CONCEPTUAL AND PRELIMINARY DESIGN OF UNMANNED GROUND VEHICLE IN MONITORING OIL AND GAS PLANT

by

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16893

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical)

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CERTIFICATION OF APPROVAL

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Approved by,

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(DR SETYAMARTANA PARMAN)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons

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MOHAMAD ANWAR BIN IDRIS

ABSTRACT

An Unmanned Ground Vehicle or UGV, as the name states, is a vehicle on the ground can operated with or without any human pilot on board. This project involves designing a robust and suitable UGV structure and integrating UGV technologies specifically to adapt in the harsh conditions of oil and gas plant and providing monitoring of a human's eye view of the plant. The process of designing will start from conceptual design until detail design. A design of UGV consisting with robust structure to install sensors, camera, boards, and all the systems. The control of this UGV will continuous by master student from electrical department. For design this UGV, the author have study types of UGV, its function and ability. For the chassis, it will be modeled using Autodesk Inventor or Solidworks software to ensure design is applicable. The expected outcome of this project is finished prototype that can be maneuvered in two modes, manually and autonomous. For now, the progress is up to detail design on the UGV and MSC ADAM view analysis for motion system. In the result, the author will show the detail design and the analysis how these UGV system function.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 Background

UGV is land based vehicle which commonly have a set of sensors installed on it to observe the environment, using the data from its sensors UGV either takes a determination itself using some intelligent algorithm or relays that data to a human operator to some other location who given the data control the UGV consequently. UGV’s are usually classified into two categories [1]. Autonomous, which is an intelligent machine it sense, plans and then acts in a rational fashion to reach the output without any interaction of any human. Remote Operated, which doesn’t plan for itself, but is an automated machine which sends the signal to a human operator, then acts on human decision. Both of these types have their own advantage and disadvantages for example in case of some life threatening situation like bomb disposal in some crowded area a human operated UGV is preferred rather than an intelligent algorithm. The choice of type of UGV depends on the application. In the improvement of UGV, factors like type of environment and application objectives are to be considered. Environment may vary from rough terrain to indoor smooth surface and objective may require a certain level of agility or size etc, design and development of such an agile, man portable UGV is given in. A combination of both autonomous and remote operated is also used where certain tasks are assigned to UGV to perform for itself and a human operator either take some particular actions or supervise the performance of UGV and interfere whenever necessary [2]. UGVs have been used recently for USAR (Urban Search and Rescue) activities such as searching for victims, searching paths through the rubble that would be quicker than to excavate, structural inspection and hazardous materials detection [3].

By manipulating what already exists to adapt to the surroundings of an oil and gas plant, we can monitor for known threats more efficiently and possibly nullify it directly. This project however involves designing and integrating UGV technologies specifically to adapt while navigating in the harsh conditions of oil and gas plant and providing monitoring replacement of a human's eye view of the plant.

1.2 Problem Statement

- Fire gas leakage in oil and gas can occur unexpectedly and can cause serious damage and even fatal deaths to the employees.
- Personnel monitoring is not convenient when it comes to a large and complex organization like an oil and gas processing plant.
- The cost of human security used would be very high due to its amount.
- Dangerous environments that are inhospitable to humans.
- Human security will get bored during long hours of surveillance and monitoring the huge plant. [4]

1.3 Objectives

To fully develop a sophisticated UGV built for an oil and gas plant, it will need a substantial amount of time. Due to time constraint, the project will be focused in the objective as follows:

Design:

- To design a robust and suitable UGV structure for oil and gas monitoring and the design must complete with structure to install sensors, camera, boards, and all the systems.

1.4 Scope of Study

To ensure the project to be completed in time, certain measures have been undertaken to narrow down the scope of this study so that it only covers certain main points. This is important because the author have limited time, resources and knowledge to investigate Unmanned Ground Vehicle (UGV) as a whole. The time allocated for the author to complete the Final Year Project is two semester, which comprised of two semester. The scope of this study is as listed below:

- To understand the importance of UGV.
- To study the design body of the UGV.
- To understand of CAD software.
- To analyze the design parameter

CHAPTER 2

LITERATURE REVIEW

2.1 Unmanned Ground Vehicles (UGVs)

Unmanned ground vehicles are mobile robots that are generally used today in cleaning, transportation, security, exploration, rescue, bomb disposal and testing of dangerous or remote areas [5]. This type of robots is commonly capable of operating outdoors and over a wide variety of terrain. They can be used as an extension of human ability because they are designed to be used in risky situations where humans are either unwilling or unable to operate [6]. It has the ability to move to a desired area and then execute some sort of work involving manipulating variety of tools. UGVs are dynamically being developed for a variety of applications in the civilian and military fields.

Figure 1: Unmanned Ground Vehicle

2.2 UGV Categories:

UGVs can be classified into many categories based on the size and mode of operation:

2.2.1 Size

- Micro UGV: An unmanned ground vehicle weighing less than 10 lbs.

Figure 2: Micro UGV

- SUGV (Small Unmanned Ground Vehicle): An unmanned ground vehicle weighing less than 200 lbs. [6].

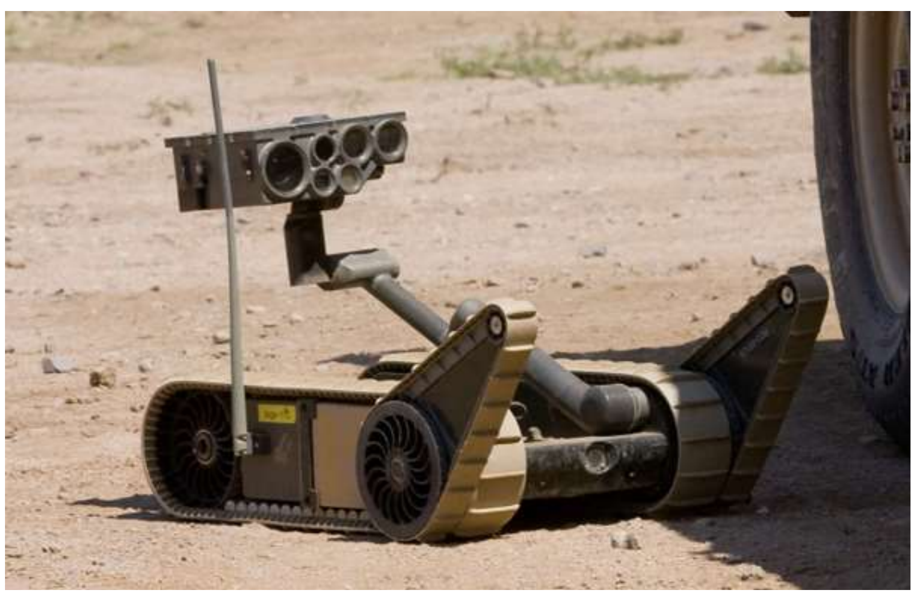


Figure 3: iRobot (SUGV)

SUGV robots are smaller and lighter, iRobot is the example. More than 3,000 iRobot robots have been delivered to military and civil defense forces worldwide. Their characteristic:

- Lightweight and compact, fit in MOLLE pack
- Rugged designs operate in all-weather conditions
- Easily climb stairs and overcome obstacles
- Game-style controller reduces training time
- Capable of performing 6-hour missions (longer durations possible depending on mission conditions)
- Perform fast tactical maneuvers
- Modular designs accommodate optional payloads and sensors
- The best choice for future adaptability

SUGV robots feature a modular design that allows multiple payloads to be easily integrated. With their plug-and-play design, SUGV robots are well-positioned to take advantage of new developments in robot technology, including the integration of additional sensors, manipulator arms and other tools.

- MUGV (Medium Unmanned Ground Vehicle): An unmanned ground vehicle weighing between 200 and 2,000 lbs. [6].

Figure 4: Guardium UGV (MUGV)

Operationally deployed by the Israeli Army, the Guardium UGV, a semi-autonomous unmanned ground system, revolutionizes the effectiveness and utility of perimeter security and represents a long awaited breakthrough in combat applications such as force protection, route proving, combat logistics support and more. The Guardium UGV was designed to perform routine missions, such as programmed patrols along border routes, but also to autonomously react to spontaneous events, in line with a set of guidelines specifically programmed for the site characteristics and security doctrine. The Guardium UGV complies with ongoing military and industry standards, for which it was exhaustively trialed over thousands of operational hours.

Vehicle Level

• Autonomous mission execution

• Real-time, self-ruling, obstacle’s detection and avoidance

• Proven safety system

• Superb off-road maneuverability

System Level

• Easy to operate, dedicated command & control application in complementary operational versions: stationary, mobile and portable

• Built-in debriefing and training capabilities

• Variety of customer tailored wireless communication solutions

Mission Level

• Modular selection of payloads for comprehensive situational awareness and different mission requirements: EO/IR camera, Radar, Remotely Operated Weapon Systems, Non-lethal Weapon Systems, Electronic Counter Measures, COMMINT, Hostile Fire Indicator (HFI), two-way audio link, CBRN sniffers, RFID Interrogator, fire extinguishers and more

• Stationary, Mobile and Portable control terminals are available

Vehicle Specification and Performance Data

• Height: 2.2 m / 7.2 ft / 86 in

• Width: 1.8 m / 5.9 ft / 70 in

• Length: 2.95 m / 9.7 ft / 116 in

• Weight: 1,400 kg

• Max speed: 50 kph (in semi-autonomous mode)

- LUGV (Large Unmanned Ground Vehicle): An unmanned ground vehicle weighing more than 2,000 lbs. [6].

Figure 5: Whelbarrow Mk 9 (LUGV)

The Wheelbarrow Revolution is the latest development in the Wheelbarrow range and is proving to be exceptionally popular with operators required to deploy in confined locations, such as between parked cars. Revolution's rotating turret offers all of the reach and payload capabilities, whilst offering 360° continuous turn of the manipulating arm.

Features:

- Unique center of gravity change facility for enhanced stability and essential for stable stair climbing
- 7 weapon firing releases – offers a large variety of tool installation without the need to change mid-operation
- 7 degrees of freedom modular telescopic arm – the strongest, longest and most versatile capability in the world
- Officially tested for International CBRNE deployment
- Proven in-service platform deployed worldwide

Specifications:

- Stowed Dimensions (L x W x H) 1.25m x 0.65m x 1.00m
- Typical Weight 330Kg
- No. Cameras 4 with picture-in-picture capability
- 1 x attack camera (colour),
- 1 x teletube camera (colour),
- 1 x left hand drive camera (colour),
- 1 x right hand drive camera (colour)
- Rotating Turret 360º (continuous)
- Audio 2-way
- Mission Time 0-3hrs (mission dependent)
- Drag Capacity 200Kg (static)
- Speed 0-5km/h

2.2 Mechanical Design

It is very significant to mechanical design the UGV according to the application to maximize its performance. There are a number of characteristics to be considered before we first move to mechanical design these parameters are defined from application perspective each design have its own advantages and disadvantage. For example, consider a military based UGV for the surveillance purposes, now the mechanical design should be rugged to withstand the harsh environment. It should be able move in the off-road environment and agility is also a very importance design factor, a differential drive could be applied for that purpose. We are using a robust all-terrain mechanical chassis as the platform for our UGV which has off-terrain rugged wheels and a decent suspension system. A DC motor with gear box is used to drive both of the rear wheels and a servo motor is used to steer the front wheels right or left. Figure 1 shows the image of remote-operated UGV, the overall design with all the electrical equipment installed on chassis. [7]

