	3.7	13.32
0 days 00:15:34	running	3.703	3.547	1190	4	302231	###	93	4	183	22.03468971	60.4761938	317	3.703	13.331
0 days 00:15:35	running	3.703	3.547	1190	4	302541	###	92	4	183	22.03474889	60.47617679	310	3.703	13.331
0 days 00:15:36	running	3.703	3.547	1200	4	302844	###	92	4	183	22.03480823	60.47615985	303	3.703	13.331
0 days 00:15:37	running	3.703	3.625	1200	4	303147	###	92	4	183	22.03486129	60.47614376	303	3.703	13.331
0 days 00:15:38	running	3.703	3.702	1210	4	303450	###	91	4	183	22.03491443	60.47612775	303	3.703	13.331
0 days 00:15:39	running	3.714	3.713	1220	4	303760	###	91	4	183	22.03495977	60.4761068	310	3.714	13.37
0 days 00:15:40	running	3.728	3.727	1240	4	304077	###	90	4	183	22.03500529	60.47608593	317	3.728	13.421
0 days 00:15:41	running	3.728	3.727	1250	4	304395	###	89	4	183	22.0350368	60.47605944	318	3.728	13.421
0 days 00:15:42	running	3.728	3.727	1260	4	304714	###	88	4	183	22.03506832	60.47603304	319	3.728	13.421
0 days 00:15:43	running	3.697	3.697	1260	4	305033	###	88	4	183	22.03508751	60.47600336	319	3.697	13.309
0 days 00:15:44	running	3.669	3.669	1260	4	305352	###	87	4	184	22.03510671	60.47597361	319	3.669	13.208
0 days 00:15:45	running	3.669	3.669	1250	4	305668	###	87	4	184	22.0351145	60.47594176	316	3.669	13.208
0 days 00:15:46	running	3.669	3.669	1250	4	305982	###	88	4	184	22.0351223	60.47590991	314	3.669	13.208
0 days 00:15:47	running	3.669	3.669	1240	4	306296	###	88	4	183	22.03512347	60.47587453	314	3.669	13.208
0 days 00:15:48	running	3.669	3.669	1240	4	306610	###	88	4	183	22.03512473	60.47583916	314	3.669	13.208
0 days 00:15:49	running	3.631	3.63	1220	4	306924	###	89	4	183	22.0351254	60.47580245	314	3.631	13.072
0 days 00:15:50	running	3.594	3.594	1200	4	307238	###	90	4	183	22.03512616	60.47576574	314	3.594	12.938
0 days 00:15:51	running	3.594	3.594	1200	4	307548	###	90	4	183	22.03512842	60.47573028	310	3.594	12.938
0 days 00:15:52	running	3.594	3.594	1200	4	307855	###	90	4	184	22.03513068	60.47569491	307	3.594	12.938
0 days 00:15:53	running	3.594	3.594	1200	4	308162	###	90	4	184	22.03513496	60.47566113	307	3.594	12.938
0 days 00:15:54	running	3.597	3.597	1200	4	308469	###	90	4	184	22.03513931	60.47562744	307	3.597	12.949
0 days 00:15:55	running	3.597	3.597	1200	4	308776	###	90	4	183	22.03514736	60.47559273	307	3.597	12.949
0 days 00:15:56	running	3.597	3.597	1200	4	309084	###	90	4	183	22.03515558	60.47555803	308	3.597	12.949
0 days 00:15:57	running	3.597	3.522	1190	4	309392	###	90	4	183	22.03516463	60.475523	308	3.597	12.949
0 days 00:15:58	running	3.597	3.45	1190	4	309700	###	90	4	182	22.0351736	60.47548804	308	3.597	12.949
0 days 00:15:59	running	3.617	3.402	1200	4	310001	###	90	4	182	22.03518097	60.47545284	301	3.617	13.021
0 days 00:16:00	running	3.636	3.355	1210	4	310295	###	90	4	183	22.03518843	60.47541764	294	3.636	13.09
0 days 00:16:01	running	3.636	3.294	1210	4	310584	###	90	4	183	22.03519866	60.47538285	289	3.636	13.09
0 days 00:16:02	running	3.636	3.233	1210	4	310869	###	90	4	183	22.03520905	60.47534798	285	3.636	13.09
0 days 00:16:03	running	3.653	3.247	1210	4	311147	###	90	4	183	22.03523319	60.47531823	278	3.653	13.151
0 days 00:16:04	running	3.669	3.261	1220	4	311419	###	90	4	182	22.03525733	60.47528839	272	3.669	13.208
0 days 00:16:05	running	3.669	3.322	1220	4	311692	###	90	4	183	22.03530352	60.47526986	273	3.669	13.208
0 days 00:16:06	running	3.669	3.383	1220	4	311966	###	90	4	182	22.03534978	60.47525134	274	3.669	13.208
0 days 00:16:07	running	3.669	3.524	1210	4	312246	###	90	4	182	22.03541256	60.47524413	280	3.669	13.208
0 days 00:16:08	running	3.669	3.669	1210	4	312533	###	91	4	182	22.03547551	60.47523692	287	3.669	13.208
0 days 00:16:09	running	3.672	3.672	1210	4	312833	###	90	4	182	22.035546	60.47523558	300	3.672	13.219
0 days 00:16:10	running	3.678	3.677	1220	4	313147	###	90	4	182	22.0356165	60.47523441	314	3.678	13.241
0 days 00:16:11	running	3.678	3.761	1220	4	313461	###	90	4	181	22.03568665	60.4752334	314	3.678	13.241
0 days 00:16:12	running	3.678	3.847	1220	4	313776	###	90	4	182	22.03575698	60.47523256	315	3.678	13.241
0 days 00:16:13	running	3.678	3.938	1220	4	314098	###	90	4	181	22.03582479	60.47522753	322	3.678	13.241
0 days 00:16:14	running	3.681	4.03	1230	4	314428	###	90	4	181	22.0358926	60.47522259	330	3.681	13.252
0 days 00:16:15	running	3.681	4.13	1220	5	314765	###	90	5	181	22.03595613	60.47521253	337	3.681	13.252
0 days 00:16:16	running	3.681	4.23	1220	5	315110	###	90	5	181	22.03601967	60.47520239	345	3.681	13.252
0 days 00:16:17	running	3.681	4.23	1210	5	315463	###	91	5	181	22.03607541	60.47518705	353	3.681	13.252
0 days 00:16:18	running	3.681	4.23	1210	5	315825	###	91	5	182	22.03613123	60.47517163	362	3.681	13.252
0 days 00:16:19	running	3.678	4.23	1210	5	316187	###	91	5	182	22.03618135	60.47514958	362	3.678	13.241
0 days 00:16:20	running	3.675	4.23	1210	5	316549	###	91	5	182	22.03623156	60.47512762	362	3.675	13.23
0 days 00:16:21	running	3.675	4.23	1210	5	316911	###	91	5	183	22.03627448	60.47510231	362	3.675	13.23
0 days 00:16:22	running	3.675	4.23	1210	5	317273	###	91	5	183	22.03631748	60.47507716	362	3.675	13.23
0 days 00:16:23	running	3.686	4.241	1210	5	317635	###	91	5	183	22.03635687	60.47505126	362	3.686	13.27
0 days 00:16:24	running	3.697	4.252	1210	5	317997	###	92	5	183	22.03639643	60.47502536	362	3.697	13.309
0 days 00:16:25	running	3.697	4.252	1210	6	318359	###	91	6	183	22.03643851	60.47500181	362	3.697	13.309
0 days 00:16:26	running	3.697	4.252	1210	5	318722	###	91	5	183	22.03648067	60.47497834	363	3.697	13.309
0 days 00:16:27	running	3.697	4.152	1210	5	319085	###	91	5	183	22.03653172	60.47496133	363	3.697	13.309
0 days 00:16:28	running	3.697	4.052	1210	5	319448	###	91	5	183	22.03658268	60.47494439	363	3.697	13.309
0 days 00:16:29	running	3.7	3.963	1200	5	319803	###	92	5	183	22.03664613	60.4749361	355	3.7	13.32
0 days 00:16:30	running	3.706	3.877	1200	5	320150	###	93	5	184	22.03670958	60.4749278	347	3.706	13.342
0 days 00:16:31	running	3.706	3.791	1200	5	320489	###	92	5	184	22.03677571	60.47492545	339	3.706	13.342
0 days 00:16:32	running	3.706	3.705	1200	5	320821	###	92	5	184	22.03684176	60.4749231	332	3.706	13.342
0 days 00:16:33	running	3.714	3.713	1200	5	321146	###	92	5	184	22.03690915	60.47492	325	3.714	13.37
0 days 00:16:34	running	3.725	3.724	1200	5	321464	###	93	5	184	22.03697663	60.4749169	318	3.725	13.41

Appendix A : Naantali Run Data

0 days 00:16:35	running	3.725	3.724	1200	5	321782	###	92	5	184	22.03704092	60.47490844	318	3.725	13.41
0 days 00:16:36	running	3.725	3.724	1200	4	322101	###	92	4	184	22.03710521	60.47490005	319	3.725	13.41
0 days 00:16:37	running	3.725	3.65	1210	4	322420	###	91	4	184	22.03715659	60.4748822	319	3.725	13.41
0 days 00:16:38	running	3.725	3.574	1220	4	322739	###	90	4	184	22.03720805	60.47486451	319	3.725	13.41
0 days 00:16:39	running	3.728	3.574	1230	4	323051	###	89	4	185	22.03723127	60.4748392	312	3.728	13.421
0 days 00:16:40	running	3.731	3.574	1240	4	323356	###	89	4	185	22.03725449	60.47481406	305	3.731	13.432
0 days 00:16:41	running	3.711	3.555	1240	4	323661	###	89	4	185	22.03725063	60.47478405	305	3.711	13.36
0 days 00:16:42	running	3.692	3.538	1240	4	323966	###	90	4	184	22.03724678	60.47475404	305	3.692	13.291
0 days 00:16:43	running	3.631	3.48	1210	4	324269	###	90	4	184	22.03722716	60.47472035	303	3.631	13.072
0 days 00:16:44	running	3.569	3.422	1190	4	324571	###	90	4	184	22.03720763	60.47468665	302	3.569	12.848
0 days 00:16:45	running	3.572	3.427	1180	4	324868	###	90	4	184	22.03718266	60.47465254	297	3.572	12.859
0 days 00:16:46	running	3.578	3.433	1180	4	325160	###	91	4	185	22.03715793	60.47461842	292	3.578	12.881
0 days 00:16:47	running	3.586	3.436	1180	4	325452	###	91	4	185	22.03713236	60.4745859	292	3.586	12.91
0 days 00:16:48	running	3.594	3.441	1180	4	325745	###	91	4	185	22.03710697	60.47455346	293	3.594	12.938
0 days 00:16:49	running	3.6	3.45	1180	4	326038	###	91	4	185	22.03708593	60.47452278	293	3.6	12.96
0 days 00:16:50	running	3.606	3.461	1190	4	326332	###	91	4	185	22.03706489	60.47449236	294	3.606	12.982
0 days 00:16:51	running	3.606	3.461	1190	3	326626	###	90	3	185	22.03704846	60.4744616	294	3.606	12.982
0 days 00:16:52	running	3.606	3.461	1200	3	326921	###	90	3	185	22.03703212	60.474431	295	3.606	12.982
0 days 00:16:53	running	3.606	3.533	1200	3	327216	###	90	3	185	22.03701619	60.47440133	295	3.606	12.982
0 days 00:16:54	running	3.606	3.605	1200	3	327511	###	90	3	185	22.03700043	60.47437166	295	3.606	12.982
0 days 00:16:55	running	3.606	3.605	1200	3	327813	###	90	3	185	22.03697789	60.47434433	302	3.606	12.982
0 days 00:16:56	running	3.606	3.605	1200	3	328122	###	90	3	184	22.03695551	60.47431709	309	3.606	12.982
0 days 00:16:57	running	3.6	3.6	1190	3	328431	###	90	3	184	22.03691787	60.47430192	309	3.6	12.96
0 days 00:16:58	running	3.594	3.594	1190	3	328740	###	90	3	184	22.0368804	60.47428675	309	3.594	12.938
0 days 00:16:59	running	3.594	3.594	1200	3	329048	###	90	3	184	22.03683372	60.47429119	308	3.594	12.938
0 days 00:17:00	running	3.594	3.594	1210	3	329355	###	89	3	184	22.03678711	60.47429572	307	3.594	12.938
0 days 00:17:01	running	3.569	3.569	1200	3	329662	###	89	3	184	22.03673892	60.47431491	307	3.569	12.848
0 days 00:17:02	running	3.544	3.544	1190	3	329969	###	89	3	185	22.03669072	60.47433411	307	3.544	12.758
0 days 00:17:03	running	3.544	3.544	1190	3	330274	###	89	3	185	22.03664387	60.47436051	305	3.544	12.758
0 days 00:17:04	running	3.544	3.544	1190	3	330577	###	89	3	184	22.0365971	60.47438691	303	3.544	12.758
0 days 00:17:05	running	3.544	3.544	1180	3	330880	###	89	3	185	22.03655133	60.47441516	303	3.544	12.758
0 days 00:17:06	running	3.544	3.544	1180	3	331183	###	90	3	185	22.03650548	60.47444341	303	3.544	12.758
0 days 00:17:07	running	3.522	3.522	1170	3	331486	###	90	3	185	22.03645921	60.47447174	303	3.522	12.679
0 days 00:17:08	running	3.5	3.5	1170	3	331789	###	90	3	185	22.03641303	60.47449999	303	3.5	12.6
0 days 00:17:09	running	3.5	3.5	1170	3	332090	###	90	3	184	22.03636349	60.4745253	301	3.5	12.6
0 days 00:17:10	running	3.5	3.5	1170	3	332390	###	90	3	184	22.03631412	60.47455061	300	3.5	12.6
0 days 00:17:11	running	3.497	3.497	1170	3	332690	###	89	3	184	22.03626241	60.47457266	300	3.497	12.589
0 days 00:17:12	running	3.494	3.494	1170	3	332990	###	89	3	185	22.03621077	60.4745947	300	3.494	12.578
0 days 00:17:13	running	3.494	3.494	1170	3	333289	###	89	3	185	22.03615562	60.47461448	299	3.494	12.578
0 days 00:17:14	running	3.494	3.494	1170	3	333588	###	89	3	185	22.03610047	60.47463435	299	3.494	12.578
0 days 00:17:15	running	3.494	3.494	1170	3	333887	###	89	3	186	22.03604079	60.4746512	299	3.494	12.578
0 days 00:17:16	running	3.494	3.494	1180	3	334186	###	89	3	185	22.03598119	60.47466821	299	3.494	12.578
0 days 00:17:17	running	3.5	3.58	1180	3	334485	###	88	3	185	22.03591808	60.4746812	299	3.5	12.6
0 days 00:17:18	running	3.506	3.669	1190	3	334784	###	88	3	185	22.03585496	60.47469419	299	3.506	12.622
0 days 00:17:19	running	3.506	3.755	1180	3	335090	###	89	3	185	22.03578933	60.47470526	306	3.506	12.622
0 days 00:17:20	running	3.506	3.844	1180	3	335404	###	89	3	185	22.03572362	60.47471624	314	3.506	12.622
0 days 00:17:21	running	3.511	3.849	1180	3	335725	###	89	3	186	22.03565916	60.47472856	321	3.511	12.64
0 days 00:17:22	running	3.517	3.855	1180	3	336054	###	89	3	185	22.03559479	60.47474088	329	3.517	12.661
0 days 00:17:23	running	3.517	3.855	1170	3	336383	###	89	3	185	22.03553427	60.47475723	329	3.517	12.661
0 days 00:17:24	running	3.517	3.855	1170	3	336713	###	90	3	185	22.03547392	60.47477365	330	3.517	12.661
0 days 00:17:25	running	3.517	3.855	1160	3	337043	###	91	3	185	22.03541768	60.47479344	330	3.517	12.661
0 days 00:17:26	running	3.517	3.855	1150	3	337373	###	92	3	185	22.03536152	60.47481322	330	3.517	12.661
0 days 00:17:27	running	3.533	3.783	1150	3	337703	###	92	3	185	22.0353088	60.47483585	330	3.533	12.719
0 days 00:17:28	running	3.553	3.711	1160	3	338033	###	92	3	185	22.03525616	60.4748584	330	3.553	12.791
0 days 00:17:29	running	3.553	3.711	1160	3	338357	###	92	3	185	22.03520562	60.47488203	324	3.553	12.791
0 days 00:17:30	running	3.553	3.711	1160	4	338675	###	92	4	185	22.03515499	60.47490575	318	3.553	12.791
0 days 00:17:31	running	3.581	3.661	1170	4	338993	###	92	4	186	22.03510176	60.47492646	318	3.581	12.892
0 days 00:17:32	running	3.611	3.611	1180	4	339311	###	92	4	185	22.03504862	60.47494724	318	3.611	13
0 days 00:17:33	running	3.611	3.611	1180	4	339624	###	91	4	186	22.03498936	60.47496082	313	3.611	13
0 days 00:17:34	running	3.611	3.611	1180	4	339933	###	91	4	186	22.03493027	60.47497449	309	3.611	13
0 days 00:17:35	running	3.611	3.611	1180	4	340242	###	91	4	186	22.03486347	60.47497792	309	3.611	13
0 days 00:17:36	running	3.611	3.611	1180	4	340551	###	91	4	186	22.03479683	60.47498136	309	3.611	13
0 days 00:17:37	running	3.628	3.549	1180	4	340860	###	91	4	187	22.03472718	60.47497683	309	3.628	13.061
0 days 00:17:38	running	3.644	3.488	1190	4	341169	###	92	4	188	22.03465769	60.47497231	309	3.644	13.118
0 days 00:17:39	running	3.644	3.488	1190	4	341472	###	92	4	187	22.03458787	60.47496493	303	3.644	13.118
0 days 00:17:40	running	3.644	3.488	1190	4	341770	###	92	4	186	22.03451813	60.47495755	298	3.644	13.118
0 days 00:17:41	running	3.661	3.508	1180	4	342068	###	92	4	186	22.03444948	60.47495252	298	3.661	13.18
0 days 00:17:42	running	3.678	3.527	1180	4	342366	###	93	4	186	22.03438092	60.47494766	298	3.678	13.241
0 days 00:17:43	running	3.717	3.566	1190	4	342665	###	93	4	186	22.03431319	60.47494775	299	3.717	13.381
0 days 00:17:44	running	3.758	3.605	1200	4	342966	###	94	4	187	22.03424547	60.47494791	301	3.758	13.529
0 days 00:17:45	running	3.767	3.688	1200	4	343270	###	93	4	186	22.03417758	60.47495202	304	3.767	13.561

Appendix A : Naantali Run Data

0 days 00:17:46	running	3.775	3.775	1210	4	343577	###	93	4	186	22.03410968	60.47495621	307	3.775	13.59
0 days 00:17:47	running	3.769	3.769	1210	4	343892	###	92	4	186	22.03404095	60.47496191	315	3.769	13.568
0 days 00:17:48	running	3.764	3.763	1220	4	344216	###	91	4	186	22.03397239	60.47496761	324	3.764	13.55
0 days 00:17:49	running	3.742	3.741	1220	4	344539	###	91	4	186	22.03390407	60.47497264	323	3.742	13.471
0 days 00:17:50	running	3.722	3.722	1230	4	344861	###	92	4	185	22.03383593	60.47497759	322	3.722	13.399
0 days 00:17:51	running	3.717	3.716	1210	4	345181	###	92	4	185	22.03376996	60.47498412	320	3.717	13.381
0 days 00:17:52	running	3.711	3.711	1200	4	345499	###	92	4	186	22.03370417	60.47499066	318	3.711	13.36
0 days 00:17:53	running	3.711	3.711	1200	4	345817	###	92	4	186	22.0336418	60.47499913	318	3.711	13.36
0 days 00:17:54	running	3.711	3.711	1200	4	346135	###	92	4	186	22.03357936	60.47500776	318	3.711	13.36
0 days 00:17:55	running	3.711	3.711	1200	4	346453	###	92	4	186	22.03351817	60.47501832	318	3.711	13.36
0 days 00:17:56	running	3.711	3.711	1200	4	346771	###	93	4	186	22.03345707	60.47502888	318	3.711	13.36
0 days 00:17:57	running	3.711	3.794	1200	4	347089	###	93	4	186	22.03339521	60.47504012	318	3.711	13.36
0 days 00:17:58	running	3.714	3.877	1200	4	347407	###	93	4	185	22.03333335	60.47505135	318	3.714	13.37
0 days 00:17:59	running	3.714	3.877	1200	4	347732	###	92	4	185	22.03326998	60.47506191	325	3.714	13.37
0 days 00:18:00	running	3.714	3.877	1210	4	348064	###	92	4	186	22.03320662	60.47507264	332	3.714	13.37
0 days 00:18:01	running	3.717	3.883	1210	4	348396	###	92	4	186	22.03314166	60.47508119	332	3.717	13.381
0 days 00:18:02	running	3.719	3.888	1210	4	348728	###	92	4	186	22.03307678	60.47508982	332	3.719	13.388
0 days 00:18:03	running	3.719	3.888	1210	4	349060	###	92	4	186	22.0330109	60.47509745	332	3.719	13.388
0 days 00:18:04	running	3.719	3.888	1210	4	349393	###	92	4	185	22.03294502	60.47510516	333	3.719	13.388
0 days 00:18:05	running	3.719	3.888	1210	4	349726	###	92	4	185	22.03287813	60.47511195	333	3.719	13.388
0 days 00:18:06	running	3.719	3.888	1210	4	350059	###	92	4	186	22.03281133	60.47511874	333	3.719	13.388
0 days 00:18:07	running	3.714	3.883	1200	4	350392	###	92	4	186	22.03274452	60.47512444	333	3.714	13.37
0 days 00:18:08	running	3.708	3.877	1200	4	350725	###	92	4	186	22.0326778	60.47513014	333	3.708	13.349
0 days 00:18:09	running	3.708	3.969	1200	4	351057	###	92	4	186	22.03261552	60.4751329	332	3.708	13.349
0 days 00:18:10	running	3.708	4.063	1200	5	351389	###	92	5	186	22.03255333	60.47513575	332	3.708	13.349
0 days 00:18:11	running	3.703	4.158	1200	5	351729	###	92	5	186	22.0324929	60.47513198	340	3.703	13.331
0 days 00:18:12	running	3.7	4.252	1210	5	352077	###	92	5	186	22.03243246	60.47512829	348	3.7	13.32
0 days 00:18:13	running	3.7	4.252	1220	5	352432	###	91	5	186	22.0323706	60.47511731	355	3.7	13.32
0 days 00:18:14	running	3.7	4.252	1230	5	352795	###	90	5	187	22.03230883	60.47510633	363	3.7	13.32
0 days 00:18:15	running	3.7	4.358	1230	5	353158	###	89	5	187	22.03224571	60.47509292	363	3.7	13.32
0 days 00:18:16	running	3.7	4.466	1230	5	353521	###	89	5	187	22.0321826	60.47507959	363	3.7	13.32
0 days 00:18:17	running	3.681	4.236	1230	5	353893	###	88	5	187	22.03211303	60.47506426	372	3.681	13.252
0 days 00:18:18	running	3.661	4.008	1240	5	354274	###	88	5	187	22.03204338	60.47504883	381	3.661	13.18
0 days 00:18:19	running	3.661	3.916	1240	5	354636	###	88	5	188	22.03197598	60.47503173	362	3.661	13.18
0 days 00:18:20	running	3.661	3.827	1250	5	354979	###	88	5	189	22.03190859	60.47501463	343	3.661	13.18
0 days 00:18:21	running	3.628	3.711	1230	4	355314	###	89	4	188	22.03185889	60.47499401	335	3.628	13.061
0 days 00:18:22	running	3.594	3.594	1210	4	355642	###	89	4	188	22.03180918	60.4749734	328	3.594	12.938
0 days 00:18:23	running	3.594	3.594	1210	4	355959	###	89	4	188	22.03177842	60.4749459	317	3.594	12.938
0 days 00:18:24	running	3.594	3.594	1210	4	356266	###	89	4	188	22.03174766	60.47491849	307	3.594	12.938
0 days 00:18:25	running	3.594	3.516	1210	4	356573	###	89	4	188	22.031735	60.47488606	307	3.594	12.938
0 days 00:18:26	running	3.594	3.441	1210	4	356880	###	89	4	188	22.03172243	60.47485362	307	3.594	12.938
0 days 00:18:27	running	3.583	3.43	1200	4	357180	###	89	4	188	22.0317231	60.47481908	300	3.583	12.899
0 days 00:18:28	running	3.572	3.422	1200	4	357474	###	89	4	188	22.03172386	60.47478472	294	3.572	12.859
0 days 00:18:29	running	3.572	3.355	1190	4	357767	###	89	4	188	22.03173333	60.47475094	293	3.572	12.859
0 days 00:18:30	running	3.572	3.288	1190	4	358059	###	89	4	187	22.0317428	60.47471724	292	3.572	12.859
0 days 00:18:31	running	3.572	3.233	1190	4	358344	###	89	4	187	22.03175747	60.47468606	285	3.572	12.859
0 days 00:18:32	running	3.575	3.18	1190	4	358623	###	90	4	187	22.03177222	60.47465488	279	3.575	12.87
0 days 00:18:33	running	3.575	3.18	1190	4	358896	###	90	4	186	22.031792	60.4746253	273	3.575	12.87
0 days 00:18:34	running	3.575	3.18	1190	4	359164	###	90	4	186	22.03181178	60.47459571	268	3.575	12.87
0 days 00:18:35	running	3.575	3.127	1190	4	359432	###	90	4	186	22.03183617	60.47456645	268	3.575	12.87
0 days 00:18:36	running	3.575	3.077	1190	4	359700	###	90	4	186	22.03186057	60.4745372	268	3.575	12.87
0 days 00:18:37	running	3.572	3.125	1190	4	359962	###	89	4	186	22.03188999	60.47450736	262	3.572	12.859
0 days 00:18:38	running	3.572	3.172	1200	4	360218	###	89	4	187	22.03191949	60.47447752	256	3.572	12.859
0 days 00:18:39	running	3.572	3.23	1210	4	360479	###	88	4	187	22.03195302	60.47444609	261	3.572	12.859
0 days 00:18:40	running	3.572	3.288	1220	4	360746	###	88	4	186	22.03198646	60.47441483	267	3.572	12.859
0 days 00:18:41	running	3.564	3.35	1210	4	361019	###	88	4	186	22.03202393	60.4743844	273	3.564	12.83
0 days 00:18:42	running	3.558	3.413	1210	4	361298	###	88	4	186	22.0320614	60.47435414	279	3.558	12.809
0 days 00:18:43	running	3.558	3.413	1210	4	361583	###	88	4	186	22.03209962	60.47432514	285	3.558	12.809
0 days 00:18:44	running	3.558	3.413	1210	4	361874	###	88	4	186	22.03213792	60.47429622	291	3.558	12.809
0 days 00:18:45	running	3.558	3.486	1200	4	362165	###	88	4	186	22.03217472	60.47426806	291	3.558	12.809
0 days 00:18:46	running	3.558	3.558	1190	3	362456	###	89	3	186	22.03221152	60.4742399	291	3.558	12.809
0 days 00:18:47	running	3.606	3.605	1190	3	362754	###	90	3	187	22.03224186	60.47421173	298	3.606	12.982
0 days 00:18:48	running	3.653	3.652	1190	3	363059	###	92	3	187	22.03227228	60.47418365	305	3.653	13.151
0 days 00:18:49	running	3.669	3.669	1190	3	363367	###	92	3	187	22.03228896	60.47415339	308	3.669	13.208
0 days 00:18:50	running	3.689	3.688	1200	3	363679	###	92	3	187	22.03230581	60.47412322	312	3.689	13.28
0 days 00:18:51	running	3.697	3.697	1200	3	363993	###	92	3	187	22.03230187	60.47409363	314	3.697	13.309
0 days 00:18:52	running	3.708	3.708	1210	3	364309	###	92	3	187	22.0322981	60.47406413	316	3.708	13.349
0 days 00:18:53	running	3.706	3.705	1210	3	364626	###	91	3	187	22.03227363	60.47403554	317	3.706	13.342
0 days 00:18:54	running	3.706	3.705	1220	3	364944	###	91	3	187	22.03224907	60.47400696	318	3.706	13.342
0 days 00:18:55	running	3.686	3.686	1220	3	365262	###	90	3	187	22.03220875	60.47398014	318	3.686	13.27
0 days 00:18:56	running	3.667	3.666	1220	3	365580	###	90	3	187	22.03216852	60.47395332	318	3.667	13.201