Figure 6: Remote – Operated UGV

2.2 Vehicle Chassis and Suspension

2.2.1 Chassis

The mechanical design of autonomous mobile robots always starts from the chassis design. The chassis structure determines the entire physical setup of the robot. It sets the foundation for developing a functional autonomous mobile robot. For the robot presented in this paper, four major criteria are considered for the chassis design: lightweight, ease of assembly, solid, and adequate space for housing sensors, batteries, mechanical and electrical components. A CAD model of the final design is shown in Figure 2. For fabrication the chassis, material needs to be as robust as possible without sacrificing the strength. These materials are commonly aluminum, plastic or carbon fiber which is optimal in terms of weight, ease of fabrication, and strength. [8]

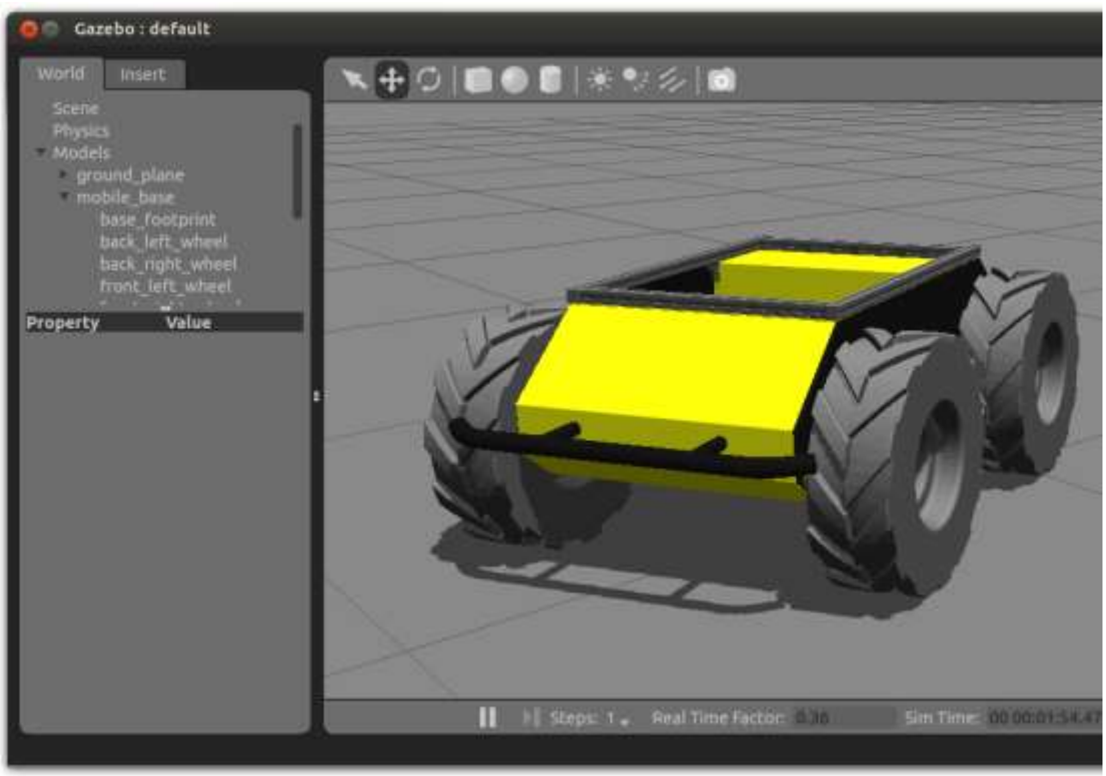


Figure 7: Example of UGV in final design

Because of the robot operate in harsh and hazardous environments, the body and the chassis may experience various collisions or crashes. These events may damage the inner important electronic and communication devices. So the body should have proper strength to contrast the loads affecting it. Also, if the body vibrates much during its motion, it may cause harm to the mechanical joints and electronic parts. So the strong chassis must be design to minimize the mechanical joints and also the vibration. [9]

2.2.2 Suspension System

To reduce vibrations and absorb shocks caused by surrounding environments, a suspension system is integrated to the developed robot. Through the standard impact analysis, a suspension system with the stiffness of 29 lb/in, and damping coefficient of 16.5 slugs/s must be design. Using A-brackets, gyroscopic eye-bolt connectors, and other various connection components, this system was attached to the chassis. Figure 3 shows a picture of the fully assembled suspension system. [8]

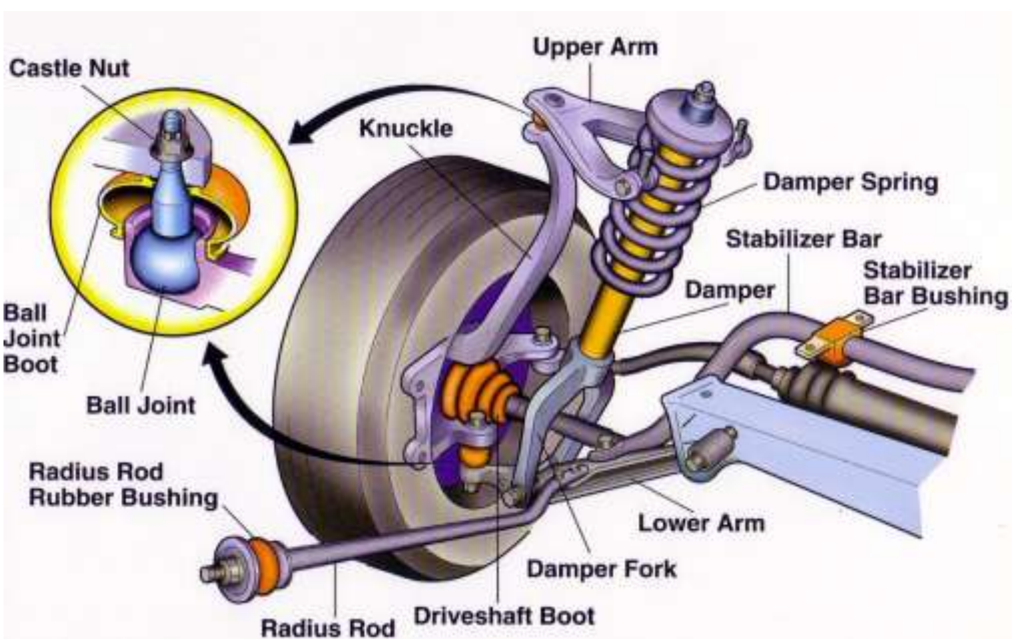


Figure 8: Example of fully assembled system

2.3 System Design

The Design procedure involved of several stages. In “Conceptual Design” we performed a wide case study and research about UGVs, their functions, missions, structure and subsystems. We set the system specifications in this stage and sorted the main objectives. Then we came to a preliminary sketch of the robot and then developed the “Detailed Design” of the whole body and movement system and also their subsystems. [10]

The Final Design should have the following Properties:

- Modularity
- Easy to assemble/ disassemble
- Reliability
- Conceivable for Fabrication/Manufacturing

2.3.1 Conceptual Design

There are three major categories of locomotion systems in the field of rescue, reconnaissance or Surveillance robots; wheeled, tracked, or legged systems. Tracked systems are mostly used because of their capability to move on uneven terrains and overwhelmed to obstacles. Wheeled robots are capable of climbing up obstacles too but depending on the diameter of the wheels while a smaller tracked robot has the same ability. In Legged robots the number of actuators and sensors is relatively high which makes them costly and their dynamic analysis and modeling more complex. With reviewing the previous works on UGVs and regarding the functions expected from the system, wheeled robot is superior to monitoring oil and gas plant. The size and weight of the wheeled mobile robot are also important parameters that can affect the robot functionality. To set the physical parameters and dimensions of the robot it was needed to specify many constraints based on the main objectives of the system. [10]

Some of these constraints are listed as below for monitoring function:

- The UGV must be visible to human eye so that people can see and beware.
- The UGV should have the capability of carrying additional modules such as safety kits or some kinds of weapons.
- Moving toward obstacles and through harsh road condition.

2.4 Movement analysis

2.4.1 Travelling over steep slopes and flat surface

Monitoring in oil and gas plant must have to travelling over steep slopes and flat surface. This some calculation instead to design a UGV. A simplified model of the robot in travelling over a 45^o slope is shown in Figure 4 [10] and travelling in flat surface in Figure 5, the minimum required power for this motion is calculated as below:

To this end, Newton's 2nd law can be written for the x direction:

$$\sum F_X = ma_X \rightarrow -mg.\, Sin(\alpha) + F - F_R = ma_X = 0. \quad (1)$$

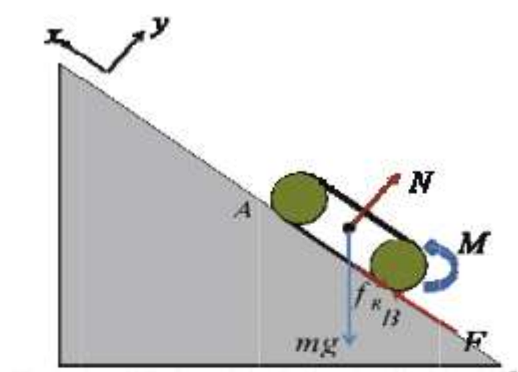


Figure 9: A simplified model of UGV in climbing 45^o slope.

Where F_R is a rolling resistant force and F is the traction force. We could assume the linear acceleration and thus the rotational acceleration of the wheels to be zero and so:

$$M = F.r \quad (2)$$

Using Equations 1 and 2 we obtain:

$$M = [F_R + mg.Sin(\alpha)].r$$

Weight of UGV can estimated using this equation and get minimum required power for motor. Then we can get power by equation 3.

$$P = M.\omega = M.\frac{v}{r} \quad (3)$$

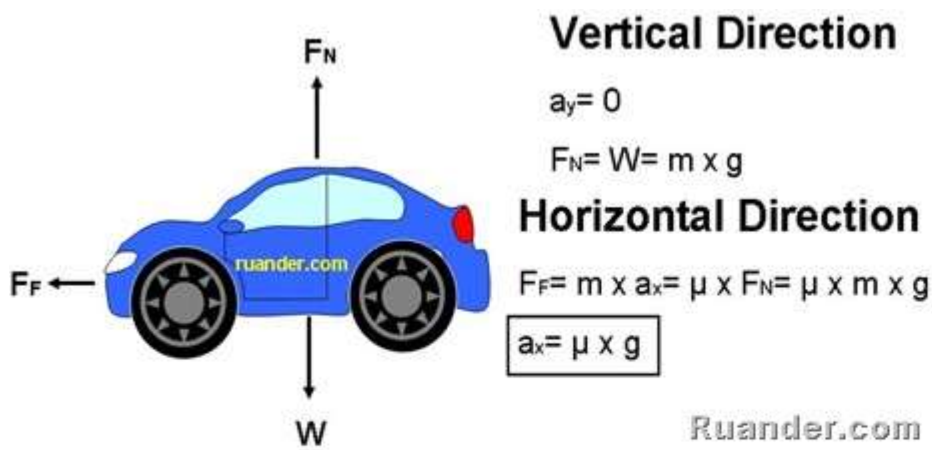


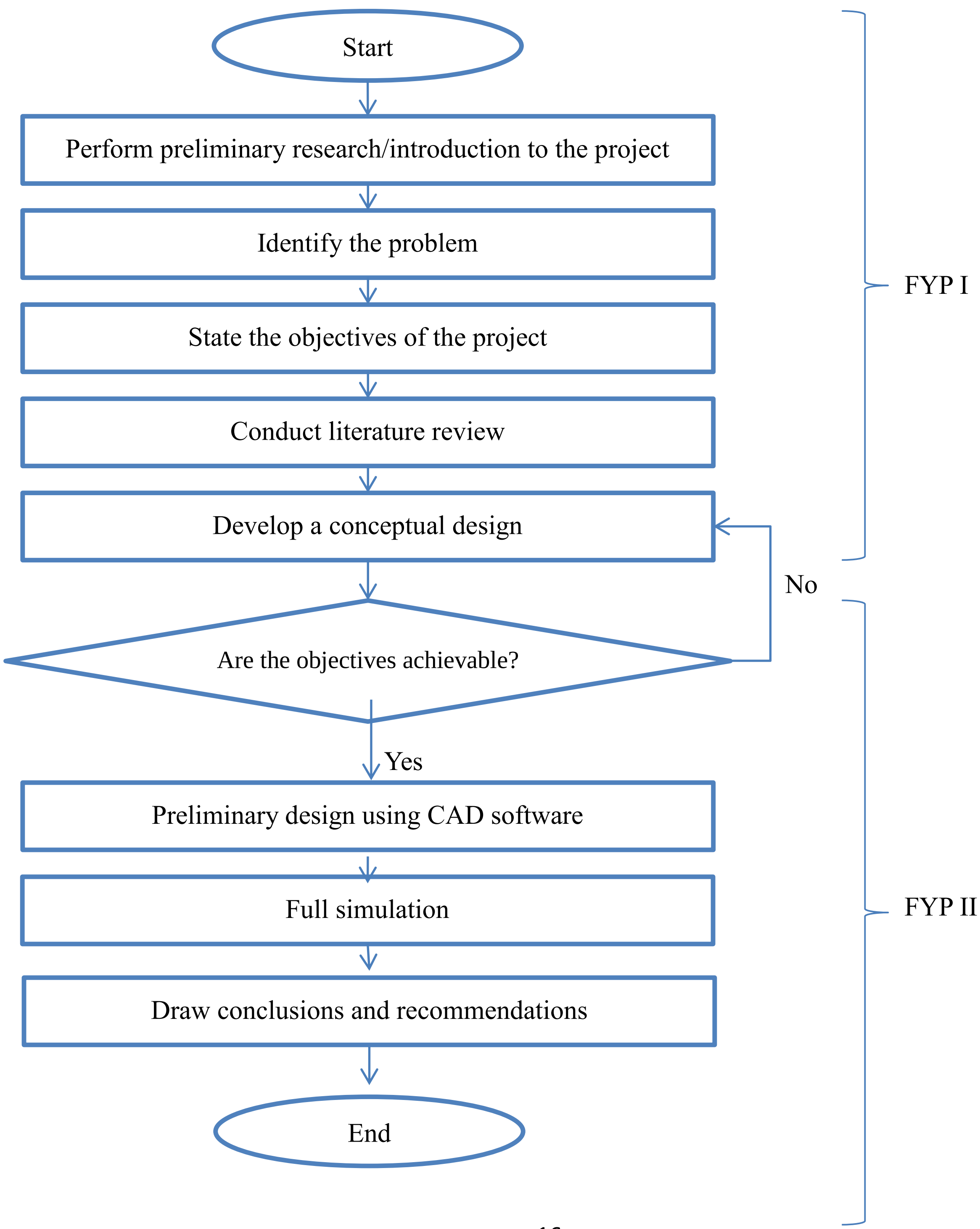
Figure 10: A simplified model of UGV on flat surface.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

A proposed project workflow is as illustrated below:



3.2 Key Milestones

The following table indicates the documentations that need to be submitted:

Table 1: Key Milestones of the Project.

No.	Milestones	Due
FYP1		
1	Extended Proposal	Week 6
2	Proposal Defence	Week 9
3	Interim Draft Report	Week 13
4	Interim Final Report	Week 14
FYP2		
5	Final Report	Week 26
6	Project Presentation	Week 27

3.3 Software Required

These are software needed for this project:

Table 2: The software required for the Project.

	Components	Details
Software	Autodesk Inventer and Solid Work	To design the preliminary and detail design
	MSC ADAM view	To Simulate mechanisms to help develop workable designssimulate the design

3.4 Gantt Chart

The following table is the amount of work needs to be done in certain periods within the two semesters given:

	Week																											
Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Identify objectives	■	■																										
Preliminary Research			■	■																								
Identify suitable software for design					■																							
Submission of extended proposal						■																						
Proposal defence							■	■	■	■	■	■	■	■														
Interim draft report submission											■	■																
Interim report submission													■	■														
Design using CAD software													■	■	■	■	■	■	■	■								
Full Simulation Testing																					■	■	■	■	■	■		
Submission of progress report																							■	■				
Pre-SEDEX																							■	■				
Submission of draft final report																									■	■		
Submission of dissertation																									■	■		
Submission of technical paper																									■	■		
Submission of project dissertation																											■	■
Project Presentation																											■	■

Table 3: Gantt chart of the Project.

3.5 Decomposition Tree

3.5.1 Physical Decomposition

The physical decomposition is where the product is separated or disassembled into its subsystem and component to describe how the parts work together in creating the behavior of the product. The system of the UGV from the previous chapter had been decomposed in figure 11 without considering the function of each subsystem and the component. The physical decomposition for this project will focusing on the subsystem of the UGV.

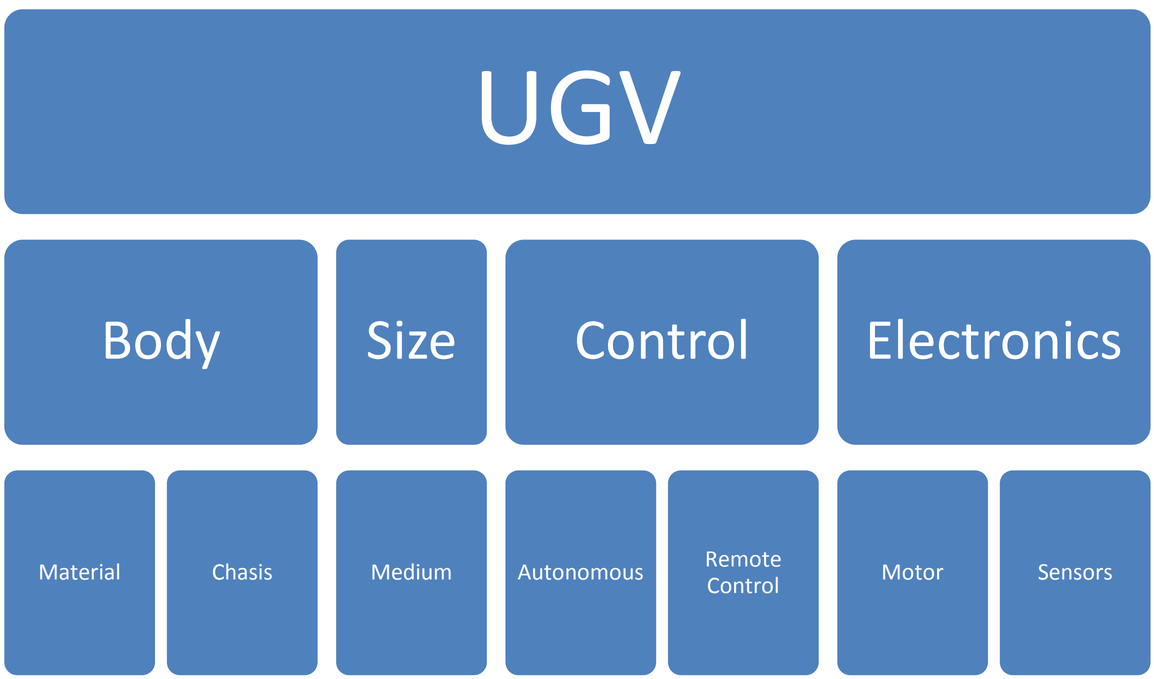


Figure 11: Physical Decomposition Diagram

3.5.2 Functional Decomposition

Functional decomposition is a process to decompose their function based on the physical decomposition. The variety idea of the physical decomposition will be transformed to functional decomposition. It can be done by using functional block diagram. Throughout functional block diagram, the system will be breakdown to specific functions and sub-functions. First, the overall function will be determined by identifying the using function basis terms. Every individual functions will be determine to accomplish the overall task of the system. After determine all the function, the function block will be arrange as the flow of the system.

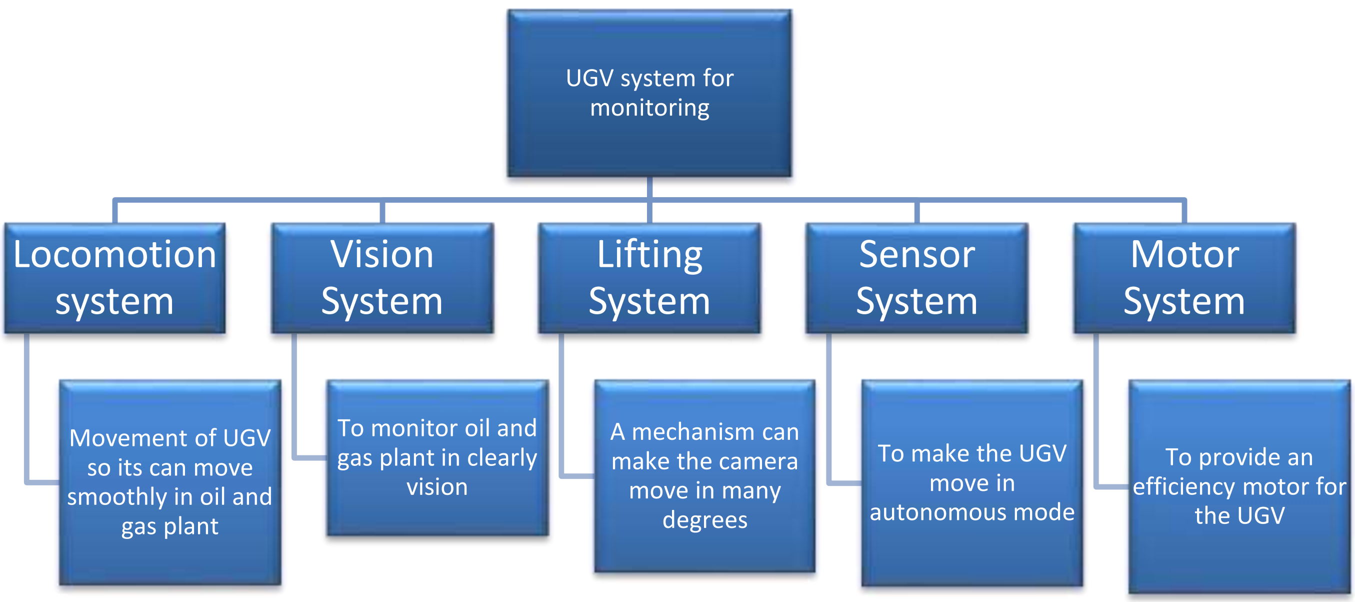
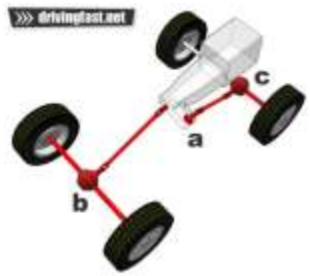


Figure 12: Functional Decomposition Diagram

3.6 Morphology Chart

	Subsystem	Means/Hows		
1	**Locomotion System:** **Move smoothly and robust in oil and gas plant**	**Wheeled system** 	**Tracked system** 	**Legged system** 
2	**Vision System:** **The camera must have clearly vision to monitor oil and gas plant**	**Wireless Infra-red Outdoor USB 4 Camera** 	**Gopro Hero 3 HD** 	**D-link Wireless N Network Camera** 
3	**Lifting System:** **One mechanism that can make camera move in many**	**Scissor Lifting System**	**Arm Robot System**	**Gears and Chain Lifting System**

	degrees of freedom			
4	**Sensor System:** **Make the UGV can move in autonomous mode**	**Light Sensor** 	**Photoelectric Sensor** 	**Ultrasonic Sensor** 
5	**Motor System:** **Provide an efficiency motor for the movement of UGV**	**AC Motor** 	**DC Motor** 	