Appendix A : Naantali Run Data

0 days 00:18:57	running	3.667	3.666	1220	3	365896	###	89	3	188	22.03211538	60.47392951	316	3.667	13.201
0 days 00:18:58	running	3.667	3.666	1230	3	366210	###	89	3	188	22.0320624	60.47390579	314	3.667	13.201
0 days 00:18:59	running	3.667	3.666	1230	3	366524	###	89	3	188	22.03200038	60.47388844	314	3.667	13.201
0 days 00:19:00	running	3.667	3.666	1230	4	366838	###	89	4	188	22.03193852	60.47387101	314	3.667	13.201
0 days 00:19:01	running	3.653	3.825	1220	4	367152	###	89	4	187	22.03187037	60.47386128	314	3.653	13.151
0 days 00:19:02	running	3.642	3.986	1220	4	367466	###	89	4	187	22.03180231	60.47385165	314	3.642	13.111
0 days 00:19:03	running	3.642	4.083	1210	4	367793	###	90	4	187	22.03173283	60.47385139	327	3.642	13.111
0 days 00:19:04	running	3.642	4.183	1200	4	368134	###	91	4	188	22.03166342	60.47385123	341	3.642	13.111
0 days 00:19:05	running	3.642	4.288	1190	4	368483	###	91	4	188	22.03159469	60.4738586	349	3.642	13.111
0 days 00:19:06	running	3.642	4.394	1190	4	368841	###	91	4	187	22.03152613	60.47386615	358	3.642	13.111
0 days 00:19:07	running	3.644	4.4	1180	4	369207	###	92	4	188	22.03145807	60.47387704	366	3.644	13.118
0 days 00:19:08	running	3.647	4.408	1180	4	369581	###	92	4	188	22.03139009	60.47388794	374	3.647	13.129
0 days 00:19:09	running	3.647	4.522	1180	4	369956	###	92	4	188	22.0313222	60.47389699	375	3.647	13.129
0 days 00:19:10	running	3.647	4.636	1190	4	370332	###	92	4	188	22.0312543	60.47390621	376	3.647	13.129
0 days 00:19:11	running	3.669	4.544	1200	4	370716	###	91	4	187	22.03118767	60.47390998	384	3.669	13.208
0 days 00:19:12	running	3.692	4.455	1220	4	371109	###	91	4	187	22.03112111	60.47391392	393	3.692	13.291
0 days 00:19:13	running	3.692	4.455	1220	4	371495	###	90	4	188	22.03105733	60.4739094	386	3.692	13.291
0 days 00:19:14	running	3.692	4.455	1220	4	371875	###	90	4	188	22.03099363	60.47390504	380	3.692	13.291
0 days 00:19:15	running	3.692	4.455	1220	4	372255	###	90	4	188	22.03093168	60.47389221	380	3.692	13.291
0 days 00:19:16	running	3.692	4.455	1220	4	372635	###	91	4	188	22.03086991	60.47387956	380	3.692	13.291
0 days 00:19:17	running	3.692	4.347	1220	4	373015	###	91	4	188	22.03081082	60.47386154	380	3.692	13.291
0 days 00:19:18	running	3.694	4.241	1220	4	373395	###	91	4	189	22.03075172	60.4738436	380	3.694	13.298
0 days 00:19:19	running	3.694	4.141	1220	4	373766	###	91	4	188	22.03069121	60.47382323	371	3.694	13.298
0 days 00:19:20	running	3.694	4.041	1220	5	374129	###	91	5	188	22.03063069	60.47380295	363	3.694	13.298
0 days 00:19:21	running	3.694	3.955	1220	4	374483	###	91	4	188	22.03056791	60.47378182	354	3.694	13.298
0 days 00:19:22	running	3.697	3.869	1220	4	374829	###	91	4	188	22.03050521	60.47376079	346	3.697	13.309
0 days 00:19:23	running	3.697	3.783	1220	4	375167	###	91	4	188	22.03044562	60.47374075	338	3.697	13.309
0 days 00:19:24	running	3.697	3.697	1220	4	375498	###	91	4	188	22.03038602	60.47372072	331	3.697	13.309
0 days 00:19:25	running	3.697	3.622	1220	4	375822	###	91	4	188	22.0303255	60.47370253	324	3.697	13.309
0 days 00:19:26	running	3.697	3.547	1220	4	376139	###	91	4	188	22.03026499	60.47368434	317	3.697	13.309
0 days 00:19:27	running	3.7	3.483	1220	4	376449	###	91	4	188	22.03020296	60.47366959	310	3.7	13.32
0 days 00:19:28	running	3.706	3.419	1220	4	376752	###	91	4	187	22.0301411	60.47365501	303	3.706	13.342
0 days 00:19:29	running	3.706	3.419	1220	4	377048	###	91	4	187	22.0300774	60.47364285	296	3.706	13.342
0 days 00:19:30	running	3.706	3.419	1220	4	377338	###	91	4	187	22.0300137	60.4736307	290	3.706	13.342
0 days 00:19:31	running	3.711	3.422	1220	4	377628	###	91	4	187	22.02994899	60.47361938	290	3.711	13.36
0 days 00:19:32	running	3.719	3.427	1230	4	377918	###	91	4	187	22.02988436	60.47360823	290	3.719	13.388
0 days 00:19:33	running	3.753	3.53	1230	4	378208	###	91	4	186	22.02981672	60.47359684	290	3.753	13.511
0 days 00:19:34	running	3.786	3.633	1240	4	378499	###	91	4	187	22.029749	60.47358544	291	3.786	13.63
0 days 00:19:35	running	3.783	3.627	1240	4	378799	###	91	4	186	22.02968337	60.47357479	300	3.783	13.619
0 days 00:19:36	running	3.783	3.625	1240	4	379109	###	92	4	186	22.0296179	60.47356431	310	3.783	13.619
0 days 00:19:37	running	3.789	3.627	1240	4	379418	###	92	4	186	22.02955261	60.47355409	309	3.789	13.64
0 days 00:19:38	running	3.794	3.633	1240	4	379727	###	92	4	185	22.02948731	60.47354403	309	3.794	13.658
0 days 00:19:39	running	3.794	3.713	1240	4	380036	###	91	4	185	22.02942068	60.47353674	309	3.794	13.658
0 days 00:19:40	running	3.797	3.797	1250	4	380346	###	91	4	186	22.02935413	60.47352953	310	3.797	13.669
0 days 00:19:41	running	3.786	3.786	1250	4	380663	###	90	4	186	22.0292859	60.4735271	317	3.786	13.63
0 days 00:19:42	running	3.778	3.777	1250	4	380988	###	90	4	186	22.02921767	60.47352483	325	3.778	13.601
0 days 00:19:43	running	3.778	3.777	1250	4	381312	###	90	4	186	22.02914952	60.47352903	324	3.778	13.601
0 days 00:19:44	running	3.778	3.777	1250	4	381636	###	91	4	186	22.02908129	60.4735333	324	3.778	13.601
0 days 00:19:45	running	3.778	3.777	1250	4	381960	###	91	4	186	22.02901491	60.47354344	324	3.778	13.601
0 days 00:19:46	running	3.778	3.777	1250	4	382284	###	91	4	186	22.02894861	60.4735535	324	3.778	13.601
0 days 00:19:47	running	3.775	3.863	1240	4	382608	###	90	4	187	22.02888063	60.4735654	324	3.775	13.59
0 days 00:19:48	running	3.775	3.952	1240	4	382932	###	90	4	186	22.02881265	60.47357731	324	3.775	13.59
0 days 00:19:49	running	3.775	4.044	1240	4	383263	###	90	4	186	22.02874778	60.47358703	331	3.775	13.59
0 days 00:19:50	running	3.775	4.138	1250	4	383602	###	90	4	186	22.0286829	60.47359675	339	3.775	13.59
0 days 00:19:51	running	3.775	4.138	1260	4	383949	###	89	4	186	22.02861761	60.47360245	347	3.775	13.59
0 days 00:19:52	running	3.775	4.138	1270	4	384304	###	89	4	186	22.02855231	60.47360815	355	3.775	13.59
0 days 00:19:53	running	3.764	4.122	1260	4	384659	###	89	4	186	22.02848475	60.47361184	355	3.764	13.55
0 days 00:19:54	running	3.753	4.108	1260	4	385014	###	90	4	187	22.02841728	60.47361553	355	3.753	13.511
0 days 00:19:55	running	3.753	4.108	1250	4	385367	###	90	4	187	22.02834796	60.47362022	353	3.753	13.511
0 days 00:19:56	running	3.753	4.108	1250	4	385719	###	91	4	186	22.02827881	60.473625	352	3.753	13.511
0 days 00:19:57	running	3.744	4.008	1230	4	386071	###	91	4	187	22.02820899	60.47363036	352	3.744	13.478
0 days 00:19:58	running	3.736	3.911	1220	4	386423	###	92	4	187	22.02813917	60.47363564	352	3.736	13.45
0 days 00:19:59	running	3.736	3.822	1220	4	386766	###	91	4	187	22.02807186	60.47364092	343	3.736	13.45
0 days 00:20:00	running	3.736	3.736	1230	5	387101	###	91	5	187	22.02800472	60.47364629	335	3.736	13.45
0 days 00:20:01	running	3.736	3.736	1230	5	387428	###	91	5	187	22.02793683	60.47365216	327	3.736	13.45
0 days 00:20:02	running	3.736	3.736	1230	5	387748	###	91	5	187	22.02786902	60.47365794	320	3.736	13.45
0 days 00:20:03	running	3.747	3.747	1230	5	388068	###	92	5	187	22.02780163	60.47366641	320	3.747	13.489
0 days 00:20:04	running	3.758	3.758	1230	5	388388	###	92	5	187	22.02773415	60.47367504	320	3.758	13.529
0 days 00:20:05	running	3.758	3.758	1210	5	388709	###	93	5	187	22.02766676	60.47368744	321	3.758	13.529
0 days 00:20:06	running	3.758	3.758	1200	5	389031	###	94	5	187	22.02759946	60.47369985	322	3.758	13.529
0 days 00:20:07	running	3.783	3.783	1200	5	389353	###	95	5	187	22.0275345	60.47371334	322	3.783	13.619

0 days 00:20:08	running	3.811	3.811	1200	5	389675	###	96	5	186	22.02746962	60.47372684	322	3.811	13.72
0 days 00:20:09	running	3.811	3.811	1190	5	389999	###	96	5	186	22.02740542	60.47373983	324	3.811	13.72
0 days 00:20:10	running	3.811	3.811	1190	5	390325	###	96	5	186	22.02734121	60.47375282	326	3.811	13.72
0 days 00:20:11	running	3.811	3.811	1190	4	390651	###	95	4	187	22.02727902	60.4737597	326	3.811	13.72
0 days 00:20:12	running	3.811	3.811	1200	4	390977	###	95	4	187	22.02721682	60.47376674	326	3.811	13.72
0 days 00:20:13	running	3.856	3.855	1220	4	391303	###	94	4	187	22.02715203	60.47376405	326	3.856	13.882
0 days 00:20:14	running	3.903	3.902	1250	4	391629	###	94	4	187	22.02708716	60.47376129	326	3.903	14.051
0 days 00:20:15	running	3.903	3.902	1250	4	391959	###	93	4	187	22.02702127	60.47375333	330	3.903	14.051
0 days 00:20:16	running	3.903	3.902	1260	4	392293	###	93	4	187	22.02695539	60.47374545	334	3.903	14.051
0 days 00:20:17	running	3.906	3.905	1270	4	392627	###	92	4	187	22.02689043	60.47373748	334	3.906	14.062
0 days 00:20:18	running	3.908	3.908	1280	4	392961	###	92	4	187	22.02682547	60.47372969	334	3.908	14.069
0 days 00:20:19	running	3.908	3.997	1280	4	393295	###	91	4	188	22.0267647	60.47372793	334	3.908	14.069
0 days 00:20:20	running	3.908	4.088	1280	5	393630	###	91	5	187	22.02670385	60.47372625	335	3.908	14.069
0 days 00:20:21	running	3.908	4.186	1290	5	393972	###	91	5	187	22.02664811	60.47373069	342	3.908	14.069
0 days 00:20:22	running	3.908	4.283	1300	5	394322	###	90	5	187	22.02659237	60.4737353	350	3.908	14.069
0 days 00:20:23	running	3.869	4.341	1290	5	394680	###	89	5	188	22.02654325	60.47374855	358	3.869	13.928
0 days 00:20:24	running	3.833	4.402	1290	5	395047	###	89	5	187	22.0264943	60.47376171	367	3.833	13.799
0 days 00:20:25	running	3.833	4.402	1300	5	395418	###	88	5	187	22.02645047	60.47378216	371	3.833	13.799
0 days 00:20:26	running	3.833	4.402	1310	5	395794	###	88	5	188	22.02640671	60.47380261	376	3.833	13.799
0 days 00:20:27	running	3.767	4.327	1290	5	396170	###	87	5	188	22.02636698	60.47382692	376	3.767	13.561
0 days 00:20:28	running	3.7	4.252	1280	5	396546	###	87	5	188	22.02632742	60.47385131	376	3.7	13.32
0 days 00:20:29	running	3.7	4.152	1280	5	396915	###	86	5	188	22.02628467	60.47387629	369	3.7	13.32
0 days 00:20:30	running	3.7	4.052	1290	6	397278	###	86	6	188	22.02624201	60.47390135	363	3.7	13.32
0 days 00:20:31	running	3.7	3.961	1300	6	397633	###	85	6	188	22.02619817	60.47392725	355	3.7	13.32
0 days 00:20:32	running	3.7	3.869	1310	6	397980	###	85	6	188	22.02615442	60.47395323	347	3.7	13.32
0 days 00:20:33	running	3.628	3.794	1280	6	398319	###	85	6	188	22.02611418	60.47398148	339	3.628	13.061
0 days 00:20:34	running	3.556	3.722	1260	6	398650	###	85	6	188	22.02607412	60.47400981	331	3.556	12.802
0 days 00:20:35	running	3.556	3.638	1250	6	398975	###	85	6	188	22.0260369	60.47403965	325	3.556	12.802
0 days 00:20:36	running	3.556	3.555	1240	6	399294	###	86	6	188	22.02599977	60.47406941	319	3.556	12.802
0 days 00:20:37	running	3.517	3.516	1220	6	399606	###	86	6	188	22.02596029	60.4740974	312	3.517	12.661
0 days 00:20:38	running	3.478	3.477	1210	6	399911	###	86	6	187	22.0259209	60.47412548	305	3.478	12.521
0 days 00:20:39	running	3.478	3.477	1200	6	400212	###	87	6	187	22.02587882	60.47415046	301	3.478	12.521
0 days 00:20:40	running	3.478	3.477	1190	6	400510	###	87	6	188	22.02583666	60.47417544	298	3.478	12.521
0 days 00:20:41	running	3.478	3.477	1180	6	400808	###	88	6	188	22.02579458	60.47419882	298	3.478	12.521
0 days 00:20:42	running	3.478	3.477	1180	6	401106	###	88	6	188	22.02575259	60.47422221	298	3.478	12.521
0 days 00:20:43	running	3.486	3.486	1180	6	401404	###	88	6	188	22.02570833	60.47424392	298	3.486	12.55
0 days 00:20:44	running	3.494	3.494	1190	6	401702	###	88	6	188	22.02566408	60.47426571	298	3.494	12.578
0 days 00:20:45	running	3.494	3.494	1190	6	402000	###	88	6	189	22.02561177	60.47428315	298	3.494	12.578
0 days 00:20:46	running	3.494	3.494	1190	5	402299	###	88	5	189	22.02555947	60.47430066	299	3.494	12.578
0 days 00:20:47	running	3.506	3.433	1190	5	402598	###	88	5	189	22.02549828	60.47431399	299	3.506	12.622
0 days 00:20:48	running	3.517	3.374	1200	5	402897	###	88	5	189	22.02543718	60.4743274	299	3.517	12.661
0 days 00:20:49	running	3.517	3.444	1190	5	403190	###	88	5	188	22.02536593	60.47433604	293	3.517	12.661
0 days 00:20:50	running	3.517	3.516	1190	5	403478	###	88	5	188	22.02529469	60.47434459	288	3.517	12.661
0 days 00:20:51	running	3.517	3.516	1190	5	403772	###	88	5	189	22.02522092	60.47435012	294	3.517	12.661
0 days 00:20:52	running	3.517	3.516	1190	5	404073	###	88	5	189	22.02514708	60.47435573	301	3.517	12.661
0 days 00:20:53	running	3.531	3.53	1190	5	404374	###	89	5	189	22.0250765	60.47436076	301	3.531	12.712
0 days 00:20:54	running	3.544	3.544	1190	5	404675	###	89	5	189	22.02500593	60.47436571	301	3.544	12.758
0 days 00:20:55	running	3.544	3.544	1180	5	404977	###	89	5	188	22.02494047	60.47437342	302	3.544	12.758
0 days 00:20:56	running	3.544	3.544	1180	5	405280	###	90	5	188	22.02487509	60.47438113	303	3.544	12.758
0 days 00:20:57	running	3.569	3.569	1190	5	405583	###	90	5	188	22.02481549	60.47439504	303	3.569	12.848
0 days 00:20:58	running	3.597	3.597	1200	5	405886	###	90	5	189	22.0247559	60.47440904	303	3.597	12.949
0 days 00:20:59	running	3.597	3.597	1200	5	406191	###	90	5	189	22.0246984	60.47442748	305	3.597	12.949
0 days 00:21:00	running	3.597	3.597	1200	5	406499	###	90	5	189	22.0246409	60.47444609	308	3.597	12.949
0 days 00:21:01	running	3.597	3.597	1200	4	406807	###	89	4	189	22.02458122	60.47446344	308	3.597	12.949
0 days 00:21:02	running	3.597	3.597	1210	4	407115	###	89	4	188	22.02452162	60.47448071	308	3.597	12.949
0 days 00:21:03	running	3.619	3.619	1210	4	407423	###	89	4	188	22.02445876	60.47448691	308	3.619	13.028
0 days 00:21:04	running	3.644	3.644	1220	4	407731	###	89	4	189	22.02439606	60.4744932	308	3.644	13.118
0 days 00:21:05	running	3.644	3.566	1220	4	408041	###	89	4	189	22.02433873	60.47448473	310	3.644	13.118
0 days 00:21:06	running	3.644	3.488	1220	4	408353	###	89	4	189	22.0242814	60.47447618	312	3.644	13.118
0 days 00:21:07	running	3.644	3.494	1220	4	408658	###	89	4	188	22.02423337	60.47445556	305	3.644	13.118
0 days 00:21:08	running	3.647	3.5	1220	4	408956	###	89	4	188	22.02418551	60.47443494	298	3.647	13.129
0 days 00:21:09	running	3.647	3.572	1220	4	409254	###	89	4	188	22.02414569	60.47440795	298	3.647	13.129
0 days 00:21:10	running	3.647	3.647	1220	4	409552	###	89	4	189	22.02410588	60.47438105	298	3.647	13.129
0 days 00:21:11	running	3.647	3.647	1220	4	409857	###	89	4	189	22.02406925	60.4743523	305	3.647	13.129
0 days 00:21:12	running	3.647	3.647	1230	4	410169	###	89	4	188	22.02403271	60.47432371	312	3.647	13.129
0 days 00:21:13	running	3.642	3.641	1230	4	410481	###	89	4	188	22.02399608	60.47429622	312	3.642	13.111
0 days 00:21:14	running	3.639	3.638	1230	4	410793	###	89	4	188	22.02395953	60.47426873	312	3.639	13.1
0 days 00:21:15	running	3.639	3.638	1230	4	411105	###	89	4	189	22.02392123	60.47424249	312	3.639	13.1
0 days 00:21:16	running	3.639	3.638	1230	4	411417	###	89	4	189	22.02388292	60.47421643	312	3.639	13.1
0 days 00:21:17	running	3.631	3.63	1220	4	411729	###	89	4	189	22.02384378	60.47419145	312	3.631	13.072
0 days 00:21:18	running	3.622	3.622	1220	4	412041	###	89	4	188	22.0238048	60.47416655	312	3.622	13.039

Appendix A : Naantali Run Data

0 days 00:21:19	running	3.622	3.622	1220	4	412352	###	89	4	188	22.02376205	60.47414183	311	3.622	13.039
0 days 00:21:20	running	3.622	3.622	1220	4	412662	###	89	4	189	22.02371939	60.47411718	310	3.622	13.039
0 days 00:21:21	running	3.622	3.622	1220	4	412972	###	88	4	189	22.02367329	60.47409263	310	3.622	13.039
0 days 00:21:22	running	3.622	3.622	1230	4	413282	###	88	4	189	22.02362719	60.47406815	310	3.622	13.039
0 days 00:21:23	running	3.619	3.702	1220	4	413592	###	88	4	189	22.02358075	60.47404208	310	3.619	13.028
0 days 00:21:24	running	3.617	3.783	1220	4	413902	###	89	4	189	22.02353449	60.4740161	310	3.617	13.021
0 days 00:21:25	running	3.617	3.783	1220	4	414219	###	89	4	189	22.02348989	60.47398944	317	3.617	13.021
0 days 00:21:26	running	3.617	3.783	1220	4	414543	###	89	4	189	22.0234453	60.47396279	324	3.617	13.021
0 days 00:21:27	running	3.617	3.783	1220	4	414867	###	89	4	188	22.02340272	60.47393681	324	3.617	13.021
0 days 00:21:28	running	3.619	3.783	1220	4	415191	###	89	4	188	22.02336006	60.47391091	324	3.619	13.028
0 days 00:21:29	running	3.619	3.783	1210	4	415515	###	90	4	188	22.02331991	60.47388551	324	3.619	13.028
0 days 00:21:30	running	3.619	3.783	1200	5	415839	###	90	5	189	22.02327968	60.47386011	324	3.619	13.028
0 days 00:21:31	running	3.619	3.699	1200	5	416163	###	90	5	189	22.02323928	60.47383564	324	3.619	13.028
0 days 00:21:32	running	3.619	3.619	1200	5	416487	###	90	5	189	22.02319887	60.47381116	324	3.619	13.028
0 days 00:21:33	running	3.631	3.63	1200	5	416804	###	90	5	189	22.02315328	60.47379121	317	3.631	13.072
0 days 00:21:34	running	3.642	3.641	1200	5	417114	###	91	5	189	22.02310768	60.47377143	310	3.642	13.111
0 days 00:21:35	running	3.642	3.641	1200	5	417425	###	91	5	189	22.02305169	60.4737628	311	3.642	13.111
0 days 00:21:36	running	3.642	3.641	1200	5	417737	###	91	5	189	22.0229957	60.47375425	312	3.642	13.111
0 days 00:21:37	running	3.656	3.655	1200	5	418049	###	91	5	189	22.02293518	60.47375986	312	3.656	13.162
0 days 00:21:38	running	3.672	3.672	1210	5	418361	###	91	5	189	22.02287466	60.4737654	312	3.672	13.219
0 days 00:21:39	running	3.672	3.672	1210	5	418674	###	91	5	189	22.02281423	60.47378166	313	3.672	13.219
0 days 00:21:40	running	3.672	3.672	1210	5	418988	###	91	5	189	22.0227538	60.47379783	314	3.672	13.219
0 days 00:21:41	running	3.672	3.672	1200	5	419302	###	91	5	189	22.02269772	60.47381954	314	3.672	13.219
0 days 00:21:42	running	3.672	3.672	1200	5	419616	###	91	5	188	22.02264173	60.47384134	314	3.672	13.219
0 days 00:21:43	running	3.681	3.68	1200	5	419930	###	91	5	188	22.02258867	60.47386455	314	3.681	13.252
0 days 00:21:44	running	3.689	3.688	1210	5	420244	###	91	5	189	22.02253578	60.47388786	314	3.689	13.28
0 days 00:21:45	running	3.689	3.688	1210	5	420559	###	91	5	189	22.0224813	60.47390973	315	3.689	13.28
0 days 00:21:46	running	3.689	3.688	1210	5	420875	###	91	5	188	22.02242682	60.47393169	316	3.689	13.28
0 days 00:21:47	running	3.697	3.783	1210	5	421191	###	91	5	188	22.02237301	60.47395474	316	3.697	13.309
0 days 00:21:48	running	3.708	3.877	1220	5	421507	###	91	5	189	22.02231928	60.47397771	316	3.708	13.349
0 days 00:21:49	running	3.708	3.877	1220	5	421831	###	91	5	189	22.02226597	60.47400093	324	3.708	13.349
0 days 00:21:50	running	3.708	3.877	1220	5	422163	###	91	5	189	22.02221283	60.47402423	332	3.708	13.349
0 days 00:21:51	running	3.708	3.791	1220	5	422495	###	91	5	189	22.02215826	60.47404694	332	3.708	13.349
0 days 00:21:52	running	3.708	3.708	1220	5	422827	###	91	5	189	22.02210378	60.47406966	332	3.708	13.349
0 days 00:21:53	running	3.722	3.722	1220	5	423152	###	91	5	189	22.02205089	60.47409405	325	3.722	13.399
0 days 00:21:54	running	3.736	3.736	1220	5	423470	###	92	5	188	22.021998	60.47411844	318	3.736	13.45
0 days 00:21:55	running	3.736	3.736	1220	5	423789	###	92	5	188	22.02194687	60.47414484	319	3.736	13.45
0 days 00:21:56	running	3.736	3.736	1220	5	424109	###	92	5	188	22.02189582	60.47417125	320	3.736	13.45
0 days 00:21:57	running	3.758	3.758	1210	5	424429	###	92	5	188	22.0218457	60.47419824	320	3.758	13.529
0 days 00:21:58	running	3.783	3.783	1210	5	424749	###	93	5	189	22.02179566	60.47422523	320	3.783	13.619
0 days 00:21:59	running	3.783	3.783	1220	5	425071	###	93	5	189	22.02174512	60.47425096	322	3.783	13.619
0 days 00:22:00	running	3.783	3.783	1230	5	425395	###	92	5	188	22.02169449	60.47427669	324	3.783	13.619
0 days 00:22:01	running	3.783	3.783	1220	5	425719	###	92	5	189	22.021639	60.47429966	324	3.783	13.619
0 days 00:22:02	running	3.783	3.783	1220	5	426043	###	93	5	189	22.0215836	60.47432262	324	3.783	13.619
0 days 00:22:03	running	3.808	3.897	1230	5	426367	###	93	5	188	22.02152442	60.4743419	324	3.808	13.709
0 days 00:22:04	running	3.836	4.013	1240	5	426691	###	93	5	189	22.02146516	60.47436118	324	3.836	13.81
0 days 00:22:05	running	3.836	3.925	1250	6	427025	###	92	6	188	22.0214007	60.47438004	334	3.836	13.81
0 days 00:22:06	running	3.836	3.836	1260	6	427369	###	91	6	189	22.02133633	60.4743989	344	3.836	13.81
0 days 00:22:07	running	3.85	3.849	1250	6	427705	###	92	6	189	22.02127196	60.47442296	336	3.85	13.86
0 days 00:22:08	running	3.864	3.863	1250	6	428034	###	92	6	189	22.02120767	60.47444693	329	3.864	13.91
0 days 00:22:09	running	3.864	3.863	1250	6	428363	###	92	6	189	22.02114958	60.47447341	329	3.864	13.91
0 days 00:22:10	running	3.864	3.863	1250	6	428693	###	92	6	189	22.0210915	60.47449999	330	3.864	13.91
0 days 00:22:11	running	3.864	3.95	1250	5	429023	###	92	5	189	22.02104347	60.47452832	330	3.864	13.91
0 days 00:22:12	running	3.864	4.036	1250	5	429353	###	93	5	189	22.02099561	60.47455665	330	3.864	13.91
0 days 00:22:13	running	3.878	4.049	1240	5	429691	###	94	5	188	22.02095043	60.47458515	338	3.878	13.961
0 days 00:22:14	running	3.894	4.066	1230	5	430037	###	95	5	189	22.02090525	60.47461364	346	3.894	14.018
0 days 00:22:15	running	3.894	3.98	1230	5	430384	###	94	5	189	22.02085462	60.47463845	347	3.894	14.018
0 days 00:22:16	running	3.894	3.894	1240	5	430733	###	94	5	188	22.020804	60.47466335	349	3.894	14.018
0 days 00:22:17	running	3.922	3.922	1250	5	431074	###	94	5	188	22.02074851	60.47468355	341	3.922	14.119
0 days 00:22:18	running	3.953	3.952	1260	5	431407	###	94	5	189	22.0206931	60.47470375	333	3.953	14.231
0 days 00:22:19	running	3.958	3.958	1270	5	431742	###	93	5	189	22.02063711	60.4747237	335	3.958	14.249
0 days 00:22:20	running	3.964	3.963	1280	5	432080	###	93	5	188	22.02058112	60.47474382	338	3.964	14.27
0 days 00:22:21	running	3.956	3.955	1280	5	432418	###	92	5	189	22.02052547	60.47476326	338	3.956	14.242
0 days 00:22:22	running	3.947	3.947	1290	5	432757	###	92	5	189	22.02046989	60.47478271	339	3.947	14.209
0 days 00:22:23	running	3.917	3.838	1280	5	433095	###	91	5	188	22.02041206	60.47479989	338	3.917	14.101
0 days 00:22:24	running	3.889	3.73	1280	5	433433	###	91	5	189	22.02035431	60.47481716	338	3.889	14
0 days 00:22:25	running	3.869	3.638	1270	5	433761	###	91	5	189	22.02028851	60.47482604	328	3.869	13.928
0 days 00:22:26	running	3.853	3.547	1260	4	434079	###	92	4	189	22.0202228	60.47483501	318	3.853	13.871
0 days 00:22:27	running	3.858	3.555	1250	4	434388	###	92	4	189	22.02015096	60.47483459	309	3.858	13.889
0 days 00:22:28	running	3.867	3.566	1240	4	434689	###	93	4	189	22.0200793	60.47483426	301	3.867	13.921
0 days 00:22:29	running	3.875	3.505	1240	4	434991	###	93	4	189	22.02000839	60.47482529	302	3.875	13.95

Appendix A : Naantali Run Data

0 days 00:22:30	running	3.883	3.447	1250	4	435294	###	93	4	189	22.01993748	60.47481649	303	3.883	13.979
0 days 00:22:31	running	3.883	3.447	1250	4	435590	###	92	4	189	22.0198726	60.47480249	296	3.883	13.979
0 days 00:22:32	running	3.883	3.447	1260	4	435880	###	92	4	189	22.01980781	60.47478849	290	3.883	13.979
0 days 00:22:33	running	3.883	3.511	1260	4	436170	###	92	4	189	22.01974997	60.47477206	290	3.883	13.979
0 days 00:22:34	running	3.883	3.574	1270	4	436460	###	92	4	189	22.01969231	60.47475563	290	3.883	13.979
0 days 00:22:35	running	3.878	3.574	1270	4	436756	###	91	4	189	22.01963732	60.47473736	296	3.878	13.961
0 days 00:22:36	running	3.875	3.574	1280	4	437059	###	90	4	189	22.01958242	60.474719	303	3.875	13.95
0 days 00:22:37	running	3.875	3.647	1290	4	437362	###	89	4	189	22.01952735	60.47469964	303	3.875	13.95
0 days 00:22:38	running	3.875	3.719	1310	4	437665	###	88	4	189	22.01947236	60.4746802	303	3.875	13.95
0 days 00:22:39	running	3.844	3.686	1300	4	437975	###	88	4	189	22.01941797	60.4746584	310	3.844	13.838
0 days 00:22:40	running	3.814	3.652	1290	4	438292	###	89	4	189	22.01936365	60.47463661	317	3.814	13.73
0 days 00:22:41	running	3.814	3.652	1290	4	438606	###	88	4	189	22.01931286	60.47461004	314	3.814	13.73
0 days 00:22:42	running	3.814	3.652	1290	4	438918	###	88	4	188	22.01926223	60.47458339	312	3.814	13.73
0 days 00:22:43	running	3.814	3.733	1290	4	439230	###	88	4	189	22.01921982	60.47455254	312	3.814	13.73
0 days 00:22:44	running	3.814	3.813	1300	4	439542	###	88	4	189	22.01917749	60.47452169	312	3.814	13.73
0 days 00:22:45	running	3.778	3.777	1290	4	439861	###	88	4	189	22.01914279	60.47449093	319	3.778	13.601
0 days 00:22:46	running	3.744	3.744	1280	4	440187	###	88	4	189	22.01910817	60.47446026	326	3.744	13.478
0 days 00:22:47	running	3.744	3.744	1270	4	440510	###	88	4	189	22.01907607	60.47443243	323	3.744	13.478
0 days 00:22:48	running	3.744	3.744	1270	4	440830	###	88	4	189	22.01904413	60.4744046	320	3.744	13.478
0 days 00:22:49	running	3.719	3.719	1260	4	441150	###	89	4	189	22.01900792	60.47437903	320	3.719	13.388
0 days 00:22:50	running	3.694	3.694	1250	4	441470	###	89	4	189	22.01897171	60.47435355	320	3.694	13.298
0 days 00:22:51	running	3.694	3.694	1240	4	441788	###	90	4	189	22.01892871	60.47433025	318	3.694	13.298
0 days 00:22:52	running	3.694	3.694	1230	4	442104	###	91	4	189	22.01888571	60.47430695	316	3.694	13.298
0 days 00:22:53	running	3.694	3.694	1220	4	442420	###	91	4	189	22.01883769	60.47428583	316	3.694	13.298
0 days 00:22:54	running	3.694	3.694	1220	4	442736	###	91	4	189	22.01878966	60.47426471	316	3.694	13.298
0 days 00:22:55	running	3.697	3.78	1210	4	443052	###	91	4	188	22.01873819	60.47424459	316	3.697	13.309
0 days 00:22:56	running	3.703	3.869	1210	4	443368	###	91	4	188	22.01868673	60.47422456	316	3.703	13.331
0 days 00:22:57	running	3.703	3.961	1200	4	443691	###	91	4	188	22.01863912	60.47420285	323	3.703	13.331
0 days 00:22:58	running	3.703	4.052	1200	4	444022	###	92	4	188	22.01859151	60.47418122	331	3.703	13.331
0 days 00:22:59	running	3.717	4.169	1210	4	444361	###	91	4	188	22.01855329	60.47415683	339	3.717	13.381
0 days 00:23:00	running	3.731	4.286	1220	4	444708	###	91	4	188	22.01851507	60.47413244	347	3.731	13.432
0 days 00:23:01	running	3.731	4.286	1220	4	445064	###	91	4	189	22.01848598	60.47410528	356	3.731	13.432
0 days 00:23:02	running	3.731	4.286	1230	4	445430	###	91	4	188	22.0184569	60.47407829	366	3.731	13.432
0 days 00:23:03	running	3.731	4.286	1220	4	445796	###	91	4	188	22.01843946	60.47404862	366	3.731	13.432
0 days 00:23:04	running	3.731	4.286	1220	4	446162	###	92	4	188	22.0184222	60.47401903	366	3.731	13.432
0 days 00:23:05	running	3.733	4.291	1210	4	446528	###	92	4	188	22.01841591	60.47398802	366	3.733	13.439
0 days 00:23:06	running	3.736	4.297	1210	4	446894	###	93	4	188	22.01840971	60.47395709	366	3.736	13.45
0 days 00:23:07	running	3.736	4.297	1200	4	447260	###	93	4	187	22.01840426	60.47392641	366	3.736	13.45
0 days 00:23:08	running	3.736	4.297	1200	4	447627	###	93	4	188	22.01839889	60.47389573	367	3.736	13.45
0 days 00:23:09	running	3.75	4.208	1210	4	447994	###	91	4	188	22.01838506	60.47386765	367	3.75	13.5
0 days 00:23:10	running	3.764	4.119	1230	4	448361	###	90	4	188	22.01837132	60.47383966	367	3.764	13.55
0 days 00:23:11	running	3.764	4.024	1240	4	448721	###	89	4	188	22.01835237	60.47381259	360	3.764	13.55
0 days 00:23:12	running	3.764	3.93	1260	4	449074	###	88	4	188	22.0183336	60.4737856	353	3.764	13.55
0 days 00:23:13	running	3.764	3.93	1270	4	449419	###	88	4	187	22.01831063	60.4737581	345	3.764	13.55
0 days 00:23:14	running	3.764	3.93	1280	4	449756	###	88	4	187	22.01828767	60.47373061	337	3.764	13.55
0 days 00:23:15	running	3.728	3.811	1260	4	450093	###	88	4	187	22.01825682	60.47370362	337	3.728	13.421
0 days 00:23:16	running	3.694	3.694	1250	4	450430	###	89	4	188	22.01822589	60.47367672	337	3.694	13.298
0 days 00:23:17	running	3.694	3.694	1250	4	450756	###	89	4	188	22.01818381	60.47365123	326	3.694	13.298
0 days 00:23:18	running	3.694	3.694	1250	4	451072	###	89	4	188	22.01814165	60.47362575	316	3.694	13.298
0 days 00:23:19	running	3.658	3.658	1230	4	451388	###	89	4	189	22.01808902	60.47360455	316	3.658	13.169
0 days 00:23:20	running	3.622	3.622	1220	4	451704	###	89	4	188	22.01803629	60.47358342	316	3.622	13.039
0 days 00:23:21	running	3.622	3.622	1210	4	452017	###	89	4	188	22.01797628	60.47356683	313	3.622	13.039
0 days 00:23:22	running	3.622	3.622	1210	4	452327	###	89	4	188	22.01791643	60.47355032	310	3.622	13.039
0 days 00:23:23	running	3.622	3.622	1210	4	452637	###	89	4	188	22.01785256	60.47353649	310	3.622	13.039
0 days 00:23:24	running	3.622	3.622	1210	4	452947	###	89	4	188	22.01778878	60.47352282	310	3.622	13.039
0 days 00:23:25	running	3.611	3.611	1200	4	453257	###	89	4	188	22.01772239	60.47351042	310	3.611	13
0 days 00:23:26	running	3.603	3.602	1200	3	453567	###	90	3	188	22.01765609	60.4734981	310	3.603	12.971
0 days 00:23:27	running	3.603	3.602	1190	3	453876	###	90	3	188	22.01758761	60.47348703	309	3.603	12.971
0 days 00:23:28	running	3.603	3.602	1190	3	454184	###	91	3	188	22.01751913	60.47347605	308	3.603	12.971
0 days 00:23:29	running	3.619	3.619	1190	3	454492	###	91	3	188	22.01744981	60.47346549	308	3.619	13.028
0 days 00:23:30	running	3.636	3.636	1190	3	454800	###	91	3	188	22.01738049	60.47345501	308	3.636	13.09
0 days 00:23:31	running	3.636	3.636	1190	3	455110	###	91	3	188	22.01731277	60.47344479	310	3.636	13.09
0 days 00:23:32	running	3.636	3.636	1190	3	455422	###	91	3	188	22.01724521	60.47343465	312	3.636	13.09
0 days 00:23:33	running	3.636	3.636	1190	3	455734	###	91	3	188	22.01717807	60.47342442	312	3.636	13.09
0 days 00:23:34	running	3.636	3.636	1190	3	456046	###	92	3	188	22.01711101	60.47341419	312	3.636	13.09
0 days 00:23:35	running	3.667	3.752	1200	3	456358	###	91	3	188	22.01704413	60.47340372	312	3.667	13.201
0 days 00:23:36	running	3.7	3.869	1220	3	456670	###	91	3	188	22.01697732	60.47339324	312	3.7	13.32
0 days 00:23:37	running	3.7	3.869	1220	3	456991	###	90	3	188	22.01691169	60.4733831	321	3.7	13.32
0 days 00:23:38	running	3.7	3.869	1230	3	457322	###	90	3	189	22.01684623	60.47337304	331	3.7	13.32
0 days 00:23:39	running	3.711	3.877	1230	3	457653	###	90	3	189	22.01678563	60.4733629	331	3.711	13.36
0 days 00:23:40	running	3.722	3.888	1240	4	457984	###	90	4	190	22.01672511	60.47335284	331	3.722	13.399

0 days 00:23:41	running	3.722	3.98	1250	4	458316	###	89	4	189	22.01667381	60.47333775	332	3.722	13.399
0 days 00:23:42	running	3.722	4.075	1260	4	458649	###	89	4	189	22.01662252	60.47332266	333	3.722	13.399
0 days 00:23:43	running	3.722	4.075	1260	4	458990	###	88	4	189	22.01658061	60.47330112	341	3.722	13.399
0 days 00:23:44	running	3.722	4.075	1260	4	459339	###	88	4	190	22.01653878	60.47327975	349	3.722	13.399
0 days 00:23:45	running	3.7	4.052	1250	4	459688	###	88	4	189	22.01650207	60.47325418	349	3.7	13.32
0 days 00:23:46	running	3.678	4.03	1240	4	460037	###	89	4	190	22.01646552	60.47322879	349	3.678	13.241
0 days 00:23:47	running	3.678	4.03	1240	4	460384	###	89	4	190	22.01643091	60.47320213	347	3.678	13.241
0 days 00:23:48	running	3.678	4.03	1240	4	460729	###	89	4	190	22.01639629	60.47317556	345	3.678	13.241
0 days 00:23:49	running	3.653	4.1	1220	4	461074	###	89	4	190	22.0163641	60.47314815	345	3.653	13.151
0 days 00:23:50	running	3.631	4.172	1200	5	461419	###	90	5	190	22.01633192	60.47312074	345	3.631	13.072
0 days 00:23:51	running	3.631	4.277	1200	5	461770	###	90	5	190	22.01630468	60.47309023	351	3.631	13.072
0 days 00:23:52	running	3.631	4.383	1200	5	462127	###	91	5	190	22.01627752	60.47305981	357	3.631	13.072
0 days 00:23:53	running	3.631	4.497	1190	5	462492	###	91	5	190	22.01625447	60.47302879	365	3.631	13.072
0 days 00:23:54	running	3.631	4.611	1190	5	462865	###	91	5	190	22.0162315	60.47299778	373	3.631	13.072
0 days 00:23:55	running	3.633	4.616	1200	6	463247	###	91	6	190	22.01621306	60.47296668	382	3.633	13.079
0 days 00:23:56	running	3.639	4.622	1210	6	463638	###	90	6	190	22.0161947	60.47293575	391	3.639	13.1
0 days 00:23:57	running	3.639	4.744	1220	6	464029	###	89	6	190	22.01617752	60.47290684	391	3.639	13.1
0 days 00:23:58	running	3.639	4.866	1230	6	464421	###	89	6	190	22.01616042	60.47287792	392	3.639	13.1
0 days 00:23:59	running	3.628	4.852	1230	6	464822	###	88	6	190	22.016145	60.47285168	401	3.628	13.061
0 days 00:24:00	running	3.619	4.838	1240	7	465233	###	87	7	191	22.01612966	60.47282562	411	3.619	13.028
0 days 00:24:01	running	3.619	4.966	1250	7	465642	###	86	7	191	22.01611449	60.47280248	409	3.619	13.028
0 days 00:24:02	running	3.619	5.097	1260	7	466050	###	86	7	191	22.0160994	60.47277943	408	3.619	13.028
0 days 00:24:03	running	3.619	5.233	1260	7	466467	###	85	7	191	22.01608205	60.47275781	417	3.619	13.028
0 days 00:24:04	running	3.619	5.369	1270	7	466894	###	85	7	191	22.01606479	60.47273635	427	3.619	13.028
0 days 00:24:05	running	3.564	5.288	1250	8	467331	###	85	8	191	22.01604282	60.47271171	437	3.564	12.83
0 days 00:24:06	running	3.508	5.208	1240	8	467778	###	85	8	191	22.01602078	60.47268715	447	3.508	12.629
0 days 00:24:07	running	3.508	5.208	1240	8	468218	###	85	8	191	22.01599698	60.47265932	440	3.508	12.629
0 days 00:24:08	running	3.508	5.208	1240	8	468652	###	85	8	191	22.01597317	60.47263149	434	3.508	12.629
0 days 00:24:09	running	3.45	4.988	1220	8	469086	###	84	8	191	22.01595146	60.47260081	434	3.45	12.42
0 days 00:24:10	running	3.392	4.772	1200	9	469520	###	84	9	191	22.01592975	60.47257022	434	3.392	12.211
0 days 00:24:11	running	3.392	4.538	1200	9	469937	###	85	9	192	22.01591576	60.4725372	417	3.392	12.211
0 days 00:24:12	running	3.392	4.305	1200	9	470337	###	86	9	192	22.01590176	60.47250425	400	3.392	12.211
0 days 00:24:13	running	3.347	4.149	1170	9	470719	###	86	9	191	22.01589849	60.47246913	382	3.347	12.049
0 days 00:24:14	running	3.306	3.997	1150	9	471084	###	87	9	191	22.01589522	60.4724341	365	3.306	11.902
0 days 00:24:15	running	3.336	3.844	1140	10	471437	###	88	10	192	22.01590142	60.47240032	353	3.336	12.01
0 days 00:24:16	running	3.369	3.691	1140	10	471778	###	89	10	191	22.01590771	60.47236654	341	3.369	12.128
0 days 00:24:17	running	3.406	3.727	1150	10	472106	###	88	10	191	22.01591802	60.47233678	328	3.406	12.262
0 days 00:24:18	running	3.442	3.766	1170	10	472422	###	88	10	192	22.01592833	60.4723072	316	3.442	12.391
0 days 00:24:19	running	3.453	3.613	1180	10	472741	###	87	10	192	22.01594023	60.47227928	319	3.453	12.431
0 days 00:24:20	running	3.464	3.463	1200	11	473064	###	86	11	191	22.01595222	60.47225146	323	3.464	12.47
0 days 00:24:21	running	3.447	3.447	1200	10	473373	###	85	10	191	22.01596353	60.4722222	309	3.447	12.409
0 days 00:24:22	running	3.433	3.433	1210	10	473669	###	85	10	191	22.01597493	60.47219303	296	3.433	12.359
0 days 00:24:23	running	3.433	3.433	1210	10	473964	###	84	10	191	22.01598172	60.47216118	295	3.433	12.359
0 days 00:24:24	running	3.433	3.433	1220	10	474258	###	84	10	191	22.01598851	60.47212942	294	3.433	12.359
0 days 00:24:25	running	3.433	3.361	1220	10	474552	###	84	10	190	22.01598356	60.47209731	294	3.433	12.359
0 days 00:24:26	running	3.433	3.288	1220	10	474846	###	84	10	191	22.0159787	60.47206521	294	3.433	12.359
0 days 00:24:27	running	3.419	3.213	1210	10	475133	###	84	10	190	22.01594853	60.47203663	287	3.419	12.308
0 days 00:24:28	running	3.406	3.141	1210	10	475414	###	84	10	191	22.01591835	60.47200805	281	3.406	12.262
0 days 00:24:29	running	3.406	3.086	1210	10	475688	###	84	10	191	22.01585859	60.47198701	274	3.406	12.262
0 days 00:24:30	running	3.406	3.03	1210	10	475955	###	84	10	191	22.01579891	60.47196605	267	3.406	12.262
0 days 00:24:31	running	3.406	3.03	1210	9	476216	###	84	9	190	22.01572272	60.47195314	261	3.406	12.262
0 days 00:24:32	running	3.406	3.03	1210	9	476471	###	85	9	190	22.01564653	60.47194032	255	3.406	12.262
0 days 00:24:33	running	3.392	2.966	1200	9	476726	###	85	9	190	22.01556548	60.47193303	255	3.392	12.211
0 days 00:24:34	running	3.381	2.905	1190	9	476981	###	86	9	191	22.01548451	60.47192582	255	3.381	12.172
0 days 00:24:35	running	3.381	2.863	1180	9	477229	###	86	9	190	22.01540572	60.47192163	248	3.381	12.172
0 days 00:24:36	running	3.381	2.825	1170	8	477471	###	87	8	190	22.01532701	60.47191744	242	3.381	12.172
0 days 00:24:37	running	3.406	2.844	1170	8	477708	###	87	8	191	22.01525342	60.47191408	237	3.406	12.262
0 days 00:24:38	running	3.431	2.866	1180	8	477940	###	88	8	191	22.01517982	60.4719109	232	3.431	12.352
0 days 00:24:39	running	3.431	2.866	1170	8	478173	###	88	8	190	22.01510707	60.47190411	233	3.431	12.352
0 days 00:24:40	running	3.431	2.866	1170	8	478408	###	89	8	190	22.0150344	60.4718974	235	3.431	12.352
0 days 00:24:41	running	3.431	2.83	1160	7	478643	###	88	7	190	22.0149655	60.47189154	235	3.431	12.352
0 days 00:24:42	running	3.431	2.794	1160	7	478878	###	88	7	190	22.0148966	60.47188559	235	3.431	12.352
0 days 00:24:43	running	3.478	2.872	1180	7	479108	###	88	7	190	22.01483156	60.47188274	230	3.478	12.521
0 days 00:24:44	running	3.528	2.949	1200	7	479334	###	88	7	190	22.0147666	60.4718798	226	3.528	12.701
0 days 00:24:45	running	3.633	2.997	1240	7	479568	###	87	7	189	22.0147039	60.47188265	234	3.633	13.079
0 days 00:24:46	running	3.739	3.047	1280	6	479810	###	87	6	189	22.0146412	60.4718855	242	3.739	13.46
0 days 00:24:47	running	3.725	3.036	1270	6	480054	###	87	6	189	22.0145806	60.47189305	244	3.725	13.41
0 days 00:24:48	running	3.711	3.025	1270	6	480300	###	87	6	189	22.01452008	60.47190059	246	3.711	13.36
0 days 00:24:49	running	3.694	3.049	1270	6	480545	###	87	6	189	22.01446108	60.47191149	245	3.694	13.298
0 days 00:24:50	running	3.678	3.074	1280	6	480789	###	87	6	189	22.01440207	60.47192255	244	3.678	13.241
0 days 00:24:51	running	3.672	3.113	1260	5	481037	###	88	5	189	22.01434256	60.47193546	248	3.672	13.219