Table 4: Morphology Chart for the UGV system

3.7 Concept Evaluation

3.7.1 Objective Tree

3.7.1.1 Locomotion System

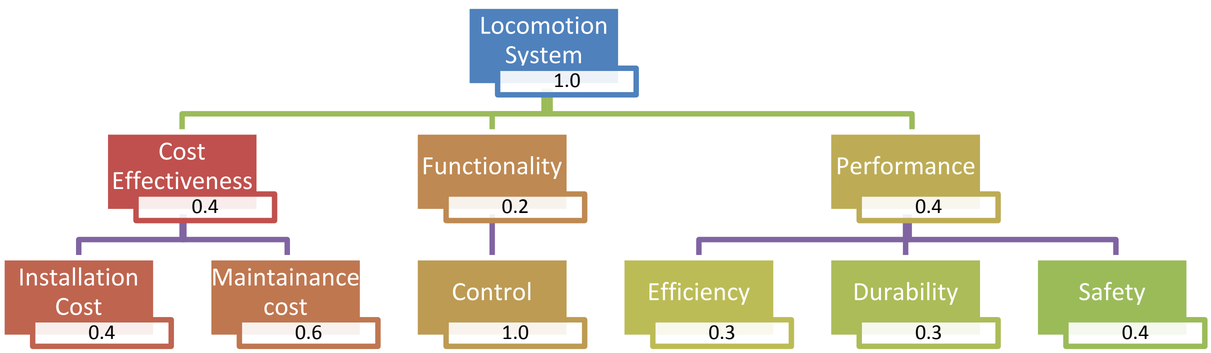


Figure 13: Objective Tree for Locomotion System

3.7.1.2 Vision System

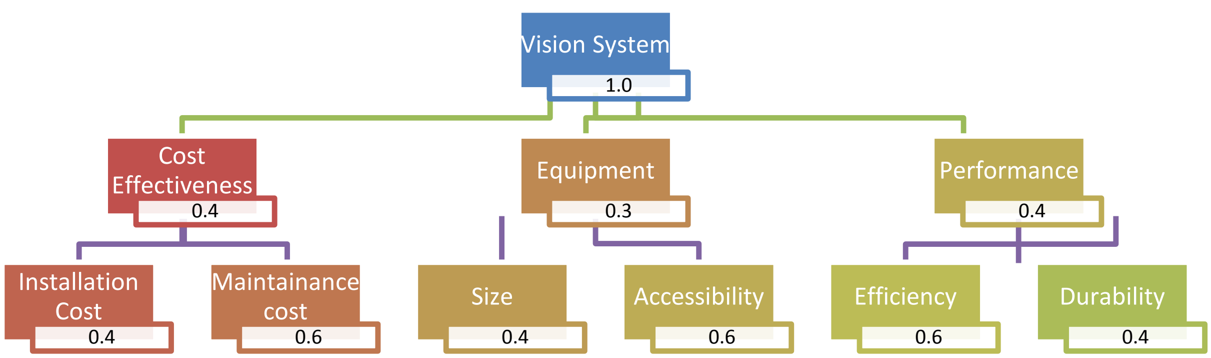


Figure 14: Objective Tree for vision System

3.7.1.3 Lifting System

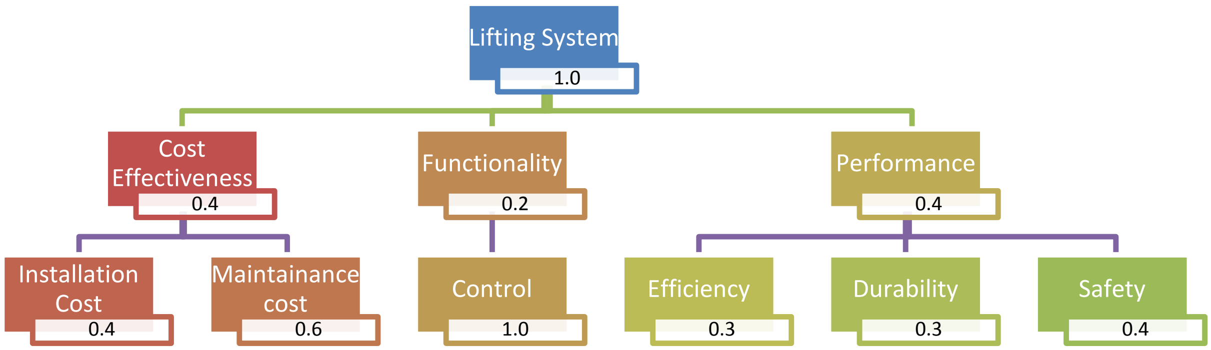


Figure 15: Objective Tree for Lifting System

3.7.1.4 Sensor System

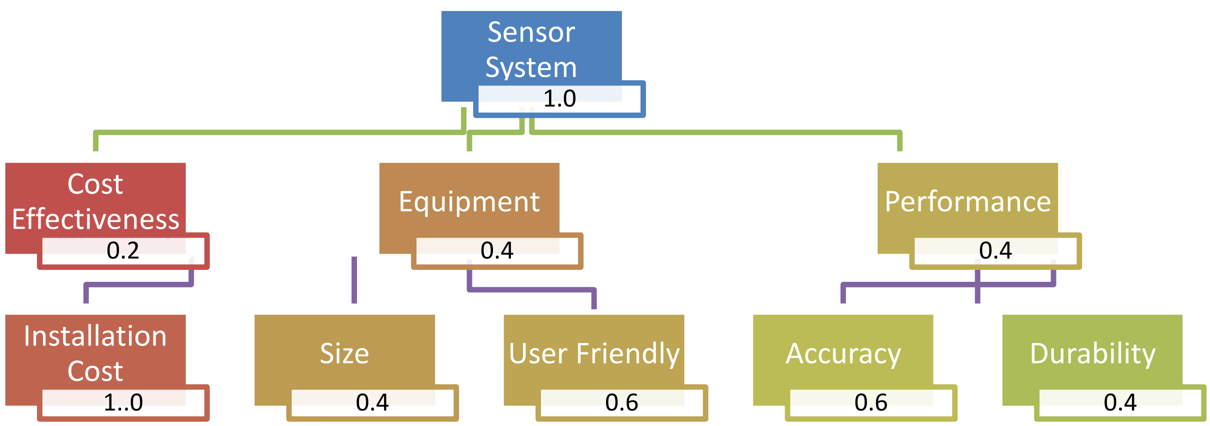


Figure 16: Objective Tree for Sensor System

3.7.1.5 Motor System

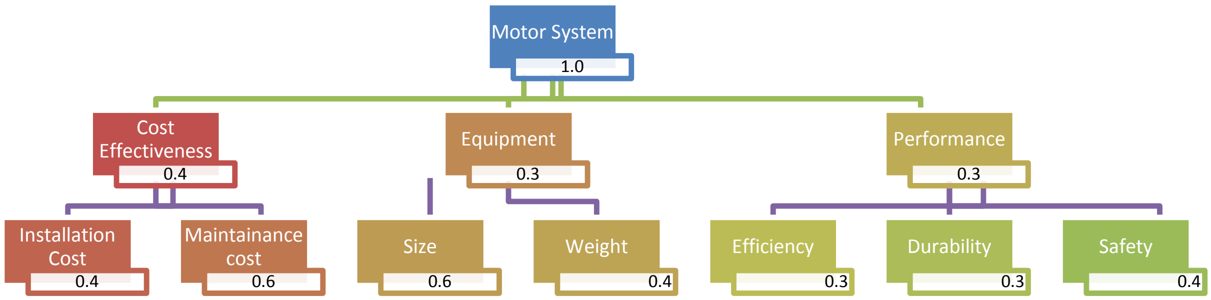


Figure 17: Objective Tree for Motor System

3.8 Weighted Decision Matrix

3.8.1 Locomotion System

Primary Criteria	Design Criteria	Weight Factor	Units	Wheeled system			Tracked system			Legged system		
				M	S	R	M	S	R	M	S	R
Cost (0.4)	Installation cost (0.4)	0.16	Experience	Low	3	0.48	Medium	2	0.32	Very High	0	0
	Maintenance cost (0.6)	0.24	Experience	Very Low	4	0.96	Low	3	0.72	High	1	0.24
Functionality (0.2)	Control (1.0)	0.2	Experience	Easy	3	0.6	Medium	2	0.4	Very Hard	1	0.2
Performance (0.4)	Efficiency (0.3)	0.12	Experience	High	3	0.36	Very High	4	0.48	High	3	0.36
	Durability (0.3)	0.12	Experience	High	3	0.36	Low	1	0.12	Very High	4	0.48
	Safety (0.4)	0.16	Risk	Low	3	0.48	Medium	2	0.32	High	1	0.16
Total						**3.24**			**2.36**			**1.44**

Table 5: Weighted Decision Matrix for Locomotion System

Where, M = Magnitude, S = Score, R = Rating

Cost		Control		Efficiency		Durability		Safety	
Score	Description	Score	Description	Score	Description	Score	Description	Score	Description
0	Very High	0	Very Hard	0	Very low	0	Very low	0	Very high
1	High	1	Hard	1	Low	1	Low	1	High
2	Medium	2	Medium	2	Good	2	Good	2	Medium
3	Low	3	Easy	3	High	3	High	3	Low
4	Very Low	4	Very Easy	4	Very High	4	Very high	4	Very low

Table 6: Scale (5-point scale) for Locomotion System

3.8.2 Vision System

Primary Criteria	Design Criteria	Weight Factor	Units	Wireless Infra-red Outdoor USB 4 Camera			Gopro Hero 3 HD			D-link Wireless N Network Camera		
				M	S	R	M	S	R	M	S	R
Cost (0.4)	Installation cost (0.4)	0.16	Experience	High	1	0.16	Medium	2	0.32	Low	3	0.48
	Maintenance cost (0.6)	0.24	Experience	Medium	2	0.48	Low	3	0.72	Low	3	0.72
Equipment (0.3)	Size (0.4)	0.12	Experience	Large	1	0.12	Small	3	0.36	Medium	2	0.24
	Accessibility (0.6)	0.18	Experience	High	1	0.18	Low	3	0.54	Medium	2	0.36
Performance (0.3)	Efficiency (0.6)	0.18	Experience	High	3	0.54	Very High	4	0.72	High	3	0.54
	Durability (0.4)	0.12	Experience	High	3	0.36	Very High	4	0.48	Low	1	0.12
Total						**1.84**			**3.14**			**2.46**

Table 7: Weighted Decision Matrix for Vision System

Where, M = Magnitude, S = Score, R = Rating

Cost		Size		Accessibility		Efficiency		Durability	
Score	Description	Score	Description	Score	Description	Score	Description	Score	Description
0	Very High	0	Very Large	0	Very High	0	Very Low	0	Very Low
1	High	1	Large	1	High	1	Low	1	Low
2	Medium	2	Medium	2	Medium	2	Good	2	Medium
3	Low	3	Small	3	Low	3	High	3	High
4	Very Low	4	Very Small	4	Very Low	4	Very high	4	Very High

Table 8: Scale (5-point scale) for Vision System

3.8.3 Lifting System

Primary Criteria	Design Criteria	Weight Factor	Units	Scissor Lifting System			Arm Robot System			Gears and Chain Lifting System		
				M	S	R	M	S	R	M	S	R
Cost (0.4)	Installation cost (0.4)	0.16	Experience	High	1	0.16	Medium	2	0.32	Very High	0	0
	Maintenance cost (0.6)	0.24	Experience	Medium	2	0.48	Low	3	0.72	High	1	0.24
Functionality (0.2)	Control (1.0)	0.2	Experience	Easy	3	0.6	Easy	3	0.6	Easy	1	0.6
Performance (0.4)	Efficiency (0.3)	0.12	Experience	High	3	0.36	Very High	4	0.48	High	3	0.36
	Durability (0.3)	0.12	Experience	High	3	0.36	High	3	0.36	Medium	2	0.24
	Safety (0.4)	0.16	Risk	Low	3	0.48	Low	3	0.48	Medium	2	0.32
Total						**2.44**			**2.96**			**1.76**