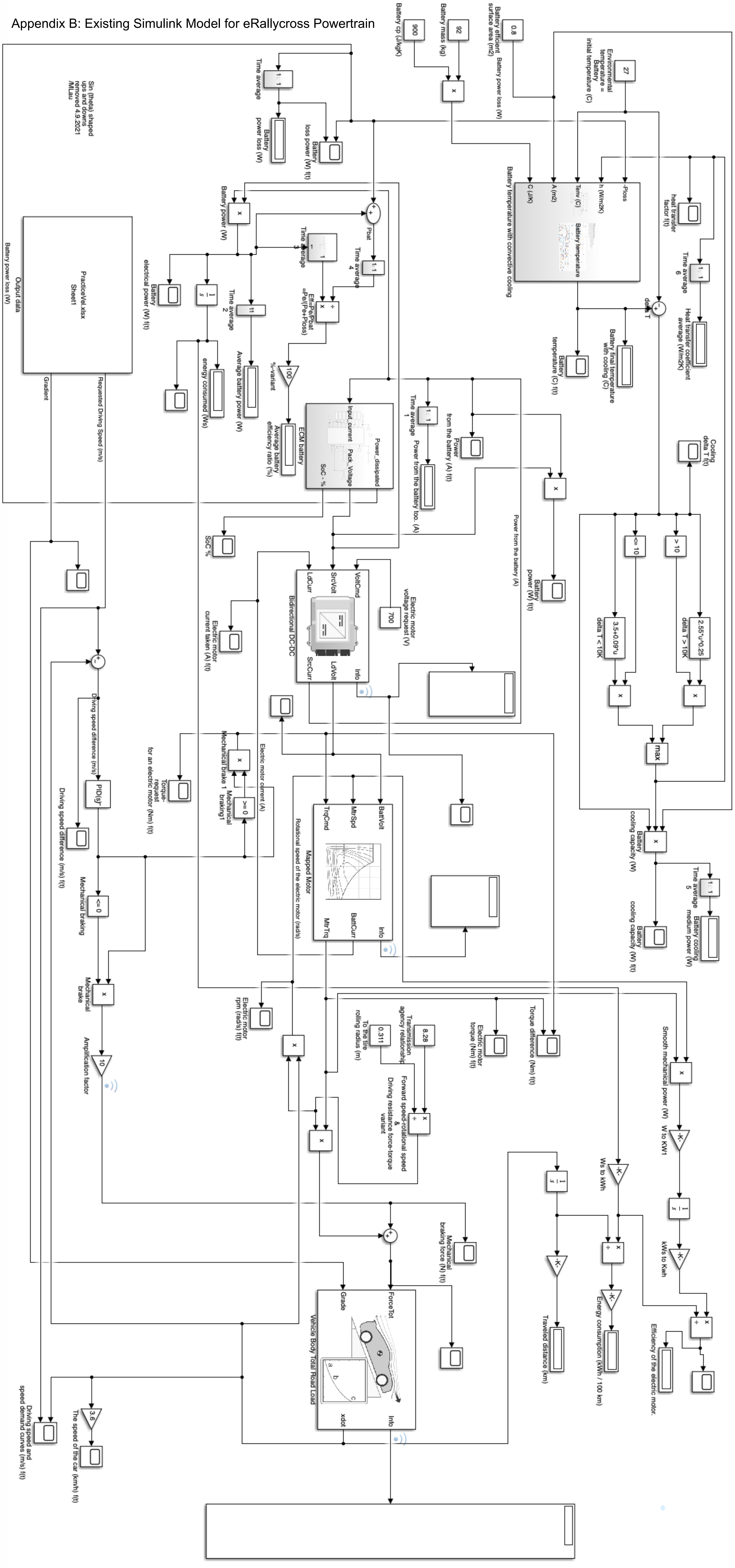
Appendix A : Naantali Run Data

0 days 00:24:52	running	3.669	3.155	1250	5	481290	###	89	5	189	22.01428313	60.47194828	253	3.669	13.208
0 days 00:24:53	running	3.678	3.216	1250	5	481548	###	89	5	189	22.01422462	60.47196396	258	3.678	13.241
0 days 00:24:54	running	3.686	3.28	1250	5	481811	###	89	5	189	22.0141662	60.47197963	263	3.686	13.27
0 days 00:24:55	running	3.686	3.338	1240	5	482080	###	89	5	189	22.01410946	60.47199816	269	3.686	13.27
0 days 00:24:56	running	3.686	3.399	1240	5	482356	###	89	5	189	22.01405279	60.4720166	276	3.686	13.27
0 days 00:24:57	running	3.686	3.469	1230	5	482638	###	89	5	189	22.01399756	60.4720373	282	3.686	13.27
0 days 00:24:58	running	3.686	3.538	1230	5	482926	###	90	5	188	22.0139424	60.472058	288	3.686	13.27
0 days 00:24:59	running	3.694	3.541	1230	5	483221	###	89	5	189	22.01388767	60.47207904	295	3.694	13.298
0 days 00:25:00	running	3.703	3.547	1240	5	483523	###	89	5	189	22.01383302	60.47210016	302	3.703	13.331
0 days 00:25:01	running	3.703	3.547	1240	5	483825	###	89	5	188	22.01377829	60.47211961	302	3.703	13.331
0 days 00:25:02	running	3.703	3.547	1240	5	484128	###	89	5	188	22.01372372	60.47213922	303	3.703	13.331
0 days 00:25:03	running	3.703	3.547	1230	5	484431	###	90	5	188	22.01366773	60.47215565	303	3.703	13.331
0 days 00:25:04	running	3.703	3.547	1230	5	484734	###	90	5	188	22.01361182	60.472172	303	3.703	13.331
0 days 00:25:05	running	3.717	3.638	1230	5	485037	###	90	5	189	22.01355323	60.4721818	303	3.717	13.381
0 days 00:25:06	running	3.733	3.733	1230	5	485340	###	91	5	188	22.01349473	60.47219161	303	3.733	13.439
0 days 00:25:07	running	3.733	3.908	1220	5	485651	###	91	5	188	22.0134353	60.47219119	311	3.733	13.439
0 days 00:25:08	running	3.733	4.086	1220	5	485970	###	91	5	189	22.01337595	60.47219086	319	3.733	13.439
0 days 00:25:09	running	3.75	4.319	1230	5	486304	###	91	5	189	22.0133172	60.47217845	334	3.75	13.5
0 days 00:25:10	running	3.769	4.552	1240	5	486654	###	91	5	189	22.01325836	60.47216613	350	3.769	13.568
0 days 00:25:11	running	3.769	4.669	1250	5	487023	###	90	5	189	22.01320413	60.47214685	369	3.769	13.568
0 days 00:25:12	running	3.769	4.788	1260	5	487411	###	89	5	190	22.01314981	60.47212766	388	3.769	13.568
0 days 00:25:13	running	3.769	4.788	1270	5	487808	###	89	5	190	22.01310472	60.47210368	397	3.769	13.568
0 days 00:25:14	running	3.769	4.788	1280	5	488214	###	88	5	190	22.01305971	60.47207996	406	3.769	13.568
0 days 00:25:15	running	3.758	4.775	1270	6	488620	###	88	6	190	22.01302651	60.47205289	406	3.758	13.529
0 days 00:25:16	running	3.747	4.763	1260	6	489026	###	89	6	190	22.0129934	60.4720259	406	3.747	13.489
0 days 00:25:17	running	3.747	4.888	1250	6	489431	###	89	6	190	22.01297555	60.47199639	405	3.747	13.489
0 days 00:25:18	running	3.747	5.013	1250	6	489835	###	90	6	190	22.01295778	60.47196706	404	3.747	13.489
0 days 00:25:19	running	3.733	5.125	1230	6	490248	###	90	6	190	22.01296298	60.47193663	413	3.733	13.439
0 days 00:25:20	running	3.719	5.238	1220	7	490671	###	91	7	190	22.01296826	60.47190629	423	3.719	13.388
0 days 00:25:21	running	3.675	5.311	1210	7	491102	###	91	7	191	22.01298628	60.4718762	431	3.675	13.23
0 days 00:25:22	running	3.633	5.386	1210	7	491541	###	90	7	191	22.01300438	60.47184619	439	3.633	13.079
0 days 00:25:23	running	3.614	5.658	1210	7	491985	###	89	7	191	22.01302132	60.47181895	444	3.614	13.01
0 days 00:25:24	running	3.597	5.933	1220	7	492434	###	88	7	191	22.01303816	60.47179171	449	3.597	12.949
0 days 00:25:25	running	3.542	5.841	1220	8	492902	###	87	8	191	22.01305317	60.47176765	468	3.542	12.751
0 days 00:25:26	running	3.486	5.75	1220	8	493389	###	86	8	191	22.01306826	60.47174351	487	3.486	12.55
0 days 00:25:27	running	3.428	5.508	1200	8	493868	###	85	8	191	22.01309248	60.47172088	479	3.428	12.341
0 days 00:25:28	running	3.369	5.269	1190	8	494340	###	85	8	191	22.0131167	60.47169842	472	3.369	12.128
0 days 00:25:29	running	3.328	5.075	1180	8	494794	###	84	8	192	22.01315417	60.47167771	454	3.328	11.981
0 days 00:25:30	running	3.286	4.88	1170	9	495230	###	84	9	193	22.01319172	60.47165701	436	3.286	11.83
0 days 00:25:31	running	3.283	4.75	1170	9	495651	###	84	9	192	22.0132395	60.47163765	421	3.283	11.819
0 days 00:25:32	running	3.283	4.619	1170	9	496058	###	84	9	192	22.01328736	60.4716182	407	3.283	11.819
0 days 00:25:33	running	3.283	4.619	1160	9	496455	###	84	9	193	22.01334117	60.47159993	397	3.283	11.819
0 days 00:25:34	running	3.283	4.619	1160	9	496842	###	85	9	193	22.01339507	60.47158166	387	3.283	11.819
0 days 00:25:35	running	3.272	4.488	1150	10	497229	###	85	10	193	22.01345173	60.47156389	387	3.272	11.779
0 days 00:25:36	running	3.261	4.358	1150	10	497616	###	85	10	193	22.0135083	60.47154629	387	3.261	11.74
0 days 00:25:37	running	3.261	4.358	1140	10	497993	###	86	10	193	22.01356329	60.47152659	377	3.261	11.74
0 days 00:25:38	running	3.261	4.358	1130	11	498361	###	86	11	193	22.01361828	60.47150706	368	3.261	11.74
0 days 00:25:39	running	3.261	4.25	1130	11	498729	###	86	11	193	22.01366739	60.4714846	368	3.261	11.74
0 days 00:25:40	running	3.261	4.141	1140	12	499097	###	86	12	193	22.0137166	60.47146222	368	3.261	11.74
0 days 00:25:41	running	3.267	4.147	1140	12	499456	###	86	12	192	22.01375926	60.47143782	359	3.267	11.761
0 days 00:25:42	running	3.272	4.152	1140	12	499807	###	86	12	192	22.01380209	60.47141352	351	3.272	11.779
0 days 00:25:43	running	3.272	3.955	1140	12	500158	###	85	12	192	22.01384182	60.47138871	351	3.272	11.779
0 days 00:25:44	running	3.272	3.758	1150	12	500510	###	85	12	192	22.01388147	60.4713639	352	3.272	11.779
0 days 00:25:45	running	3.283	3.602	1150	12	500846	###	85	12	192	22.01392438	60.47134026	336	3.283	11.819
0 days 00:25:46	running	3.297	3.45	1150	12	501167	###	86	12	192	22.0139673	60.47131662	321	3.297	11.869
0 days 00:25:47	running	3.297	3.372	1150	12	501475	###	86	12	193	22.01401692	60.47129642	308	3.297	11.869
0 days 00:25:48	running	3.297	3.297	1150	12	501771	###	86	12	192	22.01406662	60.47127622	296	3.297	11.869
0 days 00:25:49	running	3.297	3.297	1150	12	502060	###	86	12	192	22.01412077	60.47125979	289	3.297	11.869
0 days 00:25:50	running	3.297	3.297	1150	12	502342	###	86	12	192	22.01417509	60.47124345	282	3.297	11.869
0 days 00:25:51	running	3.311	3.311	1160	12	502624	###	85	12	192	22.0142294	60.4712287	282	3.311	11.92
0 days 00:25:52	running	3.325	3.325	1170	12	502906	###	85	12	192	22.01428371	60.47121411	282	3.325	11.97
0 days 00:25:53	running	3.325	3.325	1170	12	503189	###	85	12	192	22.01433828	60.47119953	283	3.325	11.97
0 days 00:25:54	running	3.325	3.325	1170	12	503474	###	86	12	191	22.01439293	60.47118503	285	3.325	11.97
0 days 00:25:55	running	3.325	3.325	1160	12	503759	###	86	12	192	22.01444649	60.47116944	285	3.325	11.97
0 days 00:25:56	running	3.328	3.327	1160	12	504044	###	86	12	192	22.01450005	60.47115385	285	3.328	11.981
0 days 00:25:57	running	3.328	3.327	1160	12	504329	###	86	12	192	22.01455235	60.47113633	285	3.328	11.981
0 days 00:25:58	running	3.328	3.327	1160	12	504614	###	86	12	192	22.01460466	60.47111889	285	3.328	11.981
0 days 00:25:59	running	3.328	3.327	1160	12	504899	###	85	12	192	22.01465512	60.47110054	285	3.328	11.981
0 days 00:26:00	running	3.328	3.327	1160	12	505184	###	85	12	191	22.01470558	60.47108218	285	3.328	11.981
0 days 00:26:01	running	3.328	3.327	1160	12	505469	###	85	12	192	22.01475637	60.47106332	285	3.328	11.981
0 days 00:26:02	running	3.331	3.33	1160	12	505754	###	86	12	191	22.01480716	60.47104455	285	3.331	11.992

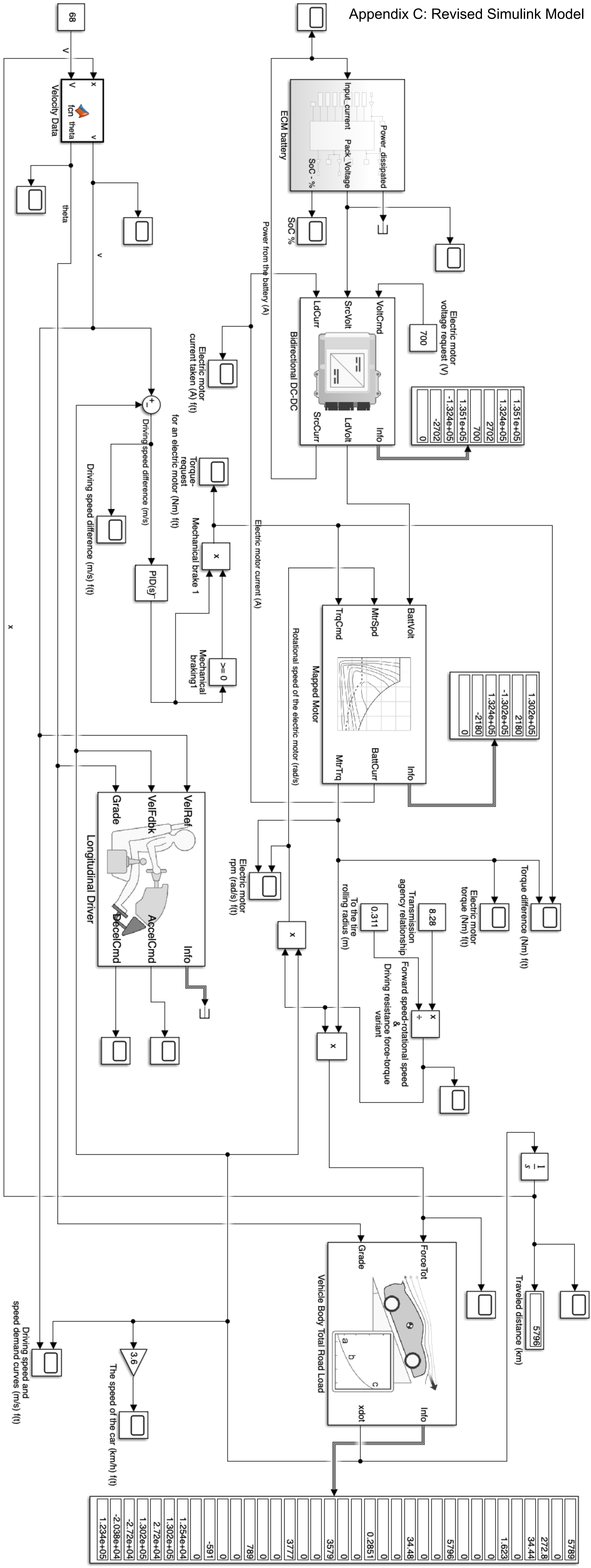
Appendix A : Naantali Run Data

0 days 00:26:03	running	3.331	3.33	1160	12	506039	###	86	12	191	22.0148593	60.47102594	285	3.331	11.992
0 days 00:26:04	running	3.331	3.33	1160	12	506324	###	86	12	191	22.01491152	60.47100741	285	3.331	11.992
0 days 00:26:05	running	3.336	3.336	1160	12	506609	###	86	12	191	22.01497329	60.47098906	285	3.336	12.01
0 days 00:26:06	running	3.344	3.344	1160	11	506894	###	86	11	190	22.01503507	60.47097062	285	3.344	12.038
0 days 00:26:07	running	3.414	3.344	1180	11	507179	###	86	11	190	22.01510246	60.47095335	285	3.414	12.29
0 days 00:26:08	running	3.486	3.347	1210	11	507465	###	86	11	191	22.01516985	60.470936	286	3.486	12.55
0 days 00:26:09	running	3.497	3.355	1210	11	507750	###	86	11	190	22.01523975	60.47091966	285	3.497	12.589
0 days 00:26:10	running	3.508	3.363	1220	11	508035	###	86	11	191	22.01530966	60.47090323	285	3.508	12.629
0 days 00:26:11	running	3.533	3.388	1230	11	508321	###	86	11	191	22.0153778	60.47088856	286	3.533	12.719
0 days 00:26:12	running	3.561	3.413	1240	11	508608	###	86	11	191	22.01544587	60.47087389	287	3.561	12.82
0 days 00:26:13	running	3.586	3.369	1240	11	508897	###	86	11	190	22.0155156	60.47086056	289	3.586	12.91
0 days 00:26:14	running	3.611	3.327	1250	11	509188	###	87	11	191	22.01558526	60.47084724	291	3.611	13
0 days 00:26:15	running	3.639	3.355	1250	11	509474	###	87	11	191	22.0156565	60.47083575	286	3.639	13.1
0 days 00:26:16	running	3.667	3.383	1260	11	509756	###	87	11	191	22.01572783	60.47082419	282	3.667	13.201
0 days 00:26:17	running	3.667	3.322	1260	11	510040	###	87	11	191	22.01579933	60.47081371	284	3.667	13.201
0 days 00:26:18	running	3.669	3.261	1260	11	510327	###	87	11	191	22.01587083	60.47080331	287	3.669	13.208
0 days 00:26:19	running	3.669	3.208	1260	11	510607	###	87	11	191	22.01593973	60.47079502	280	3.669	13.208
0 days 00:26:20	running	3.669	3.155	1270	11	510881	###	87	11	190	22.01600863	60.47078672	274	3.669	13.208
0 days 00:26:21	running	3.686	3.172	1280	10	511149	###	86	10	191	22.01607577	60.47077976	268	3.686	13.27
0 days 00:26:22	running	3.706	3.191	1290	10	511412	###	86	10	190	22.01614307	60.47077272	263	3.706	13.342
0 days 00:26:23	running	3.706	3.144	1290	10	511676	###	86	10	190	22.01621013	60.47076593	264	3.706	13.342
0 days 00:26:24	running	3.706	3.099	1290	10	511942	###	86	10	190	22.0162771	60.47075914	266	3.706	13.342
0 days 00:26:25	running	3.706	3.099	1290	10	512202	###	85	10	190	22.01633988	60.47075344	260	3.706	13.342
0 days 00:26:26	running	3.706	3.099	1300	9	512457	###	85	9	190	22.01640283	60.47074774	255	3.706	13.342
0 days 00:26:27	running	3.708	3.099	1300	9	512712	###	85	9	189	22.01646578	60.47074229	255	3.708	13.349
0 days 00:26:28	running	3.714	3.099	1300	9	512967	###	85	9	190	22.01652881	60.47073693	255	3.714	13.37
0 days 00:26:29	running	3.714	3.099	1300	9	513222	###	85	9	190	22.01659159	60.47073031	255	3.714	13.37
0 days 00:26:30	running	3.714	3.099	1310	9	513477	###	85	9	189	22.01665445	60.47072369	255	3.714	13.37
0 days 00:26:31	running	3.694	3.086	1300	8	513732	###	85	8	189	22.01671639	60.4707169	255	3.694	13.298
0 days 00:26:32	running	3.678	3.074	1300	8	513987	###	85	8	189	22.01677825	60.47071011	255	3.678	13.241
0 days 00:26:33	running	3.678	3.074	1290	8	514241	###	85	8	189	22.01683768	60.47070365	254	3.678	13.241
0 days 00:26:34	running	3.678	3.074	1290	8	514494	###	86	8	189	22.01689719	60.47069712	253	3.678	13.241
0 days 00:26:35	running	3.678	3.074	1280	8	514747	###	86	8	189	22.01695612	60.47068681	253	3.678	13.241
0 days 00:26:36	running	3.678	3.074	1280	7	515000	###	86	7	189	22.01701496	60.4706765	253	3.678	13.241
0 days 00:26:37	running	3.658	3.058	1270	7	515253	###	86	7	188	22.0170717	60.47066116	253	3.658	13.169
0 days 00:26:38	running	3.642	3.041	1270	7	515506	###	86	7	189	22.01712837	60.47064582	253	3.642	13.111
0 days 00:26:39	running	3.642	3.086	1260	7	515757	###	86	7	189	22.01718193	60.47062553	251	3.642	13.111
0 days 00:26:40	running	3.642	3.13	1260	7	516007	###	87	7	189	22.0172354	60.47060533	250	3.642	13.111
0 days 00:26:41	running	3.642	3.18	1260	6	516262	###	87	6	188	22.01728368	60.47057684	255	3.642	13.111
0 days 00:26:42	running	3.642	3.233	1260	6	516523	###	87	6	188	22.01733196	60.47054834	261	3.642	13.111
0 days 00:26:43	running	3.642	3.294	1250	6	516789	###	87	6	188	22.01736658	60.47051615	266	3.642	13.111
0 days 00:26:44	running	3.642	3.355	1250	6	517061	###	88	6	188	22.0174012	60.47048405	272	3.642	13.111
0 days 00:26:45	running	3.642	3.355	1240	6	517339	###	88	6	189	22.01742131	60.47044901	278	3.642	13.111
0 days 00:26:46	running	3.642	3.355	1240	6	517624	###	88	6	188	22.01744143	60.47041406	285	3.642	13.111
0 days 00:26:47	running	3.664	3.377	1250	6	517909	###	87	6	188	22.01744897	60.47037399	285	3.664	13.19
0 days 00:26:48	running	3.689	3.399	1270	6	518194	###	87	6	189	22.01745668	60.4703341	285	3.689	13.28
0 days 00:26:49	running	3.689	3.399	1280	6	518480	###	86	6	188	22.01745668	60.47029445	286	3.689	13.28
0 days 00:26:50	running	3.689	3.399	1290	6	518768	###	86	6	188	22.01745668	60.47025472	288	3.689	13.28
0 days 00:26:51	running	3.708	3.419	1290	5	519056	###	86	5	188	22.01744738	60.47022069	288	3.708	13.349
0 days 00:26:52	running	3.731	3.438	1300	5	519344	###	86	5	188	22.01743808	60.47018683	288	3.731	13.432
0 days 00:26:53	running	3.731	3.438	1300	5	519634	###	86	5	188	22.01742659	60.4701647	290	3.731	13.432
0 days 00:26:54	running	3.731	3.438	1300	5	519926	###	86	5	188	22.01741519	60.47014265	292	3.731	13.432
0 days 00:26:55	running	1.864	1.719	650	5	520218	###	43	5	188			292	1.864	6.7104
0 days 00:27:25	running	0.517	0.475	300	3	520656	###	25	3	172	22.01732551	60.47007585	0	0.517	1.8612
0 days 00:27:26	running	1.033	0.95	600	3	520656	###	51	3	172	22.0173188	60.47007015	0	1.033	3.7188
0 days 00:27:27	running	1.036	0.994	600	3	520696	###	51	3	171	22.01730581	60.47006738	40	1.036	3.7296
0 days 00:27:28	running	1.042	1.041	610	3	520777	###	51	3	171	22.01729282	60.47006479	81	1.042	3.7512
0 days 00:27:29	running	1.039	1.116	610	3	520862	###	50	3	171	22.01727798	60.47006629	85	1.039	3.7404
0 days 00:27:30	running	1.036	1.194	620	3	520951	###	50	3	170	22.01726323	60.4700678	89	1.036	3.7296
0 days 00:27:31	running	0.517	0.597	310	3	521046	###	25	3	170			95	0.517	1.8612

Appendix B: Existing Simulink Model for eRallycross Powertrain



Appendix C: Revised Simulink Model



Appendix D: MATLAB Parallel Server CSC Documentation

HOW TO USE MATLAB PARRELLEL SERVER AND PUHTI

Contents

USING PUHTI AS A PARRALLE SOLVER FOR MATLAB

using the CSC supercomputer Puhti to run computationally intensive MATLAB scripts.

1. Creating CSC account

https://my.csc.fi/login

Register for a CSC account using the above link, using the Haka login service, selecting Turku university of Applied Sciences as institution

Log in using TUAS credentials and create CSC profile – linking your TUAS account allow access to academic billing units

you may need to change your CSC password.

CSC Username
getliffj

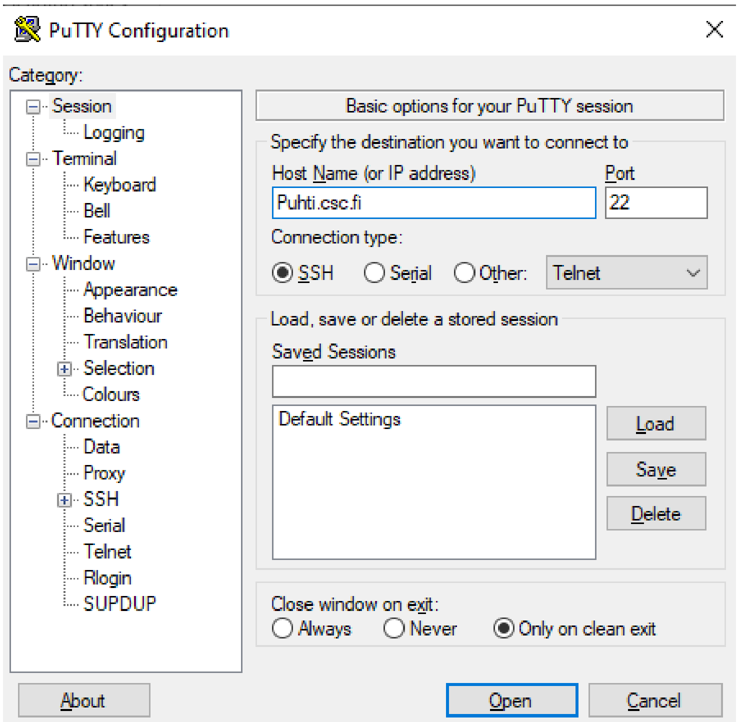
2. Checking Credentials and status of MATLAB Parrelle server licenses.

Download PuTTY client from the tutorial folder or visit the website below for the latest version.

https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html

This will enable a remote connection to the PUHTI or MAHTI supercomputers to be made from your computer, using your CSC username and password, or a pair of SSH keys.

Open the PuTTY client and type the desired computers Hostname in the specified box:



Click open, where you will be prompted to input your CSC credentials. When typing your password, no text will display, however once you have typed your password and pressed enter, the client will establish a secure connection.

Without additional software, copying and pasting commands/passwords will not work within the terminal.

This connection can then be used to upload public SSH keys to the Puhti computer, but this method of connection will not be used in this tutorial for convenience.

The number of available and used MATLAB parallel server licenses can be checked by typing the following command:

scontrol show lic=mdcs

```
[getliffj@puhti-login11 ~]$ scontrol show lic=mdcs
LicenseName=mdcs
    Total=500 Used=493 Free=7 Reserved=0 Remote=no
[getliffj@puhti-login11 ~]$ 
```

If there are no free licenses, any jobs will be queued until they are available.

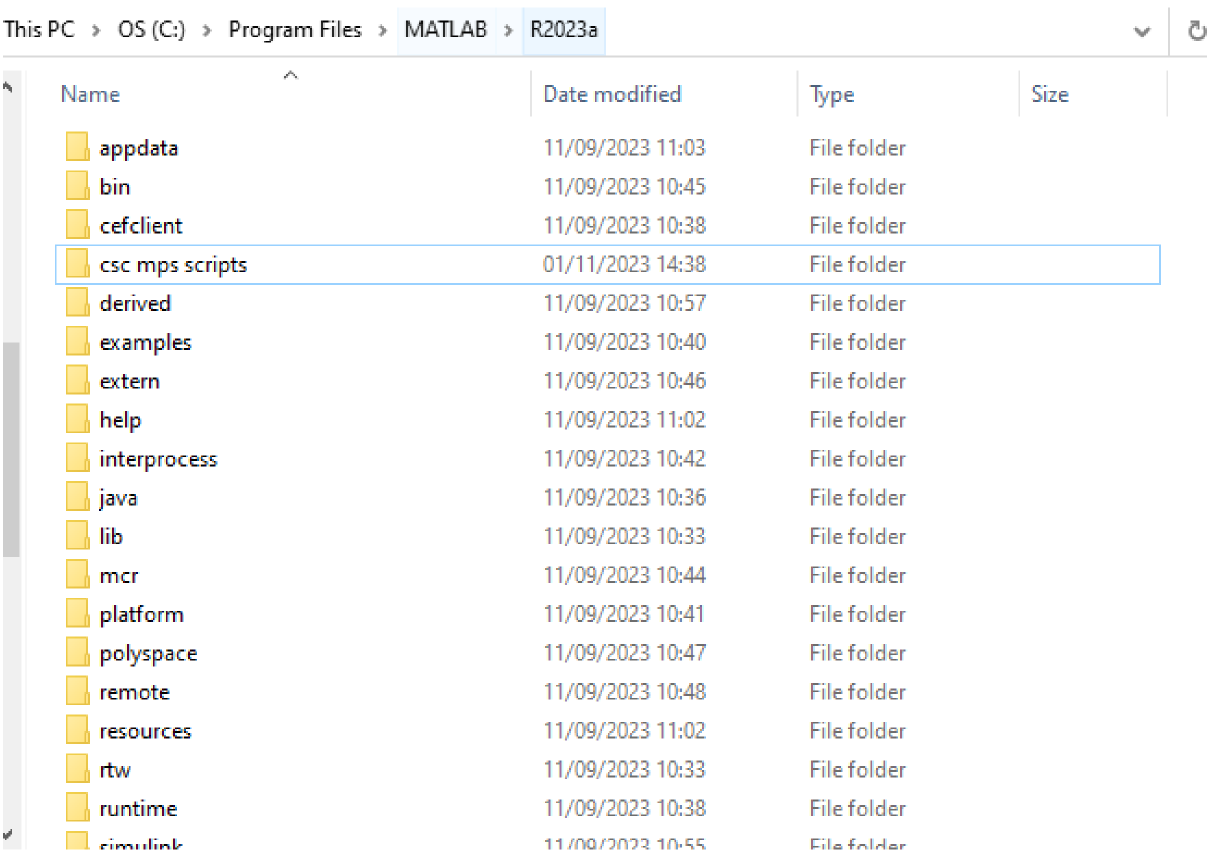
3. Installing MATLAB Parallel Server (MPS) Puhti compatibility scripts

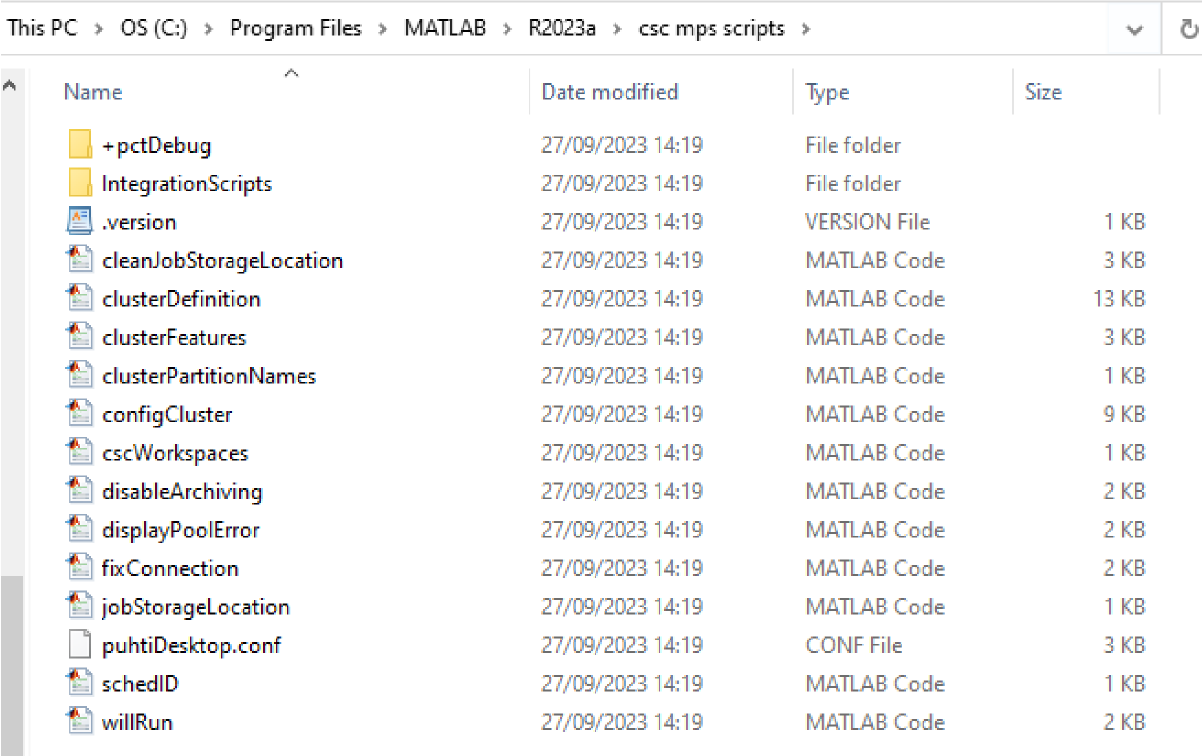
Download the zipped folder containing the required scripts shown below from the tutorial folder.

csc.Desktop

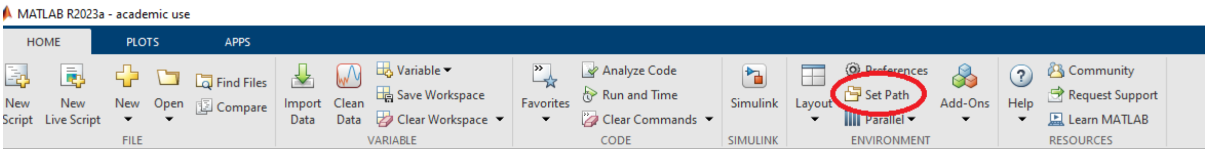
n.b these scripts are for MATLAB R2023b, however work with R2023a, further back/forwards compatibility is not guaranteed, (newer files can be found at the following link, but are restricted for TUAS accounts, https://wiki.eduuni.fi/display/cscjemma/MATLAB+MPS+configuration)

extract the folders inside and place inside a folder inside the MATLAB R2023 folder

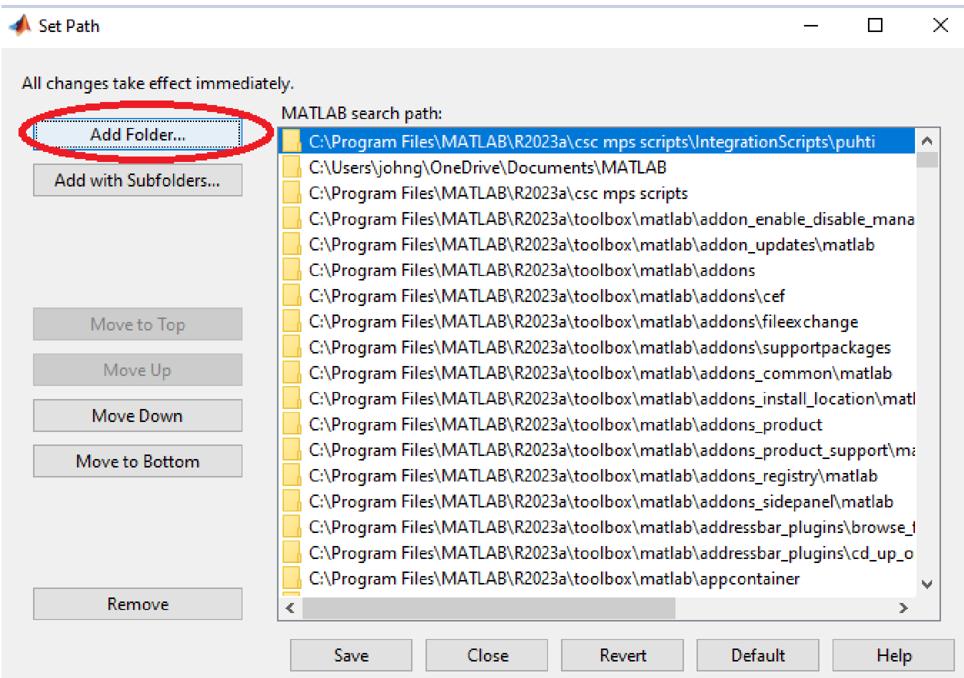




You may then need to add the folder to the path, do this by going to environment, and set path



Then use add folder and locate and select the folder you saved the scripts to.



Then Save and close the Dialog box. MPS is now ready for use on your local computer.

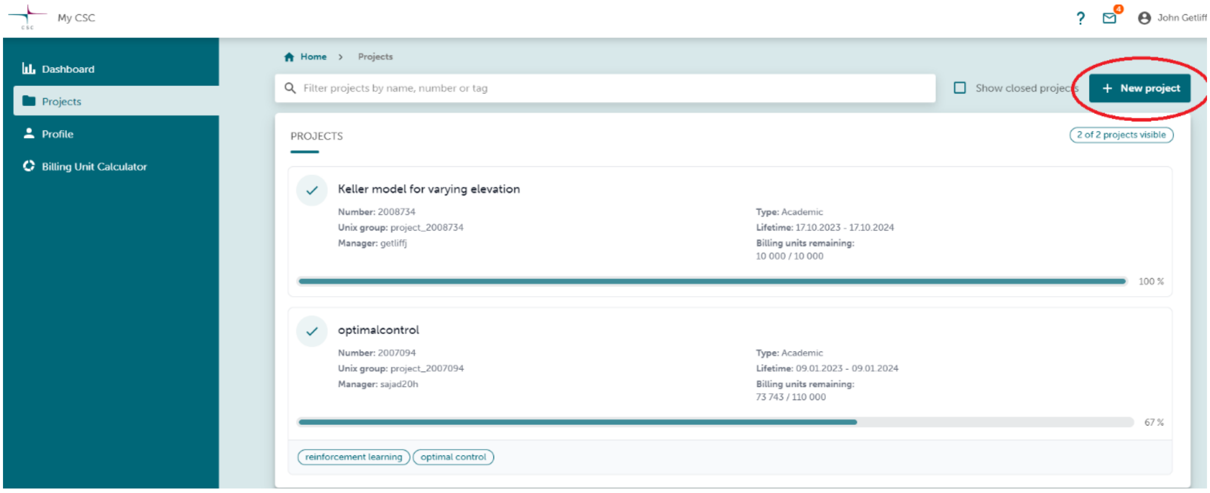
4. Creating a CSC project for Puhti

Go to

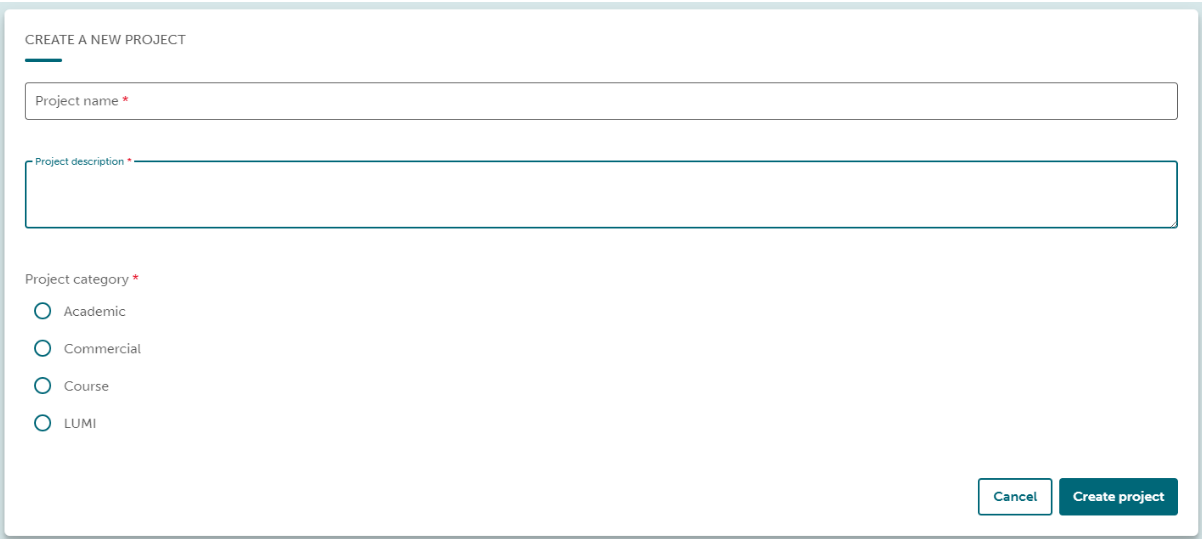
https://my.csc.fi/projects

and login with your CSC or HAKA credentials

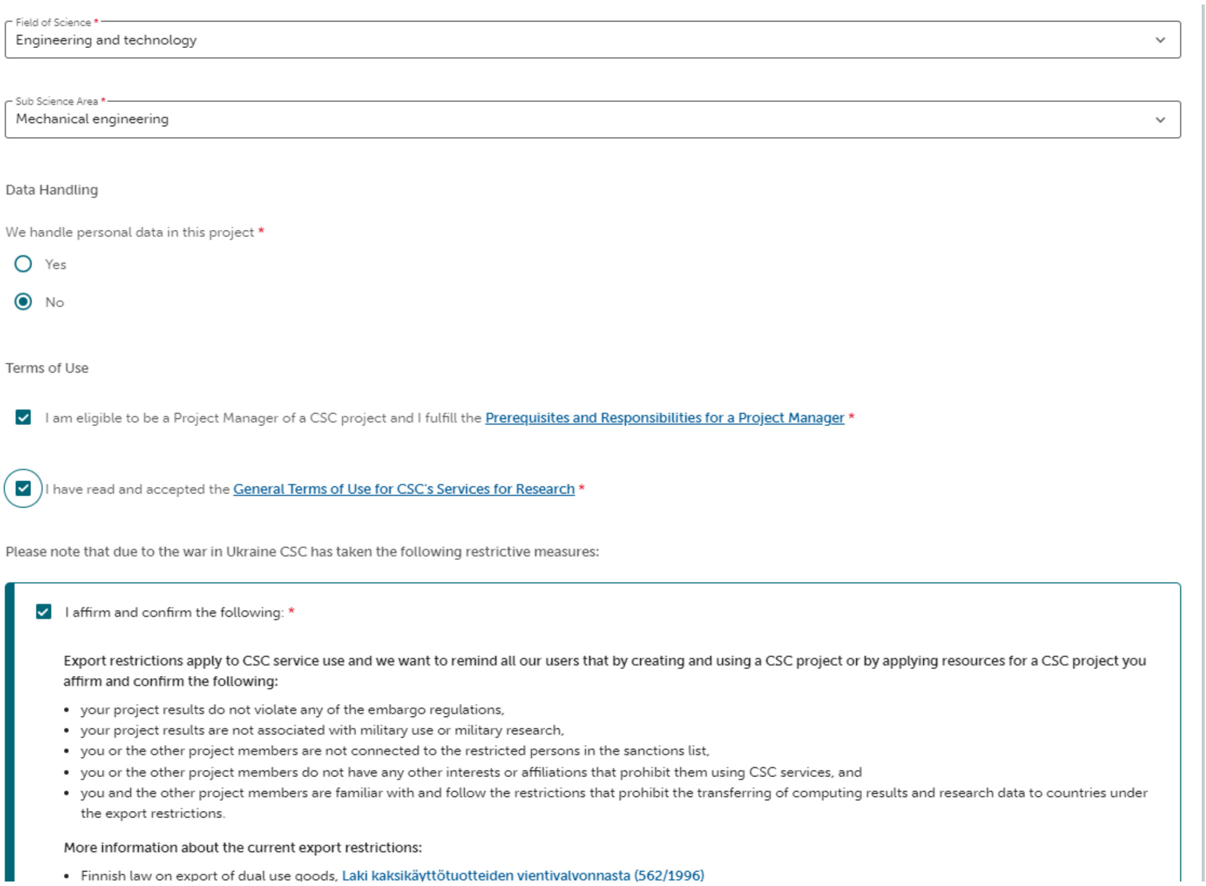
We will then create a new project using the new project button:



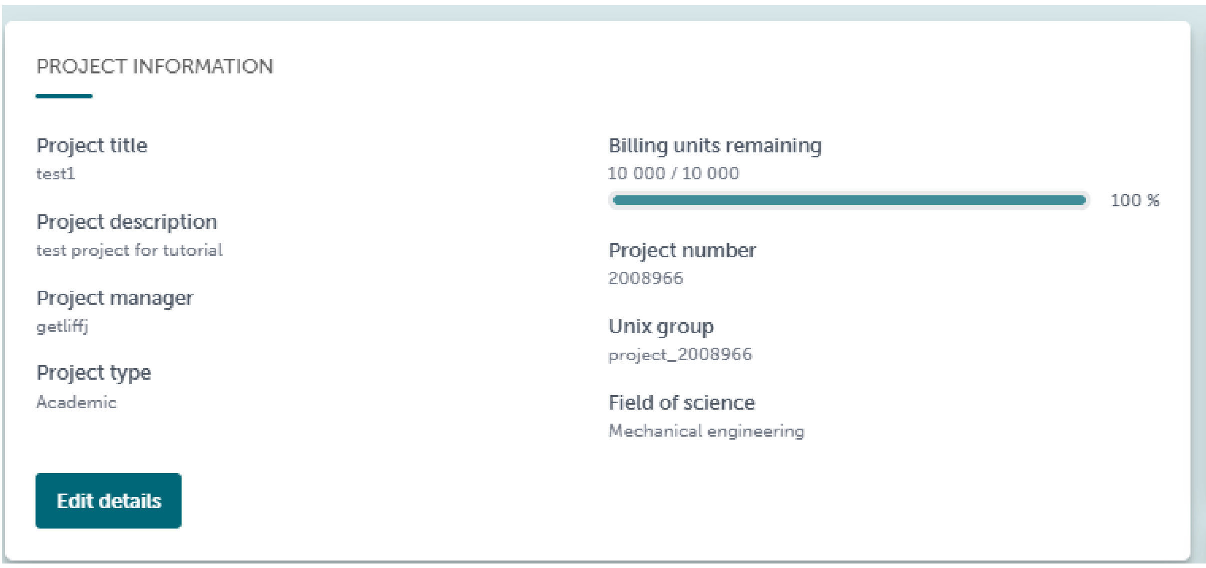
Give your project a Name, description, and Category:



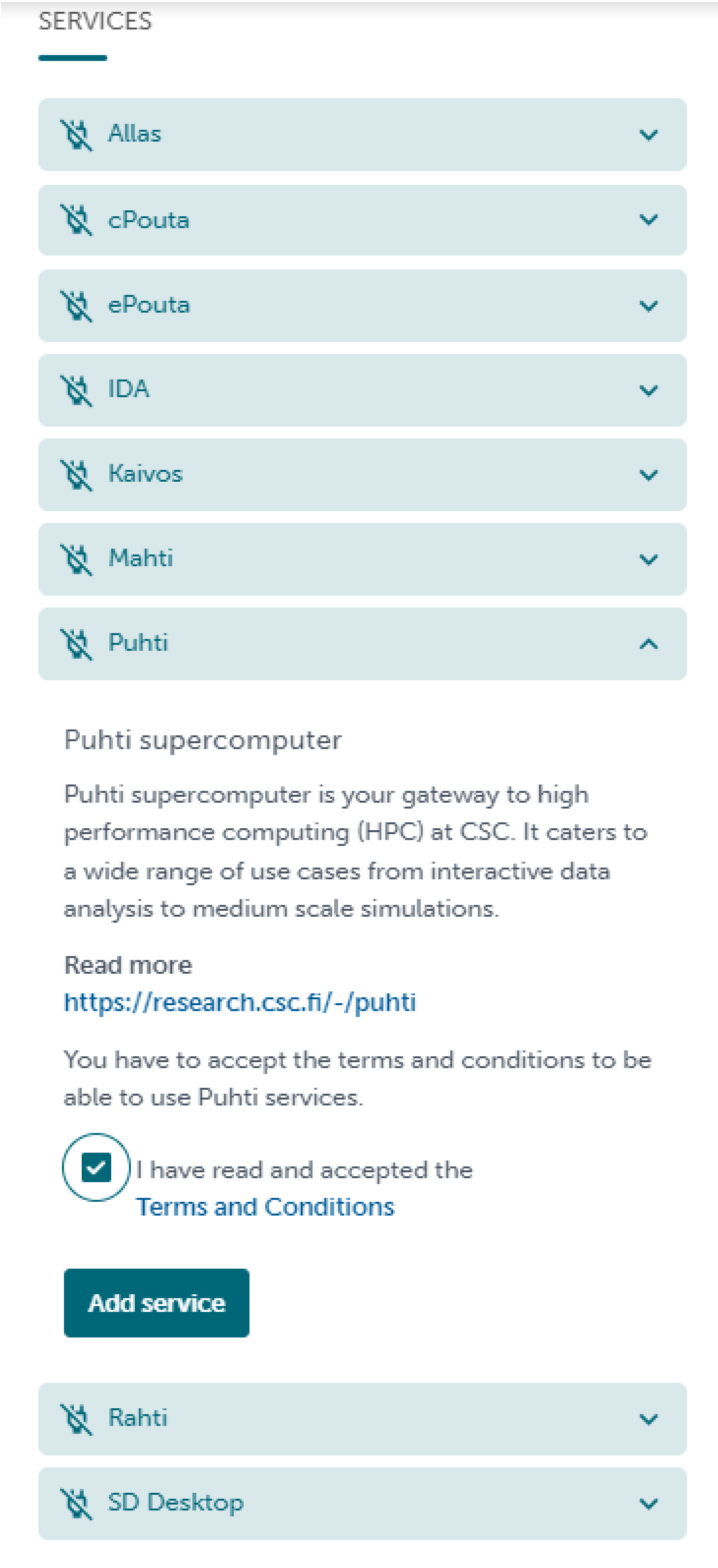
Complete the following sections and click create project at the bottom of the page:



As an academic project, it will automatically be assigned 10,000 billing units. To reference this project when loading a job to the computer, use the Unix group code:



You must then add the Puhti supercomputer as service using the selection on the right hand side of the project page:



Your project is now ready to be used to be billable for jobs carried out using Puhti.

5. Running Matlab functions using MPS and Puhti – configuring clusters

To begin running a function or set of functions using MPS, first the Cluster of workers must be configured the command:

>> configCluster

is entered, after which you are prompted for your CSC username, and then the configuration settings for the cluster. A sample settings is show below:

```
>> c = parcluster
>> c.AdditionalProperties.MemUsage = '';
>> c.AdditionalProperties.QueueName = '';
>> c.AdditionalProperties.Partition = 'large';
>> c.AdditionalProperties.MemPerCPU = '2g';
>> c.AdditionalProperties.WallTime = '48:00:00';
>> c.AdditionalProperties.ComputingProject = 'project_2007094';
```

Ensure computing project is set to unix code for selected project, such that project is billable and able to run, the following options dialog will be shown:

```
AdditionalProperties with properties:

      AdditionalSubmitArgs: ''
    ClientConnectsToWorkers: 0
               ClusterHost: 'puhti.csc.fi'
          ComputingProject: 'project_2007094'
                Constraint: ''
              EmailAddress: ''
               EnableDebug: 0
               GPUsPerNode: 0
                 MemPerCPU: '4g'
                  MemUsage: '32g'
                 Partition: ''
              ProcsPerNode: 0
                 QueueName: 'large'
   RemoteJobStorageLocation: '/users/getliffj/.matlab/generic_cluster_jobs/puhti/DESKTOP-E2MO673'
                  Username: 'getliffj'
                  WallTime: '8:00:0'
```

Partition can be selected using queue name, with options shown below.

Puhti partitions

The following partitions (aka queues) are currently available in **Puhti** for normal (CPU) nodes:

Partition	Time limit	Max tasks	Max nodes	Node types	Max memory	Max local storage (NVMe)
test	15 minutes	80	2	M	185 GiB	
interactive	7 days	8	1	IO	76 GiB	720 GiB
small	3 days	40	1	M, L, IO	373 GiB	3600 GiB
large	3 days	1040	26	M, L, IO	373 Gib	3600 GiB
longrun	14 days	40	1	M, L, IO	373 GiB	3600 GiB
hugemem	3 days	160	4	XL, BM	1496 GiB	
hugemem_longrun	14 days	40	1	XL, BM	1496 GiB	

Wall time configures the maximum run time of the routine.

Mem usage configures the maximum RAM available to the routine.

6. Running Matlab functions using MPS and Puhti – submitting batch jobs

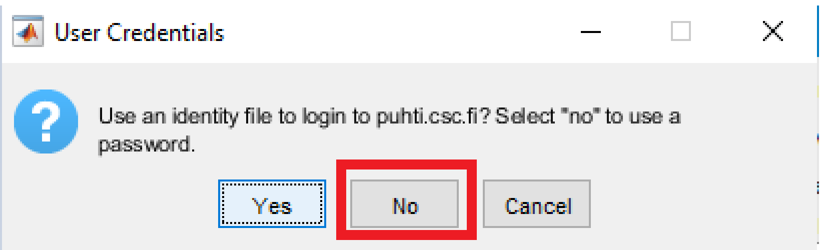
To submit a job, it must be submitted as a batch job using the following functions.

An example is shown below

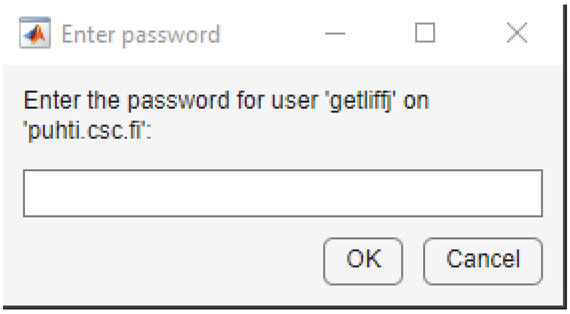
j = batch(c, @RUNME, 5, {}, 'Pool', 36 , 'CurrentFolder','.', 'AutoAddClientPath',true)

c is the cluster to be submitted to, @RUNME is the matlab function name, 5 is the number of outputs of the function (make sure this is correct for your function), 36 is the number of workers, and the total number used will be n+1 (e.g. for this 37). Ensure required files are in the current folder, and if the function requires sub-functions, set AutoAddClientPath to True to ensure that they can be accessed.

A prompt will ask if you want to use an identity file (SSH), click no:



you will then be requested to enter your csc password:



on successful job submission, the following will be displayed:

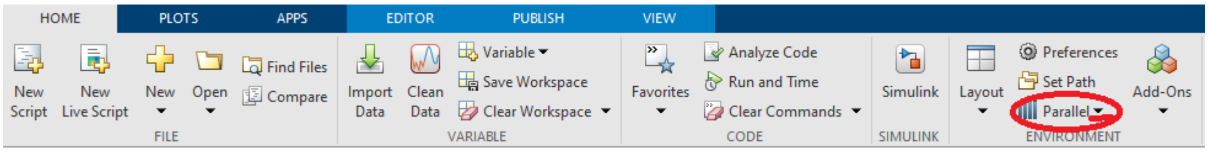
```
additionalSubmitArgs =

    '--ntasks=33 --cpus-per-task=1 --ntasks-per-core=1 -A project_2007094 --mem-per-cpu=4g -t 8:00:0 --licenses=mdcs:33'


j =

 Job

    Properties:

                   ID: 54
                 Type: pool
             Username: johng
                State: queued
       SubmitDateTime: 21-Nov-2023 16:28:54
        StartDateTime: 
     RunningDuration: 0 days 0h 0m 0s
      NumWorkersRange: [33 33]
           NumThreads: 1

      AutoAttachFiles: true
  Auto Attached Files: List files
        AttachedFiles: {}
    AutoAddClientPath: true
      AdditionalPaths: C:\Users\johng\OneDrive\Documents\MATLAB
            FileStore: [1x1 parallel.FileStore]
           ValueStore: [1x1 parallel.ValueStore]
 EnvironmentVariables: {}

    Associated Tasks:

       Number Pending: 33
       Number Running: 0
      Number Finished: 0
    Task ID of Errors: []
  Task ID of Warnings: []
   Task Scheduler IDs: 19457561
```

As the job is now on the Cluster, your local MATLAB session can now be closed.

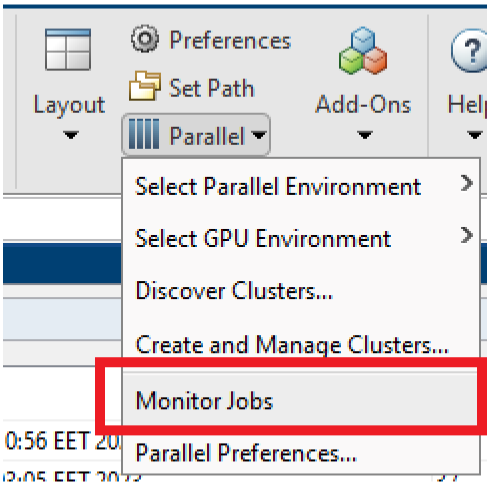
7. Checking job statuses and retrieving results

The progress/ status of jobs can be view using the parallel jobs monitor:

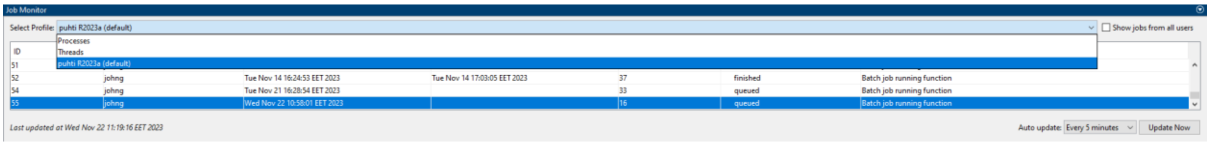
You can open the jobs monitor by clicking home, then going to environment, and clicking the dropdown arrow for parallel.



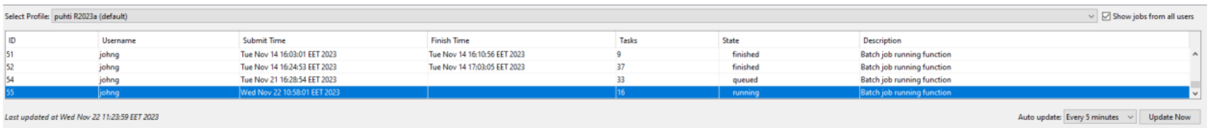
By then clicking monitor jobs, the below status table will appear.



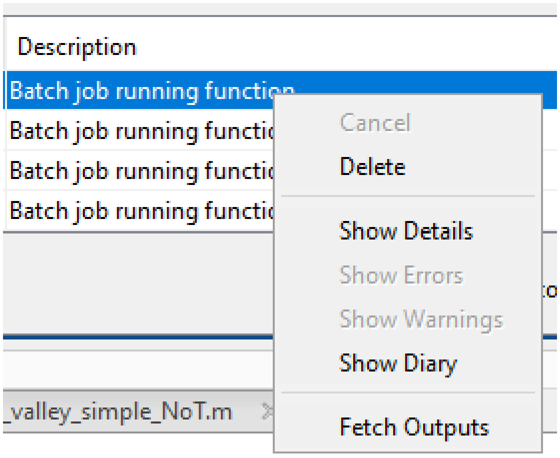
Ensure the profile is set to Puhti R2023a



The table will then display all user jobs on the Puhti server.



From here, a jobs individual details and Diary and be access by right clicking, and if the job is finished, the results can also be requested using fetch outputs.



The following commands can be used to display the users' jobs in the command window, and to request outputs from a given job

jobs = c.Jobs

j1 = c.Jobs(x) %% where x is the job number

fetchOutputs(j1)

8. Reconnecting

If you have closed MATLAB during the duration of a Puhti Job, upon reopening, if the Job monitor was previously open, you will be prompted to enter your CSC Password, upon which the job monitor will refresh. If the Job monitor was not open, connection can be established by first configuring the Cluster (see section 5), and then using the Command:

getRemoteConnection(parcluster)

upon which you will be prompted again if you want to use an identity file and for your CSC password, and after completion, you will again be connected to Puhti and be able to retrieve Job data.

9. Help

Help can be found on the CSC website:

https://docs.csc.fi/apps/matlab/#getting-started-with-matlab-parallel-server-on-puhti

or by emailing the CSC helpdesk at:

servicedesk@csc.fi

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APPLIED SCIENCES

University of Strathclyde Engineering

APPENDIX E: PROJECT HANDOVER AND USER MANUAL FOR USE BY COMEA

PROJECT HANDOVER AND USER MANUAL

Energy Constrained Time Optimal Electric Vehicle Control in Terrain with Varying Elevation

John Getliff, Alyx Mackie, Fraser Sweeney,

and Bronwyn Tunn

Keller Parameter Derivation

1.1 Required Files:

RUN_param_sol.m

NaantaliData.mat

ParamData.mat

E0_.m

F_max_tau.m

Init_Param.m

myode2.m

Sigma.m

Sin_alpha_tt.m

Sin_alpha_x.m or Slope_x.m

Vel_Plot.m

Velocity.m

Douglas_Packer_code.m (only if Slope_x.m used)

The values stored within the matrix, P0, which is used to initialise the optimisation routine are found using Init_Param.m, which employs the functions F_max_tau.m to find values for the maximum propulsive force, fmax and the resistive force, τ, Sigma to find the aerobic recovery rate, σ and finally E0_ to find the initial energy.

F_max_tau.m and Sigma.m require inputs of time, speed, distance data from the NaantaliData.mat file. The results of these are then used as inputs in E0_.m alongside the running data.

The equations implemented within these script functions to find the initial values can be seen below.

Equation 1: Expression for velocity to aid in finding of f_{max} and τ [1]

$$v(t) = f_{max}\,\tau\left(1 - \exp\left(-\frac{t}{\tau}\right)\right)$$

Equation 2: Maximum Volumetric Oxygen Recovery Rate [2]

$$\dot{V}O2_{max} = (22.351 \cdot d_{12}) - 11.28$$

Equation 3: Expression for initial energy value [1]

$$e^0 = \left(\sigma(t_2 - t_1) - \frac{1}{2}\left(v^2(t_2) - v^2(t_1)\right)\right) - \int_{t_1}^{t_2} \frac{v^2}{\tau}\, ds$$

The fundamental equation described by Keller's theory are modelled by the function myode2. This system if odes sets the foundation for the calculation of velocity. This required the local slope angle to be known for the entire course, this is done using sin_alpha_x and subsequently sin_alpha_tt, however this can be replaced with the Douglas-Peucker code by changing from sin_alpha_x to Slope_x.

The Velocity script employs ode45 in order to solve myode2 and find the velocity, using the parameters inputted.

RUN_param_sol, is the file from which this routine should be run. It initialises the optimisation routine, which aims to find the parameter matric P which minimise the error between the velocity calculated using Keller's theory (myode2) and the measured velocity from the provided running data.

Finallly Vel_Plot generates graph which shows a visual representation of how the calculated and measure velocities compare. The figure produced also includes a scaled plot of the elevation profile of the given track to aid in comparisons.

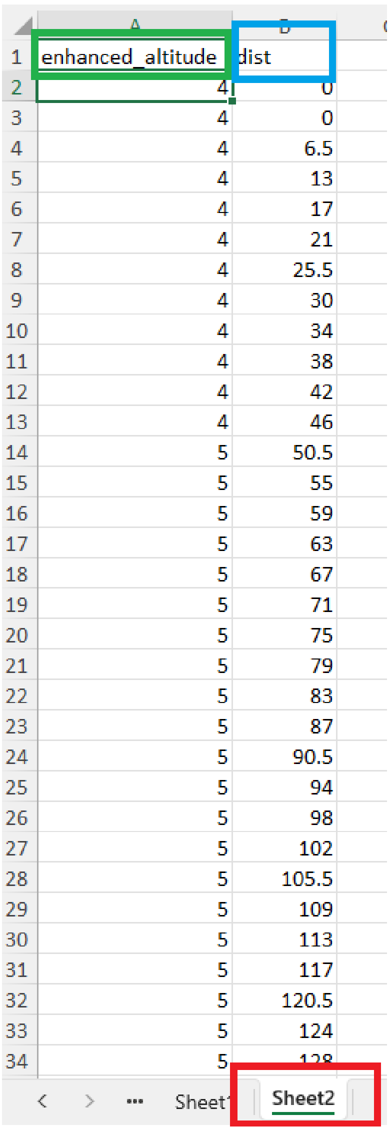
2D Keller model for runner using Fmincon.

2.1 Required files.

- RUNME.m OR runmescript.
  (If running locally, use runmescript to allow output matrix to be stored, if using CSC, code must be function so use RUNME)
- Douglas_packer_code.m
- x_and_v_and_E.m
- nonlcon_pwlinear_valley_simple_NoT.m
- CalculatePositionVelocityAndEnergyValley.m
- Constraints.m
- runmescript.
- Naantali_Run20230727060020.xlsx (or any other track data in excel)

2.2 Format of track data

Most GPS data when converted to excel has a lot of irrelevant data/ is of differing format, so a second sheet with only 2 colums is created to be read by MATLAB.



	A	B
1	enhanced_altitude	dist
2	4	0
3	4	0
4	4	6.5
5	4	13
6	4	17
7	4	21
8	4	25.5
9	4	30
10	4	34
11	4	38
12	4	42
13	4	46
14	5	50.5
15	5	55
16	5	59
17	5	63
18	5	67
19	5	71
20	5	75
21	5	79
22	5	83
23	5	87
24	5	90.5
25	5	94
26	5	98
27	5	102
28	5	105.5
29	5	109
30	5	113
31	5	117
32	5	120.5
33	5	124
34	5	128

The input file can be changed in the function Douglas_packer_code.m

by changing the file name shown below:

```
function slope = Douglas_packer_code()
% script simplifies GPS track data and calcualtes slopes of sections
    filename = 'Naantali_Run20230727060020.xlsx';
```

The number of points generated by the DP algorithm is altered by changing the function tolerance:

```
    tolerance = 0.001
%to alter number of points in reduced plot, decrease tolerance to increase
```

The Keller Parameters for the runner are inputted per kilogram in the function constraints.m

```
function [tau, Fmax, sig, E0] = Constraints()
% parameters derived from Nantalli data, devided by assumed mass 75kg
%defines initial energy, maximum propulsive force, recovery of energy rate
%and resistance
% for a UNIT MASS, i.e. m = 1 kg
tau = 0.8255; %s
sig = 21.7; %m/s^2
Fmax = 9.74; %N = m/s^2
E0 = 3265; %m^2/s^3
```

The Function x_and_v_and_E.m defines the system of differential equations for the position, velocity, and position of the runner at any given point.

The solver used for solving this system of equations can be changed in the function CalculatePositionVelocityAndEnergyValley.m

```
% solver methods for differential equations
%[tt,y] = ode23t(@(t,y) x_and_v_and_E(t,y,f,tau,sig, slope), tspan, y0);
[tt,y] = ode15s(@(t,y) x_and_v_and_E(t,y,f,tau,sig, slope), tspan, y0);

%[tt,y] = ode23t(@(t,y) x_and_v_and_E(t,y,f,tau,sig), tspan, y0);

%[tt,y] = ode45(@(t,y) x_and_v_and_E(t,y,f,tau,sig), tspan, y0);
%[tt,y] = ode15s(@(t,y) v_and_E(t,y,f,tau,sig), tspan, y0);
```

The function nonlcon_pwlinear_valley_simple_NoT.m structures the optimisation problem, and defines the inequality and equality constraints for the routine, alongside their tolerances in red :

```
    [tt,xsol,v,E] = CalculateVelocityAndEnergyInnerPWlinear(xp, yp, T, slope);

    c(1) = -max(xsol) + (slope(end,1)-0.01); % x-coordinate must be length of track

    c(2) = -min(E); % energy must be nonnegative

   %c(3) = max(E)-2000; % energy must not go higher than intial energy

    ceq = []; %no equality constraints

catch
    ceq = 1e6;
    c = 1e6;
```

The Function RUNME contains most important values for altering, in order: number of force interpolation points (red), Maximum completion time to search to (green), Maximum fuction evaluations and iteration counts (orange), function tolerance (blue), number of start points (purple)

```
function [x,fval,exitflag,output,allmins] = RUNME()
NInterpolationPoints = 3;
%number of points on force graph// number of time propulsive force can
%change
slope = Douglas_packer_code();

[tau, Fmax, sig, E0] = Constraints();

Tmax = 3500  %maximum solution time
solutions = struct([]);
objfun = @(x) x(1);

rng(NInterpolationPoints,'twister');
confun = @(x) nonlcon_pwlinear_valley_simple_NoT(x, NInterpolationPoints, slope);

% solution vector x(1) = time, x(2:end) = vertical forces at
% equidistant points on linspace(0,x(1),NInterpolationPoints)
lb = [0;2*0*ones(NInterpolationPoints, 1)];
ub = [Tmax; 2*Fmax*ones(NInterpolationPoints, 1)];
x0 = 0.5*(ub+lb);

opts = optimoptions('fmincon','Algorithm','active-set','MaxFunctionEvaluations',800*length(x0),'MaxIterations',800)
%optimisation problem options setup
problem = createOptimProblem('fmincon','objective', objfun, 'x0', x0,'lb',lb,'ub',ub, 'nonlcon', confun,'options', opts);
ms = MultiStart('Display', 'iter','FunctionTolerance',1e-3,'UseParallel',true);
[x,fval,exitflag,output,allmins] = run(ms,problem,10); %number of attempts can be altered here
% multistart for running problems in parrallel/ simultainously
```

To run complete routine, ensure all files are in active project file, then run the function RUNME using the script editor.