Table 9: Weighted Decision Matrix for Lifting System

Where, M = Magnitude, S = Score, R = Rating

Cost		Control		Efficiency		Durability		Safety	
Score	Description	Score	Description	Score	Description	Score	Description	Score	Description
0	Very High	0	Very Hard	0	Very low	0	Very low	0	Very high
1	High	1	Hard	1	Low	1	Low	1	High
2	Medium	2	Medium	2	Good	2	Good	2	Medium
3	Low	3	Easy	3	High	3	High	3	Low
4	Very Low	4	Very Easy	4	Very High	4	Very high	4	Very low

Table 10: Scale (5-point scale) for Vision System

3.8.4 Sensor System

Primary Criteria	Design Criteria	Weight Factor	Units	Light Sensor			Photoelectric Sensor			Ultrasonic Sensor		
				M	S	R	M	S	R	M	S	R
Cost (0.2)	Installation cost (1.0)	0.2	Experience	Low	3	0.6	Medium	2	0.4	Medium	2	0.4
Equipment (0.4)	Size (0.4)	0.16	Experience	Medium	2	0.32	Medium	2	0.32	Small	3	0.48
	User Friendly (0.6)	0.24	Experience	High	3	0.72	Medium	2	0.48	Very High	4	0.96
Performance (0.4)	Accuracy (0.6)	0.24	Experience	Low	1	0.24	Medium	2	0.48	High	3	0.72
	Durability (0.4)	0.16	Experience	Medium	2	0.32	Very High	4	0.64	Very High	1	0.64
Total						**2.20**			**2.32**			**3.20**

Table 11: Weighted Decision Matrix for Sensor System

Cost		Size		User Friendly		Accuracy		Durability	
Score	Description	Score	Description	Score	Description	Score	Description	Score	Description
0	Very High	0	Very Large	0	Very Low	0	Very Low	0	Very Low
1	High	1	Large	1	Low	1	Low	1	Low
2	Medium	2	Medium	2	Medium	2	Good	2	Medium
3	Low	3	Small	3	High	3	High	3	High
4	Very Low	4	Very Small	4	Very High	4	Very high	4	Very High

Table 12: Scale (5-point scale) for Vision System

3.8.5 Motor System

Primary Criteria	Design Criteria	Weight Factor	Units	AC Motor			DC Motor		
				M	S	R	M	S	R
Cost (0.4)	Installation cost (0.4)	0.16	Experience	High	1	0.16	Medium	2	0.32
	Maintenance cost (0.6)	0.24	Experience	Medium	2	0.48	Low	3	0.72
Functionality (0.3)	Size (0.6)	0.18	Experience	Medium	2	0.36	Medium	2	0.36
	Weight (0.4)	0.12	Experience	Medium	2	0.24	Medium	2	0.24
Performance (0.4)	Efficiency (0.3)	0.12	Experience	High	3	0.36	Very High	4	0.48
	Durability (0.3)	0.12	Experience	High	3	0.36	Medium	2	0.24
	Safety (0.4)	0.16	Risk	Medium	2	0.36	Low	3	0.48
Total						**2.32**			**2.84**

Table 13: Weighted Decision Matrix for Motor System

Cost		Size		Efficiency/ Weight		Durability		Safety	
Score	Description	Score	Description	Score	Description	Score	Description	Score	Description
0	Very High	0	Very Large	0	Very low	0	Very low	0	Very high
1	High	1	Large	1	Low	1	Low	1	High
2	Medium	2	Medium	2	Good	2	Good	2	Medium
3	Low	3	Small	3	High	3	High	3	Low
4	Very Low	4	Very Small	4	Very High	4	Very high	4	Very low

Table 14: Scale (5-point scale) for Vision System

3.9 Analysis Tool

3.9.1 MSC ADAM view

ADAMS stands for Automatic Dynamic Analysis of Mechanical Systems and was originally developed by Mechanical Dynamics Inc.(MDI). MDI was formed by researchers/developers of the original ADAMS code at University of Michigan, Ann Arbor, MI, USA. Later on, it was absorbed into McNeil Schindler Corp (MSC) in 2002. At the core of ADAMS is a large displacement code called ADAMS/Solver that solves nonlinear numerical equations. Models are built in text format and then submitted into ADAMS/Solver. In the early 90's, ADAMS/View was released which allowed users to build, simulate and examine results in a single Graphical User Environment (GUI). MSC.ADAMS Simulation Package is a powerful modeling and simulating environment that lets one build, simulate, refine, and ultimately optimize any mechanical system, from automobiles and trains to VCRs and backhoes.

ADAM view Adams helps engineers to study the dynamics of moving parts, how loads and forces are distributed throughout mechanical systems. Adams improves engineering efficiency and reduces product development costs by enabling early system-level design validation. Engineers can evaluate and manage the complex interactions between disciplines including motion, structures, actuation, and controls to better optimize product designs for performance, safety, and comfort. Along with extensive analysis capabilities, Adams is optimized for large-scale problems, taking advantage of high performance computing environments. Utilizing multi-body dynamics solution technology, Adams runs nonlinear dynamics in a fraction of the time required by FEA solutions. Loads and forces computed by Adams simulations improve the accuracy of FEA by providing better assessment of how they vary throughout a full range of motion and operating environments.

Model the author create will simulation in MSC ADAM view to see the movement and measure rotational velocity to find the suitable motor to use in actual design. All parameters will setting in ADAM and simulation will show the movement, velocity, angular velocity and others result. After the result come out the author will include in chapter 4.

3.9.2 Autodesk Inventor

Autodesk Inventor is a 3D mechanical solid modeling design software developed by Autodesk to create 3D digital prototypes. It is used for 3D mechanical design, design communication, tooling creation and product simulation. This software enables users to produce accurate 3D models to aid in designing, visualizing and simulating products before they are built.

This software incorporates integrated motion simulation and assembly stress analysis, whereby users are given options to input driving loads, dynamic components, friction loads and further run the dynamic simulation to test how the product will function in a real-world scenario. These simulation tools enable users designing cars or automotive parts, for example, to optimize the strength and weight of a product, identify high-stress areas, identify and reduce unwanted vibrations, and even size motors to reduce their overall energy consumption.

The author will design using Autodesk Inventor to design the UGV. Using 2D sketch to start the sketching the design and will using 3D to do create mechanical solid design. Then, the 3D model is updated based on these optimized parameters. Autodesk Inventor also uses special file formats for parts, assemblies and drawing views. The files are imported or exported in a DWG (drawing) format. However, the 2D and 3D data interchange and review format that Autodesk Inventor uses most frequently is design web format (DWF).

CHAPTER 4
RESULT AND DISCUSSION

As the result of this project the author will select the medium UGV as the final design. For the systems for this UGV will select according to weighted Decision Matrix.

Advantages of medium size:

- The UGV be visible to human eye so that people can see and beware.
- The UGV have the capability of carrying additional modules such as safety kits or some kinds of weapons.

Advantages of wheeled system:

- Moving toward obstacles and through harsh road condition.

The first draft of the UGV's base design was based on the criteria below:

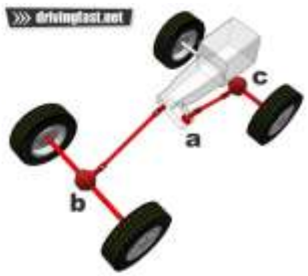
- Simple frame design
- Easy to fabricate
- Ease of assembly
- Lightweight
- Robust material
- Low cost
- Safety priority

This first design will not be expected will be robust enough to move around oil and gas plant but instead will give the first general idea on how the UGV should be built in order to move in a safe manner. The material that will be used on the fabrication of this UGV design will be made of aluminum to ensure it to be robust and not easily break while the simple square shape of the aluminum helps to ease the fabrication process. The aluminum is also lightweight as it is hollow in the middle and relatively cheap.

This chapter presents the results of this project. This chapter starts with the UGV Design. The design is first simulated in 3D using Autodesk Inventor 2015. After that, the author discusses the components that are selected to be used in the prototype in future to be put in this design. Then the author analyzes and discusses the motor testing part of this project. Finally, the author will produce detail design and the results are recorded.

4.1 Selected Concept

Table 15: Selected concept

Subsystem	Locomotion System	Vision System	Lifting System
Selected Alternative	Wheeled system 	Gopro Hero 3 HD 	Arm Robot System 
	Sensor System	Motor System	
	Ultrasonic Sensor 	DC Motor 	

4.2 Justification of Selected Concept

Subsystem	Selected Alternative	Justification/Benefits
Locomotion System	**Wheeled system**	• low production costs – this is the case if we compare the prices for wheels and tracks • speed – compared with tracks, the wheels need a lower amount of torque to move on from stationary • lightweight – continuous tracks and legged are much heavier than wheels, and this is the main reason why wheels are used especially in cases when the mass of the robot is a critical property • simplicity – a wheel has less moving parts, which means that there are fewer components that can get damaged • materials – several materials can be used to build wheels that meet environmental conditions
Vision System	**Gopro Hero 3 HD**	• Wearable, mountable design • Immersive, wide angle capture of oil and gas plant • Professional quality HD video & 12MP photos • Built-in Wi-Fi enables remote control via included Wi-Fi Remote or live video preview and remote control on Smartphones and tablets running the free Go Pro app. • Rugged housing is waterproof to 197'/60M and captures sharp images above and below water.

Lifting System	**Arm Robot System**	• Technical advantages: compact size, broad work envelopes, high speed, precision, resistance to all types of environments and the flexibility to adapt to the greatest number of tasks. • Quicker recovery period than scissor lifting system and gears and chain Lifting System.
Sensor System	**Ultrasonic Sensor**	• Discrete distances to moving objects can be detected and measured. • Less affected by target materials and surfaces, and not affected by color. Solid-state units have virtually unlimited, maintenance free life. Can detect small objects over long operating distances. • The performance of this sensor cannot be interfere by the sunlight or dark material and very sensitive.
Motor System	**DC Motor**	• Provide excellent speed control for acceleration and deceleration • Easy to understand design • Simple, cheap drive design • High starting torque • Accurate steep less speed with constant torque

4.3 Material

The material that is suitable to make the UGV is Aluminium Alloy. The benefits the author want using aluminium is because of:

- Weight
  - One of the best known properties of aluminium is that it is light, with a density one third that of steel, 2.700 kg/m. The low density of aluminium accounts for it being lightweight but this does not affect its strength.
- Strength
  - Aluminium alloys commonly have tensile strengths of between 70 and 700 MPa. The range for alloys used in extrusion is 150 – 300 MPa. Unlike most steel grades, aluminium does not become brittle at low temperatures. Instead, its strength increases. At high temperatures, aluminium's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account.
- Linear expansion
  - Compared with other metals, aluminium has a relatively large coefficient of linear expansion. This has to be taken into account in some designs.
- Machining
  - Aluminium is easily worked using most machining methods – milling, drilling, cutting, punching, bending, etc. Furthermore, the energy input during machining is low.
- Formability
  - Aluminium's superior malleability is essential for extrusion. With the metal either hot or cold, this property is also exploited in the rolling of strips and foils, as well as in bending and other forming operations.
- Joining
  - Features facilitating easy jointing are often incorporated into profile design. Fusion welding, Friction Stir Welding, bonding and taping are also used for joining.
- Reflectivity
  - Another of the properties of aluminium is that it is a good reflector of both visible light and radiated heat.

- Corrosion resistance
    - Aluminium reacts with the oxygen in the air to form an extremely thin layer of oxide. Therefore it provides excellent corrosion protection. The layer is self-repairing if damaged.
    - Anodising increases the thickness of the oxide layer and thus improves the strength of the natural corrosion protection.
    - Aluminium is extremely durable in neutral and slightly acid environments.In environments characterised by high acidity or high basicity, corrosion is rapid.