Discrete Force Strategy Code

All four MATLAB files which entail the new discrete force strategy for the runner system run in relatively the same way with the same general ideology applied.

For the Naantali track, there are two files which concern this track data – the only difference between these is the number of choices that the system has when selecting the force which the runner should be running that section at. One of the MATLAB code files will run between two discrete force choices with the other allowing the runner to choose between five different force values. The range of the force values is kept the same (between 30% and 40% of the maximum runner force). This range was selected as a sensible range based on the attributes of the runner based on the Keller parameter derivations – this range could be changed dependant on each individual runner and their capabilities. The five force choices can be changed to suit the range of forces chosen.

3.1 Files Required

DouglasPackerCodeNaantaliTrack

NaantaliTrack2ForceChoices

NaantaliTrack5ForceChoices

NaantaliTrackData

NaantaliAngles

3.2 Discrete Force Strategy– Naantali Track

The first section of the code imports the excel file containing the track data and calculates the differences between each track segment to give the distance of each segment (these distances will be used in the calculations). The first filename can be changed to change the DP data file that the code will read. The next section (lines 13-18) imports the angles of each of the track segments – this is where the first alterations could be made to this code.

3.2.1 Changes to the angles of track segments

```
% Import file with Naantali track run data angles
filename = 'NaantaliAngles.xlsx';
sheet = 1;
angle_range_n = 'A3:A8';
angles2 = xlsread("NaantaliAngles.xlsx",1 , angle_range_n);
theta = deg2rad(angles2); % Convert to radians
```

The excel sheet entitled ‘NaantaliAngles’ is a file which contains the angles of each of the track segments. These are calculated separately from the code – all that was needed was to take the graph found from the DP code and find the angle between each of the points on the graph.

For example,

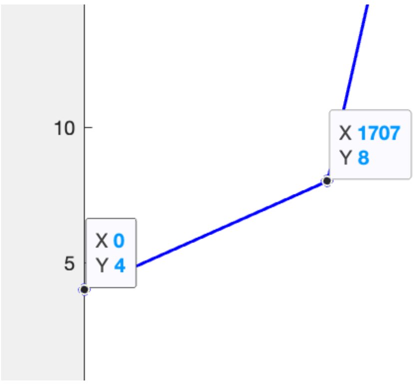


Figure 1: Segment one from the DP code graph

Figure 1 is a screenshot of the DP code graph but only section one with the coordinates of each point. The angle for section one was then calculated –

$$ang1 = tan^{-1}\left(\frac{8-4}{1707} - 0\right) = 0.1343°$$

The same calculation was done for each segment using the coordinates for each point. This file would need to be changed based on changes made to the DP code (for example if more interpolation points used). All that would need to be done is to recalculate these values using hand calculations and change the angles in column A of the excel file. If there ends up being more angles than the original file, then the 'angle_range' would need to be altered the match the new number of angles.

3.2.2 Changes to the initial data

```
% Initial data
mass = 75; % The mass of the runner
Fmax = 9.74*mass ;  % The runner's maximum force in Newtons found from Keller parameters
forces = [0.15*Fmax, 0.175*Fmax, 0.2*Fmax, 0.225*Fmax, 0.25*Fmax] ; % The force choices of the runner in Newtons
energy_run = 305.5 ; % Energy found through Keller parameters
calories = mass*energy_run;% The runner's initial energy in calories
ini_energy = calories*4.184 % The runner's initial energy in Joules
ini_vel = 0 ;  % The runner's initial velocity in m/s
g = 9.81 ; % Acceleration due to gravity in m/s^2
sigma = 6.29*mass ; % Regen energy in Joules/second
```

Figure 2: Initial data

Any of the values of the initial data can be changed dependant on each individual runner.

The 'Fmax' value can be changed based on the runner's Keller parameters. The 'forces' line is the force choices of the runner – these can be changed dependant on the maximum force value as they need to be high enough for the runner to be fast but not too high that they end up with negative energy levels. Again, the mass can be changed to fit the runner as well as the 'energy run' which is initial energy found from the Keller parameters.

The rest of the code should then run without needing any changes to get results.

eRallycross Car MATLAB

Three files are required to fully model the optimised eRallycross car model.

4.1 Files Required

- eRC_Vel_optimum.m
- ECM_matrices.mat
- eRallycross_Naantali.slx

4.2 Track Data

```
% Initial data
Vmax = 68;
% The vehicles max velocity (m/s)
v = [0.5*Vmax, 0.55*Vmax, 0.6*Vmax, 0.65*Vmax, 0.7*Vmax]; % The speed choices of the car in m/s
mass = 1280; % The mass of the car in kg
distances = [1707, 645, 504.5, 2409.5, 518, 191];  % Distance between each segment in metres
angles = [0.1343, 1.3322, -2.1568, -0.0238, 0.9954, -2.6978];  % Angles between each segment in degrees
initial_vel = 0;  % The runner's initial velocity in m/s
```

The above code shows the initial parameters of the track and the vehicle velocity choices. The ‘distances’ array contains the value of distance for each section of the track in metres. The ‘angles’ array contains the gradient of each section in degrees. The ‘distances’ and ‘angles’ arrays can be modified to suit each individual track for which to be simulated.

4.3 Simulink

The ECM_matrices.mat file must be uploaded to the base MATLAB script before running the Simulink model as the ECM battery requires the data to run.

The matlab function below is used in the Simulink model to ensure the velocity and gradient change when the car reaches the corresponding displacement.

```
%Initialise output
v = 0; %output velocity (m/s)
theta = 0; %output gradient (deg)

%Velocity for each section
if x>= 5975
    v = 0;
elseif x >= 5784
    v = 0.7*V;
elseif x >= 5266
    v = 0.55*V;
elseif x >= 2856.5
    v = 0.65*V;
elseif x >= 2352
    v = 0.7*V;
elseif x >= 1707
    v = 0.5*V;
elseif (x<1707)
    v = 0.6*V;
end
```

```
%Gradient of each section
if (x >= 5784 && x <= 5975)
    theta = -2.6978;
elseif x >= 5266
    theta = 0.9954;
elseif x >= 2856.5
    theta = -0.0238;
elseif x >= 2352
    theta = -2.1568;
elseif x >= 1707
    theta = 1.3322;
elseif (x<1707)
    theta = 0.1343;
end
end
```

This can be modified for each individual track. The variable ‘x’ is the displacement in metres. The if loops are used to change velocity and gradient when the vehicle travels between track sections.

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[2] E. Quinn, “Using the Cooper Test 12-Minute Run to Check Aerobic Fitness,” VeryWell Fit, 27 October 2022. [Online]. Available: https://www.verywellfit.com/fitness-test-for-endurance-12-minute-run-3120264. [Accessed September 2023].

Appendix F: Reflective Report

Reflective Report

‘ENERGY-CONSTRAINED TIME-OPTIMAL ELECTRIC VEHICLE CONTROL IN TERRAIN WITH VARYING ELEVATION’

Group Members

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Supervisor: EERO IMMONEN

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1.0 Introduction

Over the course of the months spent in Finland studying at the Turku University of Applied Sciences (TUAS) we as a group have worked both collaboratively and individually in order to complete the tasks and objectives set out for the fulfilment of the project and all associated works within the time allocated and to the standard expected of a master's level research dissertation.

1.1 Project Definition

The primary aim of this project was to formulate a computational procedure which would produce a graph of the optimum propulsive force required for an eRallycross vehicle. It was also required that this procedure be able to account for the restrictions imposed upon electric vehicles by the limitations of battery capacity and the associated energy constraints inflicted. This is all with the intention of enabling an eRallycross car, such as the one under development by the Turun Ammattikorkeankoulun (TUAS) eRallycross-autoprojekti, to complete an unknown rallycross circuit, which has variations in elevation throughout, within a minimal amount of time. In order to formulate the previously described procedure, the scope of the project was set in such a way that first a solution for a case involving a simpler energy system would be considered, in this case it was a human runner which was to be considered prior to implementation into the eRallycross system.

2.0 Project Plan

Given the limited timeframe of one semester, it was crucial to establish a well-defined plan with achievable objectives to successfully complete the project within the allowed timeframe. This would also be essential to aid in evenly distributing the workload amongst the team members to prevent any group members experiencing an excessive workload and thus ensuring the production of the highest possible quality of work throughout.

2.1 Planning Phase

2.1.1 Risk Mitigation

Effective risk management was crucial to the success of this project, which requires technical skill and simultaneous completion of several tasks. The team was initially tasked with identifying and analysing project risks. Each risk's severity and likelihood were then considered based on its occurrence during the project. The team needed to comprehend the risk's potential outcomes and collaborate to develop alternative tactics in case of unexpected issues. This management method was essential for project success since disruptions to key milestones can delay deliverables. A summary of the risks identified for this project and the consequences along with whether these are applicable to the team now or whether these risks are no longer a concern can be seen in Appendix A . The risk product is calculated by multiplying effect severity by likelihood and displayed with a risk level colour. Light green denotes minimum risk, green low risk, and yellow moderate risk.

2.1.2 Initial Work Breakdown

In order to best understand the extent of the project and ensure that ,as a group, we all understood the tasks which were to be undertaken and how they link together. A preliminary work breakdown of how we were expecting the project to unfold, and the key stages envisioned, was created during one of the foremost meetings. This preliminary breakdown of work the diagram below.

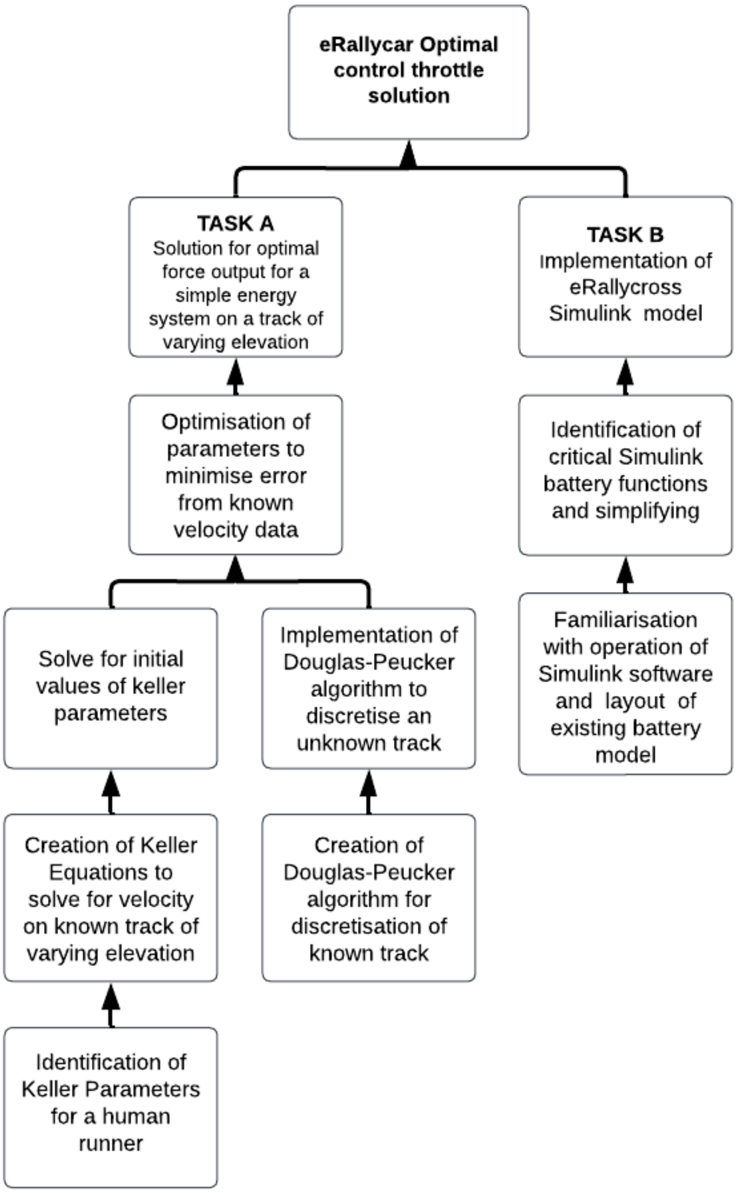


Figure 1: Initial Breakdown of Work

Two key branches of research were clear to the group, firstly the human energy system study, which involved implementing Keller's theory of competitive running in order to find the optimal velocity profile, minimising both the completion time and energy expenditure required by the runner. The first task (denoted Task A) could be further divided into two sub-tasks, the initialisations of the Keller method and of the Douglas-Peucker method. A set of initial Keller parameters – four physiological constants, which produce the velocity profile with the lowest degree of error form the known running data provided, could be found. In parallel to the Keller initialisation the Douglas-Peucker discretisation of the known track could be generated and then subsequently implemented with the Keller parameters, in order to validate the Douglas-Peucker discretisation methods. This validation meant that Douglas-Peucker could later be implemented as means for discretising the unknown track for the runner, in order to complete Task A. The optimisation routine centred around the vehicle dynamics of the eRallycross car was deemed to be Task B, this was to start with an initial review of the existing Simulink model of the which we were given access to by the Turku AMK eRallycross-autoprojekti team. It was thought that once this

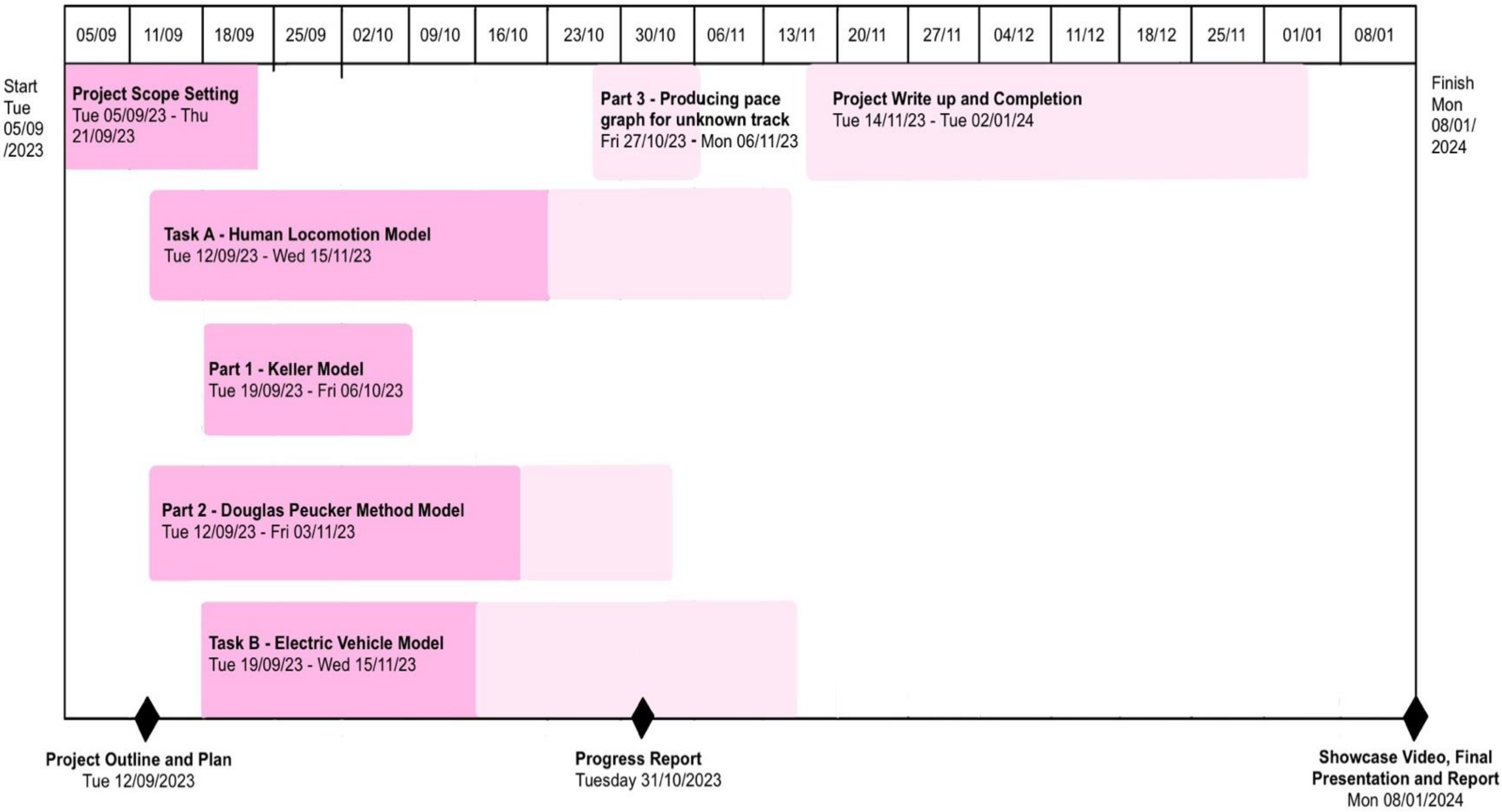
Simulink model had been translated into English, we would be able to adapt and simplify the model to suit our needs and would then be able to apply the routines generated for the runner to the vehicle model as seen by the two branches of Tasks A and B converging in order to find the theoretical optimal solution for a new unknown track.

2.1.3 Timeline

The team opted to utilise a Gannt chart as the primary timeline management tool for monitoring project development and progress, seen in Appendix B, with a summary shown in the timeline below in Figure 2.

This enabled the team to schedule multiple tasks to start simultaneously and assign dependencies to them, whilst also monitoring the progress of individual project components, as well as ensuring the overarching tasks do not excessively slip from the expected timeline. The Gannt chart was routinely updated at the biweekly group meetings to track progress and identify areas requiring more attention from the team, ensuring timely completion of the project and preparation of deliverables.

Figure 2: Summary of Project Timeline



2.2Implementation

Subsequent to the planning phase of the project, it was important to apply the strategies and procedures decided upon in order to best fulfil the aims and objectives as a whole. The key features to this execution phase on the project was the allocation of both roles and tasks.

2.2.1 Team Roles

Each team member was assigned with a role for the project to ensure consistent workflow throughout as well as aid in the distribution of responsibility across the group and alleviate any one group member from becoming overwhelmed. When assigning these team roles the strengths and interests of each member of the group were considered to make sure everyone was as satisfied as possible with their role. This strategy of assigning roles prompted teamwork and helped increase team productivity. However, it is also important to acknowledge that the purpose of these roles was not to mean that the team member assigned a specific role was solely responsible for all tasks within their overarching section.

The role of project manager was assigned to John for numerous reasons. John has held the role of Chassis Head in the USM (University of Strathclyde Motorsport) formula student team for the last two years. This means that he has experience with leading a team and understands how to keep a team on track and motivated. He also had the necessary skills to organise group meetings in a fair manner, giving everyone time to exchange ideas while ultimately ensuring that needed decisions were made in order to keep the project progressing smoothly and in a timely manner.

Alyx was assigned the role of Quality Assurance Lead which involved the support of both the human and vehicle energy system teams. This role acts as a bridge between the optimisation of both energy system models with Alyx working on the final stages of optimisation of the runner generating a discrete force system in a manner which can then be transferred to the vehicle system for implementation.

Fraser was given the Electric Vehicle Battery Analysis Lead role for this project. This was a suitable role for him as he was largely familiar with the Simulink software as he had previous experience with it from his fourth-year project, making him able to understand and adapt the existing model of the electric vehicle battery. Fraser also has keen communication skills which helps with his collaboration with the human energy system team members and equipping him with the ability to guide other group members with this section of the project if and when required.

The Engineering Analysis Lead role was assigned to Bronwyn, this role requires a keen sense of analytical thinking as well as eye for detail. Bronwyn’s attributes of determination and diligence made her very suitable for this role.

2.2.2 Task Allocation

Following on from the initial breakdown of the project task (Figure 1), the group was initially split so that team members worked on different aspects of the project allowing work to be conducted on each of the central task (Task A and B) in parallel, the decision was made to have Bronwyn and Alyx working more towards the human energy system model with John and Fraser working on the electric vehicle battery. It was thought at the start of the project that we could work on these two tasks independently with neither of the tasks requiring a larger allocation of resources than the other.

2.3 Monitoring Phase

With the project being undertaken within a limited amount of time it is very important that group have a method for monitoring of progress made towards the accomplishment of the key aims and objectives of the project progress. This was achieved through regular team meetings as well as regular communication with the client. Furthermore, to ensure that there was constant access and updated version of each person's section the team made sure that all work files were stored in folders which everyone has access to. Some of this was done through GitHub while some were just sent directly to the team member who required the files.

2.3.1 Group Organisation

Although the group had been divided into two sub teams, the group as a whole made sure to communicate openly, a key aspect of the communication strategy employed was the regular group meetings which were scheduled to ensure that the team met twice a week at a minimum, this schedule can be seen in Table 1 below. These meetings allowed for the group to update each other on progress made since the last meeting and share any potential problems encountered offering an opportunity for collaboration to generate new ideas to solve these issues. These meetings were scheduled for Tuesdays and Fridays each week, so as to allow for plenty of time to work in between meetings such that there were always new things to discuss in order to help advance the project in a timely manner.

Table 1: Meeting Schedule

Day and Time	***Description***
Tuesdays (even weeks) 12pm-2pm	Meeting with Supervisor
Tuesdays (odd weeks) 12-2pm	Group Meeting
Friday (every week) 2pm-4pm	Group Meeting

2.3.2 Supervisor Meetings

In addition to group meetings a standing technical progress meeting with our project supervisor (Eero Immonen) and their research team was organised on a fortnightly basis. These biweekly meetings served as a platform for the team to seek clarification on technical matters and offer the customer an overview of the project's advancement. We would structure these meetings ahead of time, so each team member was able to ask as many questions as possible – with not one group member taking up too much time. This meant that the team didn't become frustrated with one another in meetings as everyone got their allotted time to discuss their technical problems with Eero, allowing for steady advancement of the project, with no team member missing the opportunity to receive support they needed and preventing the stagnation of progress.

3.0 Reflections

It was believed that failing to prepare adequately with a suitable plan for the project would have had a detrimental effect on the effectiveness of the team as whole and could ultimately lead to failure in the group's ability to accomplish the various tasks required to complete the project in its entirety. The team lacking collaboration could also have meant that certain tasks or sections began falling behind schedule, or being completed to a lower standard or not at all, all which could ultimately lead to customer dissatisfaction as an optimum solution may not have been reached.

3.1 Adaptability

After the initial period of work on the project on the project was underway it became very evident that the initial assumptions of the work breakdown and consequent manpower allocations were not correct, this meant we had to make alterations to the set-up of the team.

The Keller model for the human energy system exhibited a higher level of initial complexity and required a significant amount of time for problem formulation. Without the parameters being obtained from this model, the group faced limitations in making significant progress on the vehicle portion of the project. As a result, John moved his focus from the vehicle model over to the human system team so as to assist by working on the formulation of the Douglas-Peucker Method. Meanwhile Alyx began work on formulating the research which had been conducted thus far into a first draft of a Literature Review for the final report. This was then be used when formulating the discrete force method to aid in a more streamlined link between the runner and the vehicle. This shift left Fraser with the task of the simplification of the Simulink model, this was a vital task, but it was decided it did not require the involvement of two team members at this stage. This exchange of effort helped facilitate advancement in the project by appropriately allocation team members to fit the updated understanding of the needs of each section.

As headway was made in the project and different tasks were undertaken, and the group's understanding of the different problems and processes involved grew it was found that, contrary to our original beliefs there was more overlap between the two main task branches than predicted and more steps were required in order to be able to determine a definitive result for the optimal control regime for the eRallycross car. This can clearly be seen in Figure 3 below which shows the final version of our breakdown of work, the evolution of our project can be clearly observed from this diagram. This exemplifies how crucial teamwork and flexibility of both allocation of both effort and time throughout the project were towards the completion of the project.