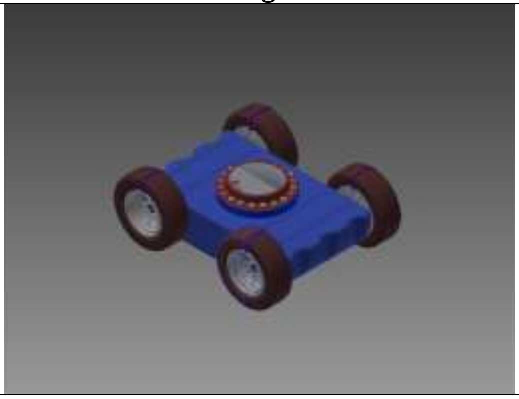
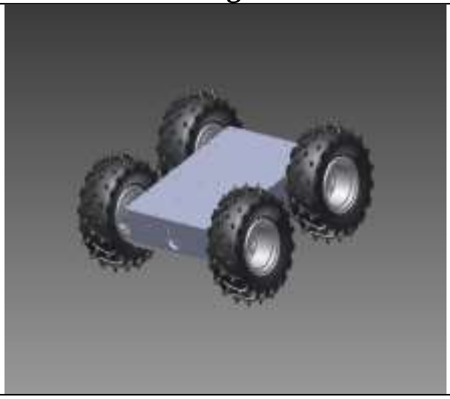
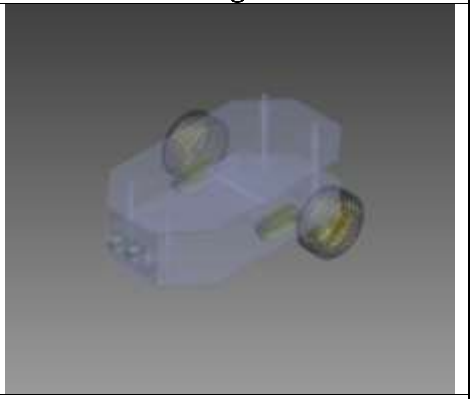
Aluminum alloy type	2014
Minimum tensile strength, psi/MPa	64000/441
Minimum yield strength, psi/MPa	58000/400
Minimum elongation % in 2"	7
Minimum shear yield strength, psi/MPa	33000/228
Brinell hardness	135
Modulus of Elasticity, psi/MPa	$10.6x10^6$/73084
Shear Modulus, psi/MPa	$3.9x10^6$/27000
Poisson's ratio	0.33
Density, ppg / kg/l	23.2/2.78

Figure 18: Specification of aluminium alloy

4.4 UGV Base Design (3D Simulations)

There are 3 base designs that have been simulated in Autodesk Inventor 2015. Between the three designs the author have selecting 2nd design because more suitable in monitoring oil and gas plant. After proceed with the base design that most suitable to become monitoring UGV the author will proceed to detail design.

Below are the designs of the structure using the Autodesk Inventor 2015 software:

	Design 1	Design 2	Design 3
Base Design			
Justification	• Suitable on road • Dimension of body stable and robust • Suitable to put lifting system on top of it • Simple chassis and ease of fabrication	• Suitable on off-road • Dimension of body easily to climb stairs • Limited space on top of it • Simple chassis and very clean	• Suitable on cement • Front tire easily to make rotational move • Cannot handle a lot of weight because of front tire • Simple chassis and light

4.5 UGV Detail Design (3D Simulations)

After the base design was selected, the author continue assemble the arm part with the base part. The base design 1 was selected because its dimension is the most stable to assemble the arm part. With the dimension 420mm length and 224mm width the author sure this is the right dimension to maintain the stability of the UGV. Moreover, this UGV can easily move in oil and gas plant because of the tire. 4 sensors was placed in 4 different position which is front, back, right side and left side. The function of the sensors is to detect any surrounding obstacle when UGV is moving. The arm can fully straight into vertical position and the camera can rotate in 180 degrees. The position of camera have many advantages to monitoring pipes, tank and other equipment in oil and gas plant.

Figure 19: UGV Final Design

4.6 Motion Analysis (MSC Adam view)

"Motion study" is a catch-all term for simulating and analyzing the movement of mechanical assemblies and mechanisms. Traditionally, motion studies have been divided into two categories: kinematics and dynamics. Kinematics is the study of motion without regard to forces that cause it; dynamics is the study of motions that result from forces.

This ADAM help author on:

- Simulate mechanisms to help develop workable designs
- View physically realistic animations to detect problems
- Find interferences among moving parts and fix them
- Produce animations for output to video to show how products will actually work

The basic output of motion studies are numerous, including animation, detecting interference, trace functions, basic motion data, and plots and graphs. Animated motions are the classic output of simple kinematic analyses. Initially, the author uses simple animation as a visual evaluation of motion to see if it is what is desired. More sophisticated animations can show motion from critical angles or even inside of parts, a definite advantage over building and running a physical prototype**.**

The author design arm system in ADAM to see the motion analysis of the system.

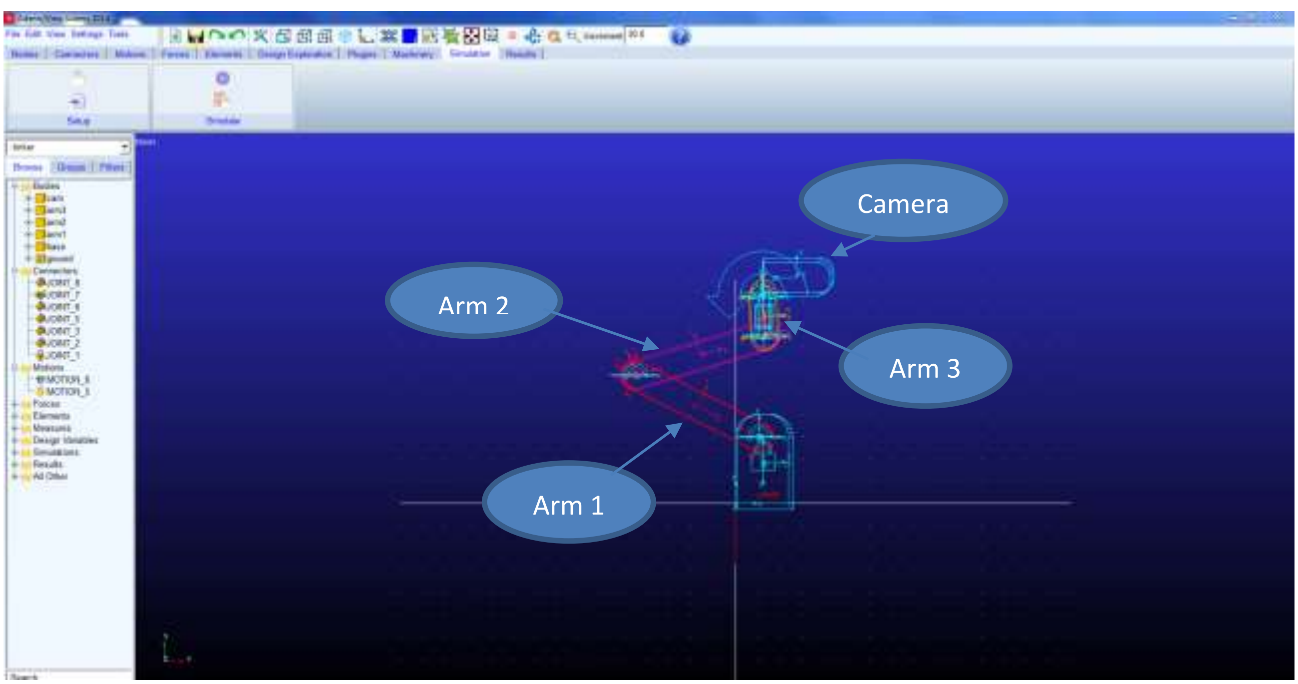


Figure 20: Simulation on MSC ADAM view

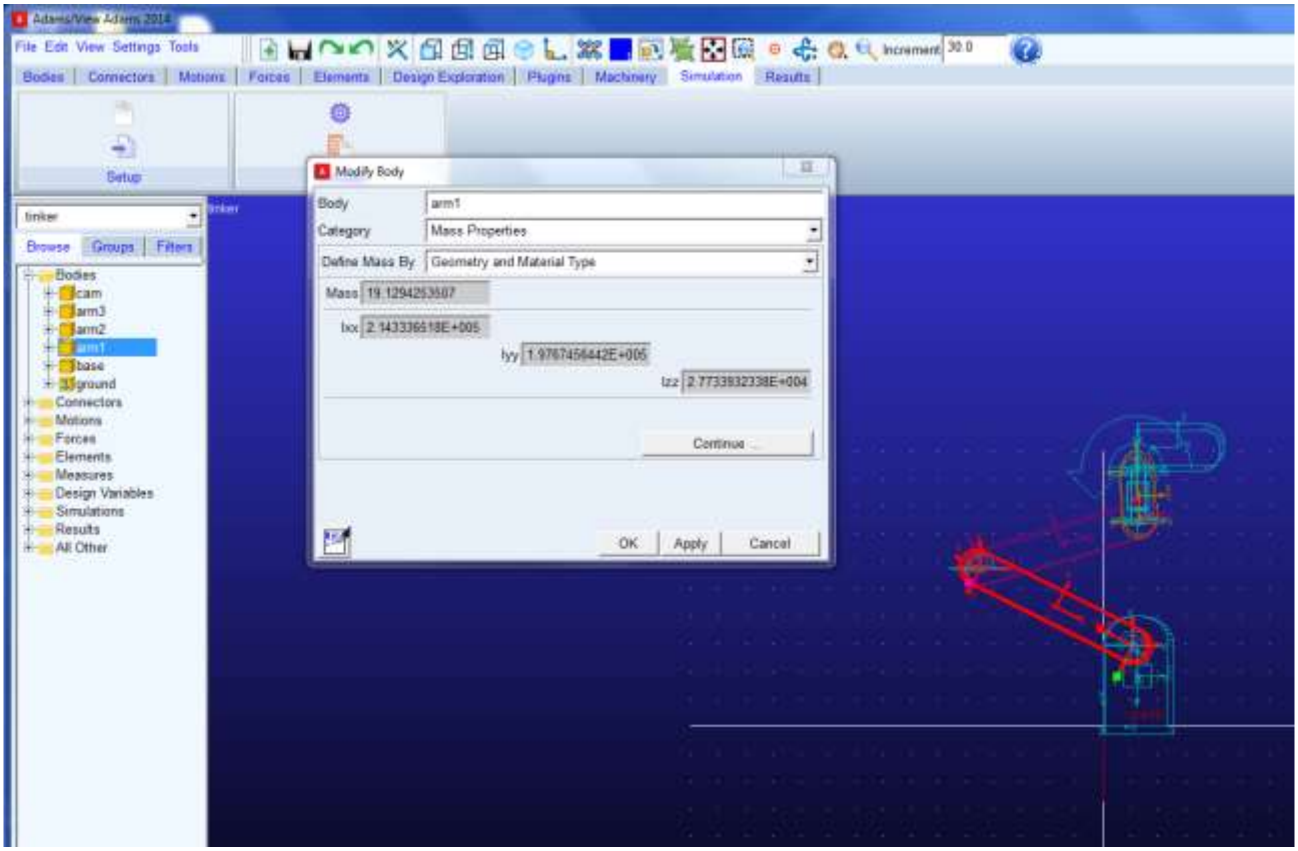


Figure 21: Parameter of simulation

All parameters was setting on ADAM like mass of arm and camera, rotational motion of camera and translational motion of arm. Translational motion is set on arm 3 to move in Y-axis to analysis angular velocity at arm 2 and arm 1. The result of angular velocity will be used to determine the power of motor. This simulation also show how the arm system function and to show maximum degree the arm can rotate.

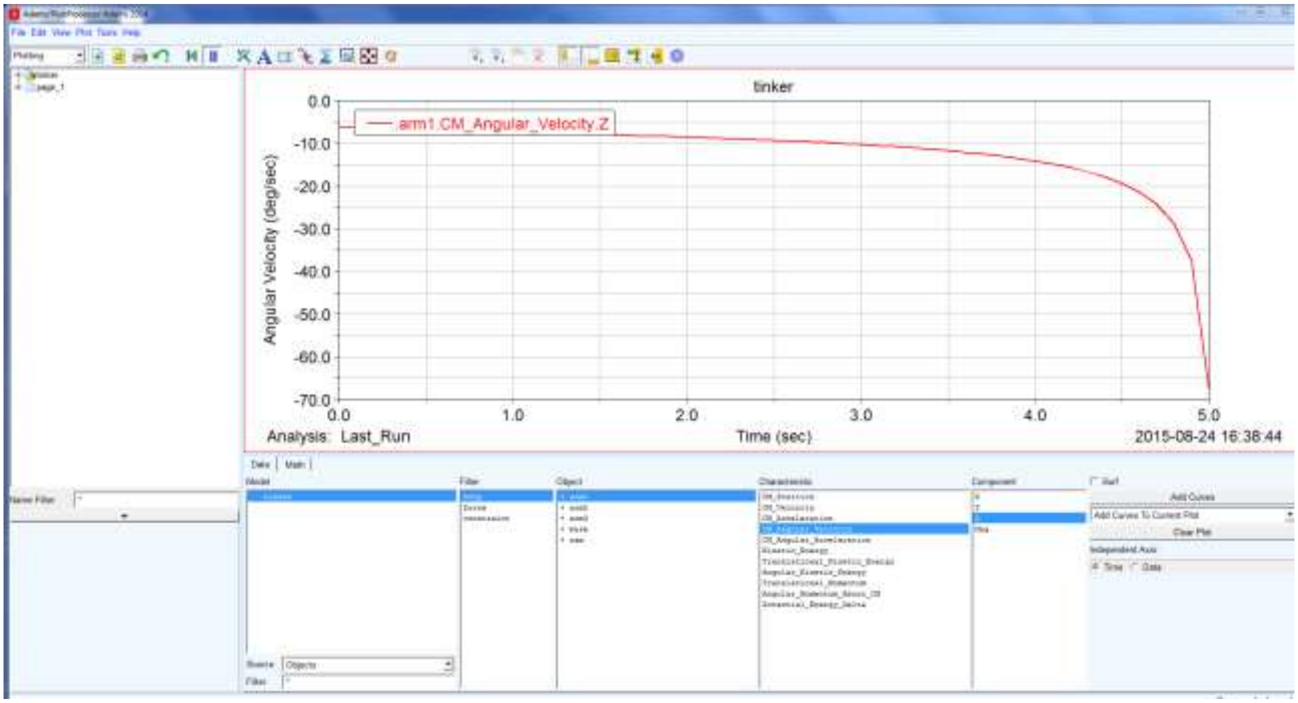


Figure 23: Angular velocity for arm 1

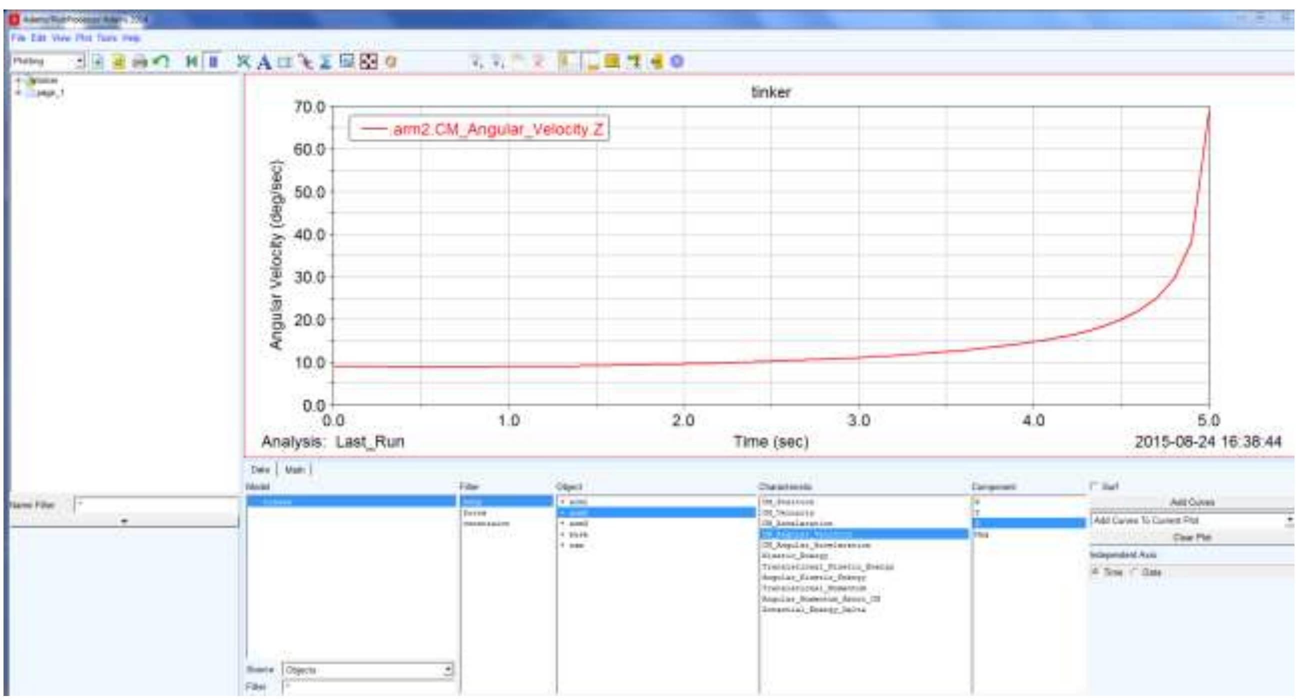


Figure 22: Angular velocity for arm 2

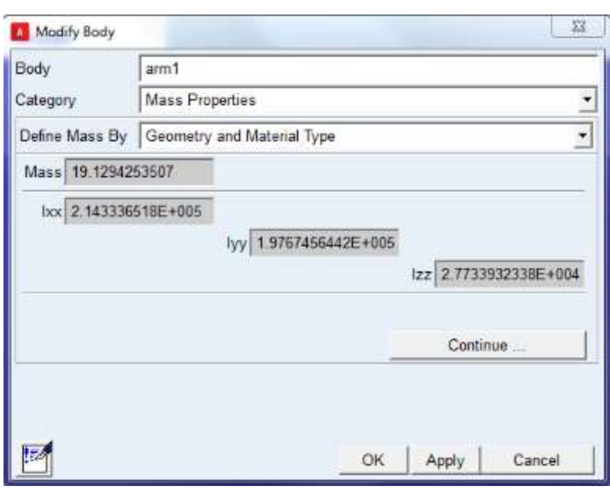
Based on angular velocity on the analysis the author can find power of servo motor to be use in arm system. The angular velocity for arm 1 is 68 deg/sec and for arm 2 is 69 deg/sec. The author use formula $P_{rot} = M \times \omega$.

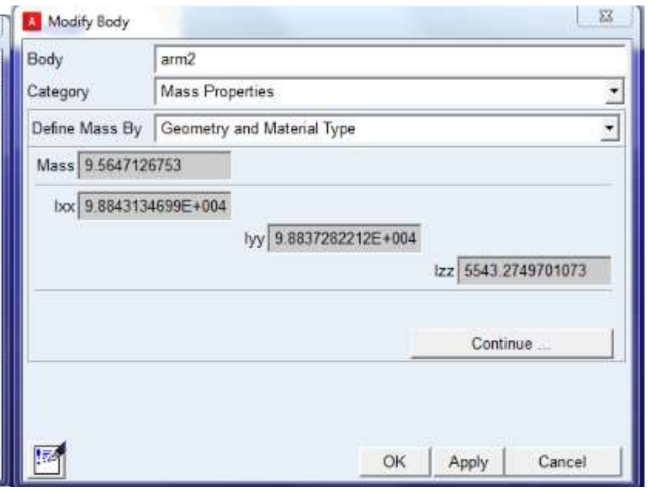
Where:

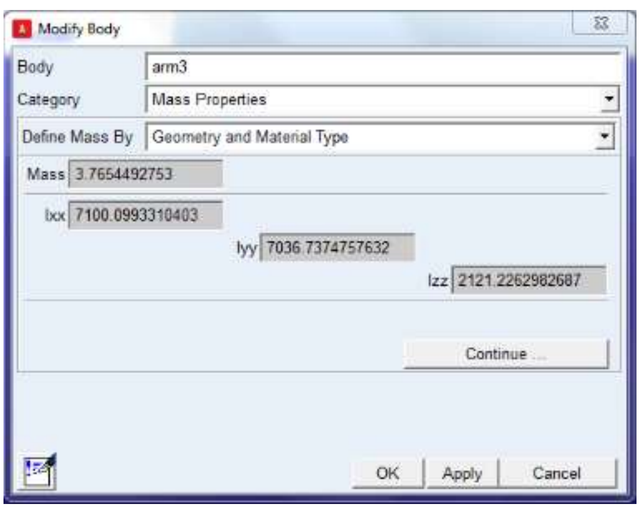
P_{rot} = rotational mechanical power

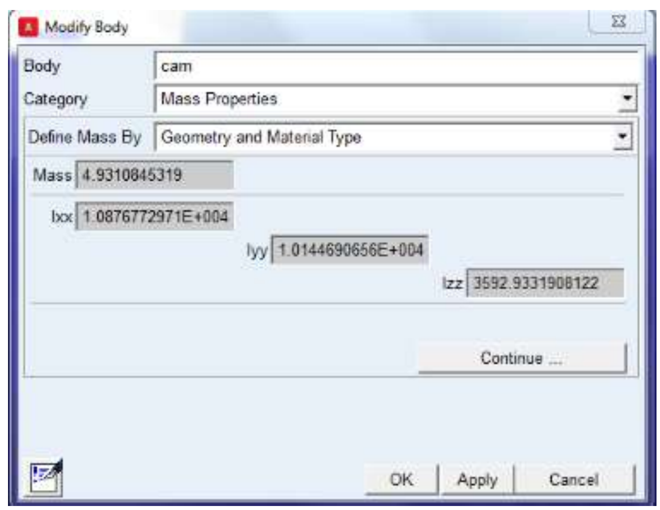
M = torque

ω = angular velocity









M = torque (τ)
$\boldsymbol{\tau = F x\, d}$
F = Weight (N)
d = distance

Sum all the mass = 35kg
The author create arm model in ADAM all solid state, so the real model must be double lower than model in ADAM. The author assume the real mass for arm system is 17kg.
F= 17kg X 9.81
= 166.77N
d = 300mm (0.3m)
τ = 50 N.m

P_{rot} = M x ω
M (τ) = 50 N.m
ω = 68deg/sec (11.33rpm)
P_{rot} = 566.5 W
Thus the power for servo motor for arm 1 must be higher than 566.5 W.

Sum all the mass from arm 2,3 and camera = 10kg
F= 10kg X 9.81
= 98.1N
d = 300mm (0.3m)
τ = 29.43 N.m

P_{rot} = M x ω
M (τ) = 29.43 N.m
ω = 69deg/sec (11.5rpm)
P_{rot} = 338.45 W
Thus the power for servo motor for arm 2 must be higher than 338.45 W. The calculation only show for arm 1 and arm 2 because this part are critical part for selected the motor to be use.