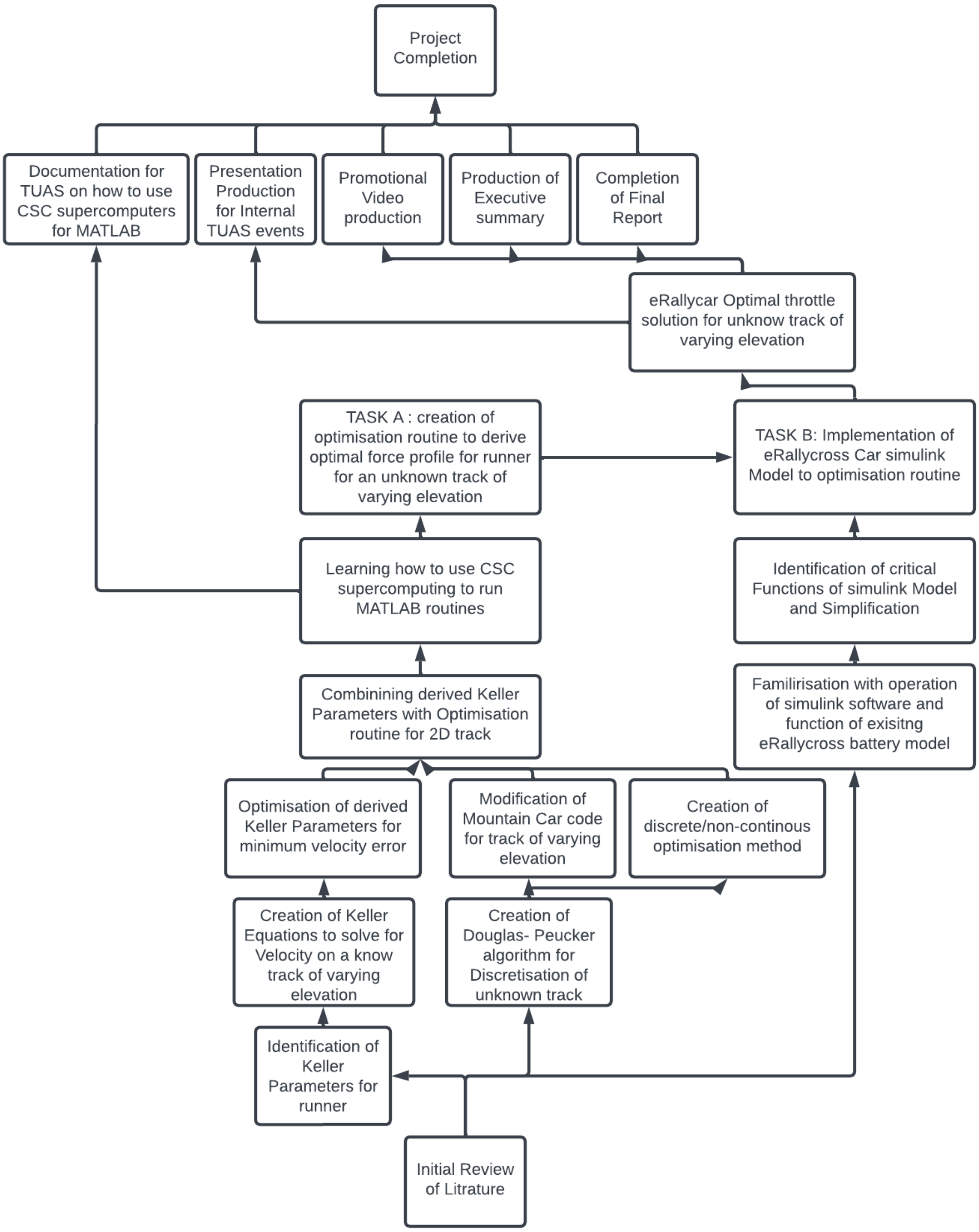


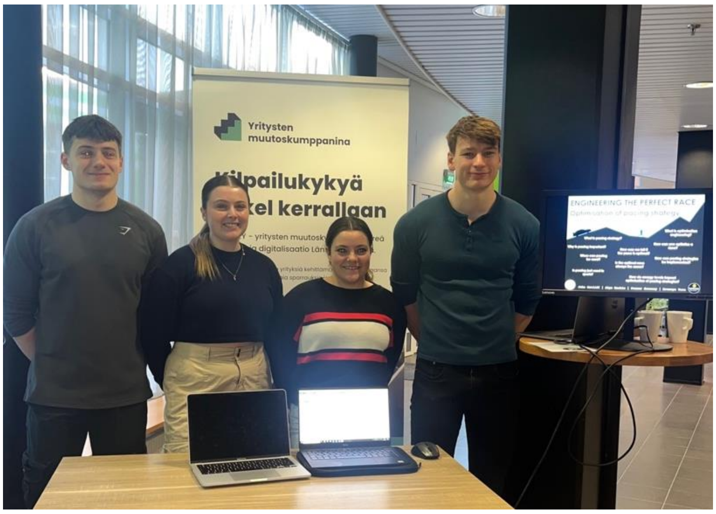
Figure 3: Updated Breakdown of Work

3.2 Exchange Experience

Effective team management during the course of this project has been a key aspect to keeping our team on track in terms of the overarching timeline. This experience has facilitated the enhancement of personal development and the cultivation of collaborative skills in the face of various challenges. With the move to Finland there have been obstacles which have emerged while trying to effectively accomplish the project. The experience of adapting to a new country, university campus and, lifestyle and all that these changes encompass, incited a variety of responses among the individuals in the group, attributable to the phenomenon of culture shock. Although the culture in Finland is not massively different to that in Scotland, there was certainly still some element of change for all, with some group members not only in an entirely new country but also living alone for the first time which was initially challenging. It was important for us as individuals to get involved with the Finnish customs by going to various activities – an example is our attendance at various Sitz Parties. These are a big part of the Finnish university experience and helped us feel better integrated into the society as a whole. Consequently, the group was successful in adapting to the Finnish lifestyle without succumbing to an overwhelming preoccupation with project-related tasks. Another activity our group did, to allow for group members to properly bond and strike a healthy work life balance, was our trip to Helsinki – this trip allowed us to get to see another Finnish city and enjoy spending time as a group out with the context of the project. This helped with us not succumbing to work-related burnout while not taking too much time out of the project which could have led to hinderances and delays of the project timeline; achieving this balance was of utmost importance. Considering the challenges associated with this endeavour, the team has committed wholeheartedly to this new adventure and adopted this approach to operations and have consistently exhibited a high level of motivation. As anticipated, there have been variations in opinions and preferred methodologies pertaining to specific activities. Upon careful consideration, it was at this juncture that the strong use of project management principles came into play, thereby mitigating excessive time delays due to deliberation of project tasks. The team established an environment that supported the respectful discussion of essential concepts and ideas, upon doing so the team organised meetings in such a way that enabled the group to collectively decide upon which route was the best to follow after some deliberation over the task. This allowed all opinions and viewpoints to be heard and prevented any team members from feeling overlooked or dismissed.

3.2.1 Collaborative Opportunities

In late November, our group were invited to have a stall at a student/company brokerage event which was organised by Turku AMK. At this event we had the opportunity to promote our projects and showcase the progress that we have made during our time in Finland. This showcase event was not a technical event and as such was to have an audience which had varying backgrounds, this meant that it was important that we were able to clearly explain our project to those who did not have previous engineering experience or knowledge. The team were asked to focus on the sporting aspects of the project, to aid in catching the attention of our audience we designed a poster which was displayed on a monitor. This included things like an eye-catching title and key phrases relating to our project. This presentation allowed all of our group to gain practice in speaking about the specifics of the project. We explained how our project can be implemented in many applications as this strategy of optimisation can be used by companies in different ways – for example the runner optimisation could be altered to apply to other time-based sports like swimming. This presentation also helped bring the group together and appreciate our progress over the months of studying in Turku and allowed us to see the sections which needed focussed on over for the next month to help us finish our project on time.



A second invitation to present our work was extending to the group, this time we were asked to attend the Capstone project presentations which took place in December during the last week of that the semester. This presentation had a similar format as the first, with the group setting up a stall and discussing the project in a short elevator pitch fashion with anyone who approached. Furthermore, the audience at this event had a more extensive understanding of engineering principles, this meant that the group could talk more in depth about the different processes employed and the more technical details of the project as well. We felt this would be a good opportunity to understand if there were any areas of the project which people found were difficult to understand without the level of familiarity which we have with data, and how best to communicate our progress. This would ultimately be helpful to the team both for clarity of the write up within the final report, as well as for the presentation of this project during our oral exam at our home university, to a panel who won't have the same knowledge of the project that the people we have a primary contact with throughout the project possess.

The group once again utilised the poster we created, this time printing to be displayed behind the table. This allowed for the screen to be used to display our various results and graphics now that further progress was made, and the project was so close to completion.

3.3 Personal Development and Reflections

3.3.1 John Getliff

Implementing the Douglas - Peucker algorithm using MATLAB was fairly easy to do, however it took some time to relearn the basics of MATLAB, as I had not used the Software since 2nd year, beyond this the learning curve to when working with the existing MATLAB optimisation scripts was steep, and definitely expanded my skills and knowledge of MATLAB, for example running jobs in parallel using multiple workers. The time initially allocated for this was insufficient, as such we adjusted our timeline during our weekly meetings so that I could spend more time working on the implementation of a 2D track of any length to the existing optimisation functions for the mountain car problem. Additionally, making a method of implementing the gradient of the track robust enough to work for any track, with any number of points was more challenging than expected due to the configuration of the optimisation script not progressing through values of x only in one direction, and the need to avoid for/while loops to allow code to run efficiently, as such a number of attempted were required to reach the final solution, which I believed to be quite good, as it worked for any point on the track of any length without data from previous iterations (e.g. a counting variable such as i), and uses minimal lines of code. Initial runs of the code however produced erroneous results such as energy finishing higher than initially, and velocity reaching 0 at some points. This was caused by both errors in the Keller's parameters and by having to wide a Timescale to search, which once corrected produced results consistent with the expected time actually ran. However, the code was only able to run locally on my computer for attempts with a low number of interpolation points, as increasing the number of interpolation points for the force profile would greatly increase the computing power required to solve in a realistic amount of time. As such I looked to use the Computing power available to us from the CSC - Science Information Technology Centre. However as no one in the department had used the CSCs supercomputers Puhti and Mahti with MATLAB before, it took significantly more time than expected to get working, as a large portion of the knowledge and skills needed were beyond my own, leaning more into computing science. This took more of my time than we hoped, but also widened my skillset and experience in problem solving in areas I am not familiar with, whilst also allowing me to provide Eero with documentation on how to use MATLAB parallel server to ran batch jobs on the CSC service. Overall, the project has forced me to further develop skillsets I have not previously used to anywhere near this degree, which I believe has helped me become a more well-rounded engineer, with a wider and more in-depth knowledge of using MATLAB and optimization. Alongside this I believe the team has worked well by allowing each member to work to their strengths, allowing the group as a whole to produce the best work possible.

3.3.2 Alyx Mackie

The collaborative experience I had working on this project while studying in Finland has taught me a lot about what it takes to work as a professional engineer. The project's group work component has given me the opportunity to learn new techniques for collaborating alongside others including how to efficiently handle disagreements over approaches to problem solving. During the early stages of the project, a significant amount of reading literature was done by me and a large amount of the write-up for the literature review section was developed. This task helped me discover the quality of my writing skills and how crucial it is to comprehend the project content as a whole, not just the technical aspects I would be working on. Even though this task occasionally felt like tedious and that I was not making any technical progress, I knew that this literature review was still crucial to the project's advancement because my primary technical responsibilities involved other team members finishing their work before I could start my own. Upon starting my technical content, I ran into multiple problems when trying to optimise the force choices. I struggled with trying to simulate the runner while setting bounds for the velocity and energy. At this stage I found it difficult to fully motivate myself after trying many methods and having no tangible results after several weeks of trying to get results. Upon discussing this with our supervisor Eero, he greatly helped in my confidence with a new method to try solving the problem in a simpler manner with single forces. This enabled me to gain a simple model which I understood clearly and helped me fully visualise the problem. After writing this simplified code, I was then able to greatly advance with my method of force strategy finding by adding up to five forces for my system rather than the original one. Another aspect of the group work which greatly helped me during the completion of the project was the flexibility and adaptiveness of my team members. Although we had weekly meeting scheduled, these did not always have to be in person as we utilised discord often. This meant that on days where I was not feeling well, I could still attend meetings and be productive while not having to meet everyone and potentially make them unwell also. We made sure to set deadlines for certain tasks and regularly update the Gannt chart which I felt was very beneficial to me during this project as I always like to have goals to strive towards which kept me motivated.

3.3.3 Fraser Sweeney

My time working on this project whilst abroad has been an invaluable experience that has taught me a lot and expanded my horizons. This was my first experience collaborating with others on a project of this magnitude. I have further improved my teamworking and communication skills over this time, which are very important skills to have in a professional engineering environment. Working as a team during group meetings to quickly produce ideas and solve problems was an aspect I found very gratifying. These meetings were also imperative to the progression of the thesis. Simulink formed a significant part of the project, which I undertook due to my previous experience working with the software. It didn't take long to refamiliarize myself with the basics, however, the model I was working with used a different toolbox which I had to spend time understanding. I also put a lot of effort into understanding the given model. This being very important to comprehend what steps should be taken moving forward. There were some problems in this stage due to simply not being able decipher aspects of the model. However, emails and bi-weekly meetings with our supervisor allowed these problems to be solved quickly and efficiently. In addition, I had to refamiliarise myself with writing Matlab scripts and functions due to not using the software since my second year of university. Again, this didn't take too long to become comfortable writing at a high enough standard to complete the tasks I had such as collaboratively writing the force and velocity choice codes for the runner and car. Studying in Finland came with multiple benefits in both my academic and personal life. Being abroad meant that every team member could focus solely on the task in hand. This was greatly beneficial to productivity and the ability to meet with group members on short notice to discuss any issues that had arisen. Despite my commitment to the project, I was still able to make the most of being in a new part of the world by engaging in Finnish cultural activities and exploring the surrounding areas.

3.3.4 Bronwyn Tunn

During the months spent studying abroad in Finland, towards the completion of this group masters project a lot was learnt in relation to working alongside other engineers towards a common goal. In addition this was the first time throughout my university career in which I have had the opportunity to complete project in which there was direct interface with a previously unknown client, this provided an opportunity to gain an insight into the form project work could take in the future beyond my time studying at university and into to the world of work as a professional engineer. The methods we as team employed to first define and understand the scope of our workload and the subsequent allocation the work among the team, I believe were beneficial as they allowed each team member to have a sense of purpose and focus while also allowing for a degree of flexibility for each team member to work to a schedule which suited them. I found this particularly helpful as I tend to be most productive in the afternoons and evenings, so being able to work individually during these time and then report my findings and progress to the group during our frequent meetings both online and in person. Although I feel that on the whole our group has worked well and managed ourselves effectively in order to complete this project within the timescale outlines and the high standards required of work at this level, there are of course aspects which with the benefit of hindsight I feel could have been improved upon. One thing in particular which I would change for future projects would be in relation to file management and sharing as, we were not always the best with keeping the code files in the shared cloud spaces up to date, however due the parallel nature of our work structure this was not a massive hinderance to progression of the project as a whole in this instance.

One of the biggest technical challenges I faced personally during this project was due to the fact that I was out of practice using MATLAB since last using the software during my second year studies. As a result a chunk of my time at the beginning of this project was spent refamiliarising myself with

MATLAB operations and refreshing my knowledge before beginning work towards the project. Furthermore optimisation as a whole was a new challenge for me, this meant I learnt new skills and developed a more in depth understanding of MATLAB as a whole and how it can be implemented, giving me a wider range of experience which I feel has led to me becoming a more well-rounded engineer on the whole.

Moving to a different country has a been a new and exciting venture for me, and I am extremely grateful for having been granted this opportunity as I feel it has led to personal growth on my part, as I had to step out my comfort zone in order to fully appreciate this experience of living and studying somewhere new so far out of range of my support system at home. I also believe that having undertaken this exchange with people I have worked with previously at Strathclyde has lessened the effects of culture shock I experienced, although not entirely mitigating them.

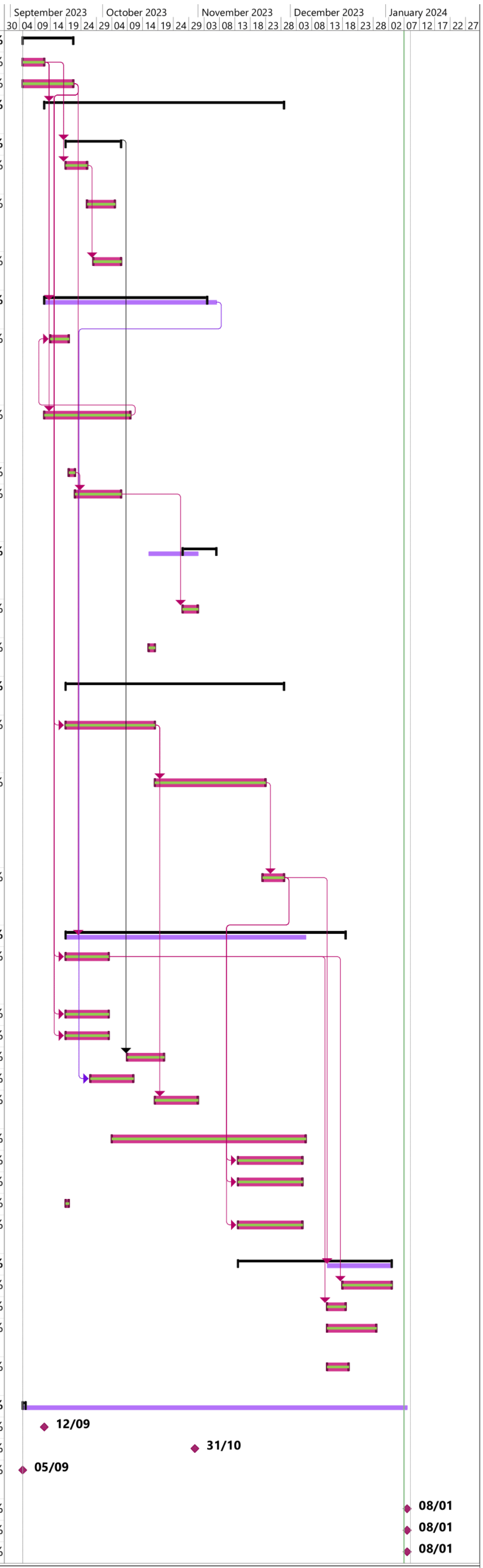
4.0 Appendices

Appendix i: Risk Assessment Table

Risk	Severity of Impact	Likelihood	Risk Product	Consequences	Mitigation / Contingency	Is this still a risk?
Members residence permit is denied	4	1	**4**	Group member would likely have to work from Scotland for a period of the semester.	Ensure completion of immigration meetings early. Can do remote / online meetings if necessary.	No, since all permits have now been approved.
Computation of Erallycross car model is computationally expensive	2	3	**6**	The group will be able to run less simulations.	Ensure the conversion of Simulink model to MATLAB script to increase programme efficiency. Potential access to HPC if required.	Yes, since the group is still in the conversion process of the Simulink files.
Unable to access required MATLAB version	3	2	**6**	Start of the MATLAB programming is delayed.	MATLAB should be downloaded in week 0 such that if there are any issues, they are quickly rectified.	No, since the team all have access to the MATLAB files needed for the project.
Non-convergence of Keller and Douglas-Peucker algorithm	2	3	**6**	Stalling of the project progression.	Meet with advisors to work together to discover errors / issues.	Yes, always room to improve efficiency of the algorithm
Loss of work due to corruption of files / accidental deletion	5	1	**5**	Portions of the code/report will be lost, causing significant delay to the project schedule.	Ensure that documents and code are always in shared folders and saved on multiple devices – hard backups biweekly.	Yes, this risk will carry throughout the semester until submission.
Project plan rejected by Strathclyde supervisor	2	1	**2**	Project aims and scope would need to be reworked.	Meet with Strathclyde and Turku AMK advisors to discuss improvements needed.	No, the team's initial scope document was accepted by the Strathclyde supervisor.
Lack of time / availability of high-performance computer	3	2	**6**	Portions of code may not get run as many times as needed.	Ensure code is finished to give plenty time for getting access to HPC.	Yes, there is still many sections that may require use of HPC.
Team member taking unwell	3	3	**9**	Their work may need redistributed until they are feeling better.	Make sure the team prioritise health and looking after themselves especially with colder months coming.	Yes, this will be an ongoing issue.

Appendix ii: Concluding Gantt Chart

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	% Complete
1		**Project Scope setting**	**12.5 days**	**Tue 05/09/2:**	**Thu 21/09/2:**		**100%**
2		Project Definition	5 days	Tue 05/09/2:	Mon 11/09/2		100%
3		Intial Review of Litratur	12.5 days	Tue 05/09/2:	Thu 21/09/2:		100%
4		**Task A - Human Locomotion model**	**56 days**	**Tue 12/09/23**	**Tue 28/11/23**	**2**	**100%**
5		**part 1- keller model**	**14 days**	**Tue 19/09/2:**	**Fri 06/10/23**	**2**	**100%**
6		Identifacation of Keller Parameters for	5 days	Tue 19/09/23	Mon 25/09/23	2	100%
7		Solving for keller Parameters using GPS data	7 days	Tue 26/09/23	Wed 04/10/23		100%
8		compliton of sensitivity analysis of	7 days	Thu 28/09/23	Fri 06/10/23	6	100%
9		**Part 2 - Douglas Pecker model**	**39 days**	Tue 12/09/23	**Fri 03/11/23**	**2**	**100%**
10		formuliusation of Douglas pecker script to convert track into descit sections	4 days	Thu 14/09/23	Tue 19/09/23	11	100%
11		Adaptation of Optimisation routine for DP input	20 days	Tue 12/09/23	Mon 09/10/23	2	100%
12		solving of DP algorithr	2 days	Wed 20/09/2	Thu 21/09/2:		100%
13		Validation of DP algorithm converges with Keller model	11 days	Fri 22/09/23	Fri 06/10/23	12	100%
14		**Part 3 - producing pace graph for unknown track**	**7 days**	**Fri 27/10/23**	**Mon 06/11/23**		**100%**
15		discretise unknown track	3 days	**Fri 27/10/23**	Tue 31/10/23	13	100%
16		establish optimal force profile	2 days	Mon 16/10/23	Tue 17/10/23		100%
17		**Task B - Electrice vehicle model**	**51 days**	**Tue 19/09/23**	**Tue 28/11/23**		**100%**
18		convert eRallyCross car simulink model to Matlab	21 days	Tue 19/09/23	Tue 17/10/23	3	100%
19		modify existing opimal control code to use eRallycross energy model and vehicle parameter	26 days	Wed 18/10/23	Wed 22/11/23	18	100%
20		produce optimal force plot for unknown rally stage	5 days	Wed 22/11/23	Tue 28/11/23	19	100%
21		**Project write up**	**65 days?**	Tue 19/09/2:	Mon 18/12/2	**3**	**100%**
22		background rallycross/erallycross information	10 days	Tue 19/09/23	Mon 02/10/23	3	100%
23		desciption of task	10 days	Tue 19/09/2:	Mon 02/10/23		100%
24		litrature review	10 days	Tue 19/09/2:	Mon 02/10/23		100%
25		keller theory	10 days	Mon 09/10/2	Fri 20/10/23	5	100%
26		douglas-pecker theory	10 days	Wed 27/09/2	Tue 10/10/2:	9	100%
27		review of ev battery simulink model	10 days	Wed 18/10/23	Tue 31/10/23	18	100%
28		Methods Writeup	45 days	Wed 04/10/2	Tue 05/12/2:		100%
29		Results Writing	15 days	Tue 14/11/2:	Mon 04/12/2	20	100%
30		Analysis Writing	15 days	Tue 14/11/2:	Mon 04/12/2	20	100%
31		reflections	1 day	Tue 19/09/2:	Tue 19/09/2:		100%
32		Conclusions and discussions writing	15 days	Tue 14/11/23	Mon 04/12/23	20	100%
33		**Project Completion**	**36 days**	**Tue 14/11/2:**	**Tue 02/01/2**	**20**	**100%**
34		Report Draft Review	12 days	Mon 18/12/2	Tue 02/01/2	22	100%
35		Production of project vic	4 days	Wed 13/12/2	Mon 18/12/2	22	100%
36		TurkuAMK innovation presentation	12 days	Wed 13/12/23	Thu 28/12/23		100%
37		production of 15min presentation	5 days	Wed 13/12/23	Tue 19/12/23		100%
38		**Project Deadlines**	**1 day?**	**Tue 05/09/2:**	**Tue 05/09/2:**		**100%**
39		Project outline and plan	0 days	Tue 12/09/2:	Tue 12/09/2:		100%
40		Progress Report	0 days	Tue 31/10/2:	Tue 31/10/2:		100%
41		Innovation Project Presentation	0 days	Tue 05/09/23	Tue 05/09/23		100%
42		Final Report	0 days	Mon 08/01/2	Mon 08/01/2		100%
43		Showcase Video	0 days	Mon 08/01/2	Mon 08/01/2		100%
44		Final Presentation	0 days	Mon 08/01/2	Mon 08/01/2		100%



Project: Group Project plan
Date: Sun 07/01/24

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Baseline
Baseline Milestone
Baseline Summary
Progress
Manual Progress

Student No. 201932877, 201920765, 201920781, 201920341