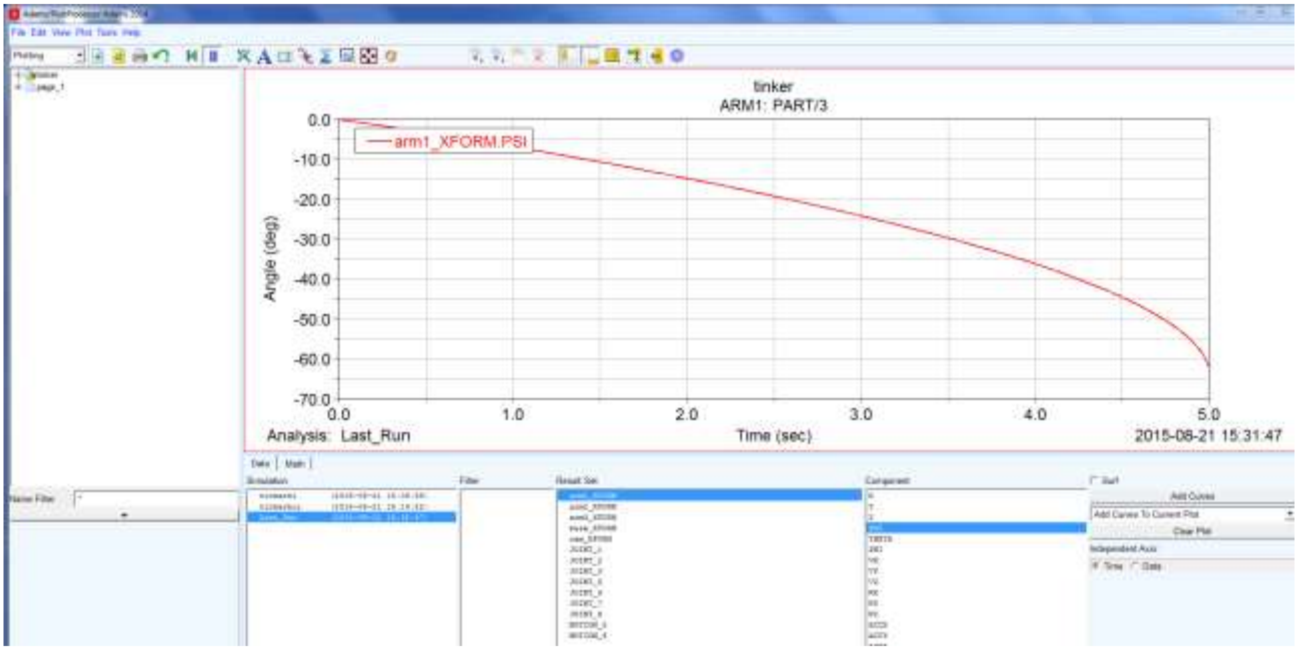


Figure 25: Arm 1 degree

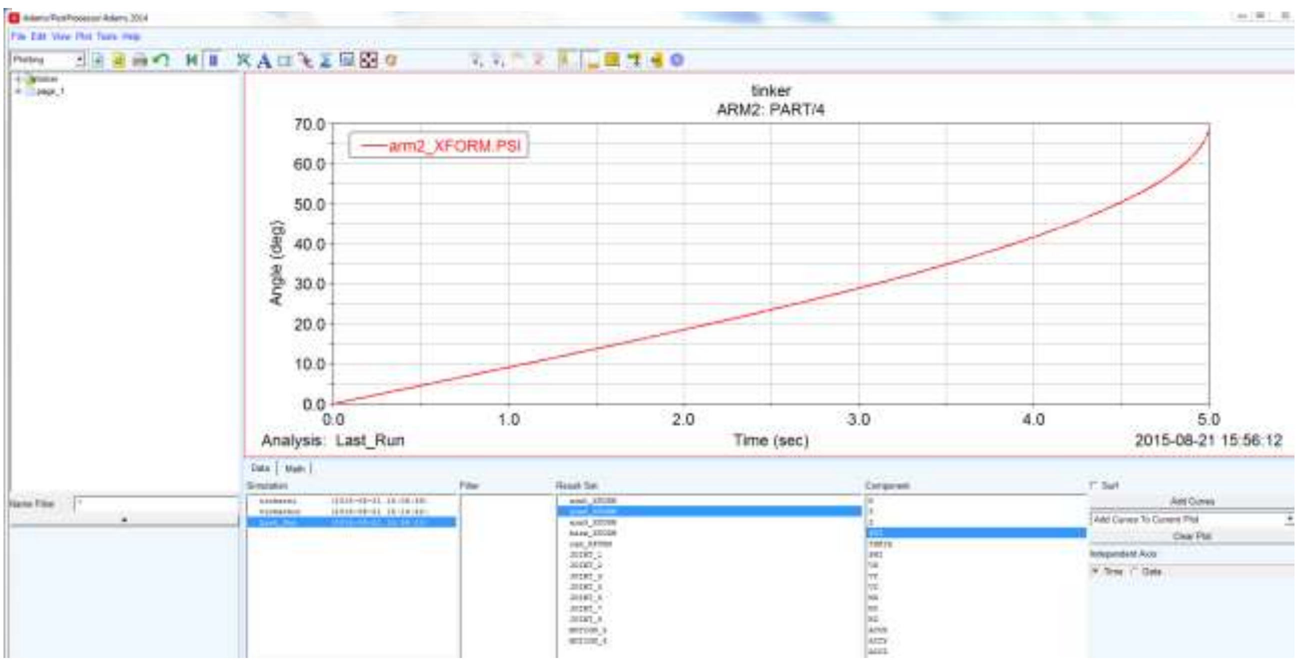


Figure 24: Arm 2 degree

The picture show maximum degree that arm 1 and arm 2 can rotate in achieved vertical lifting in arm system.

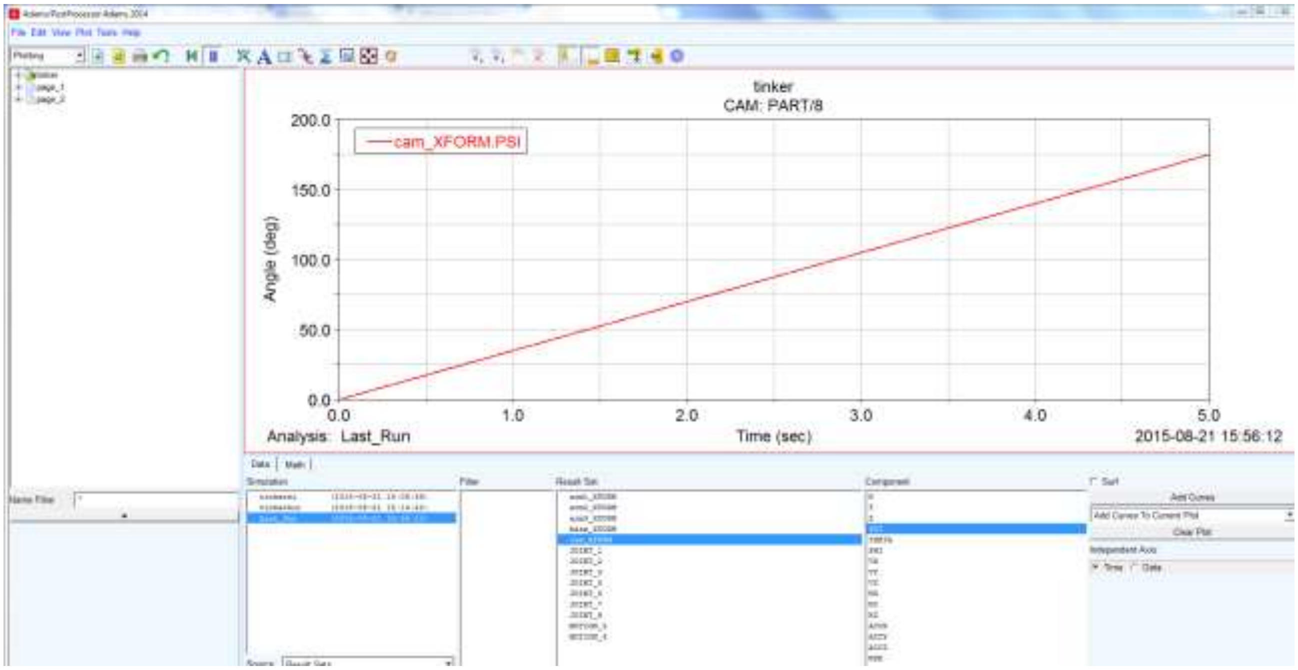


Figure 27: Rotational degree of camera

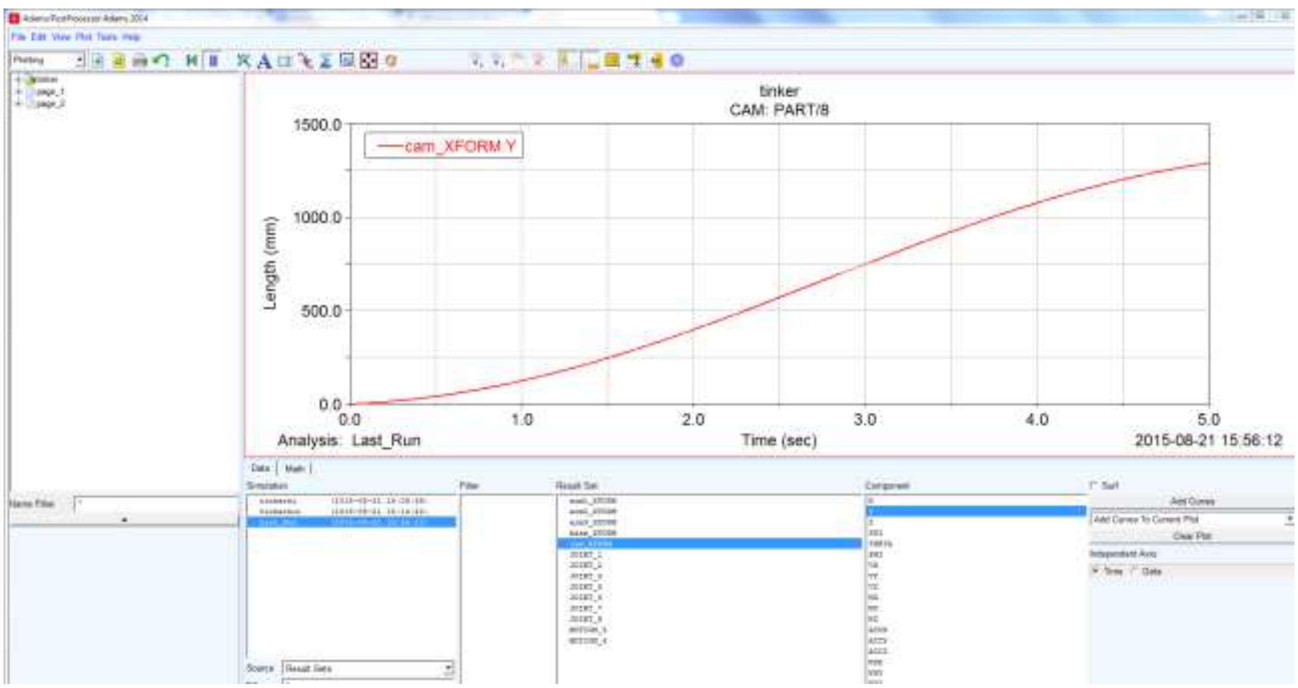


Figure 26: Maximum length of monitoring system

The picture show the camera can rotate to 180 degree and maximum length that the camera can achieved. Using ADAM software, it's prove that not impossible the camera can rotate in 180 degree and can go to its maximum length.

4.7 Components selection and functionality

4.7.1 System block diagram

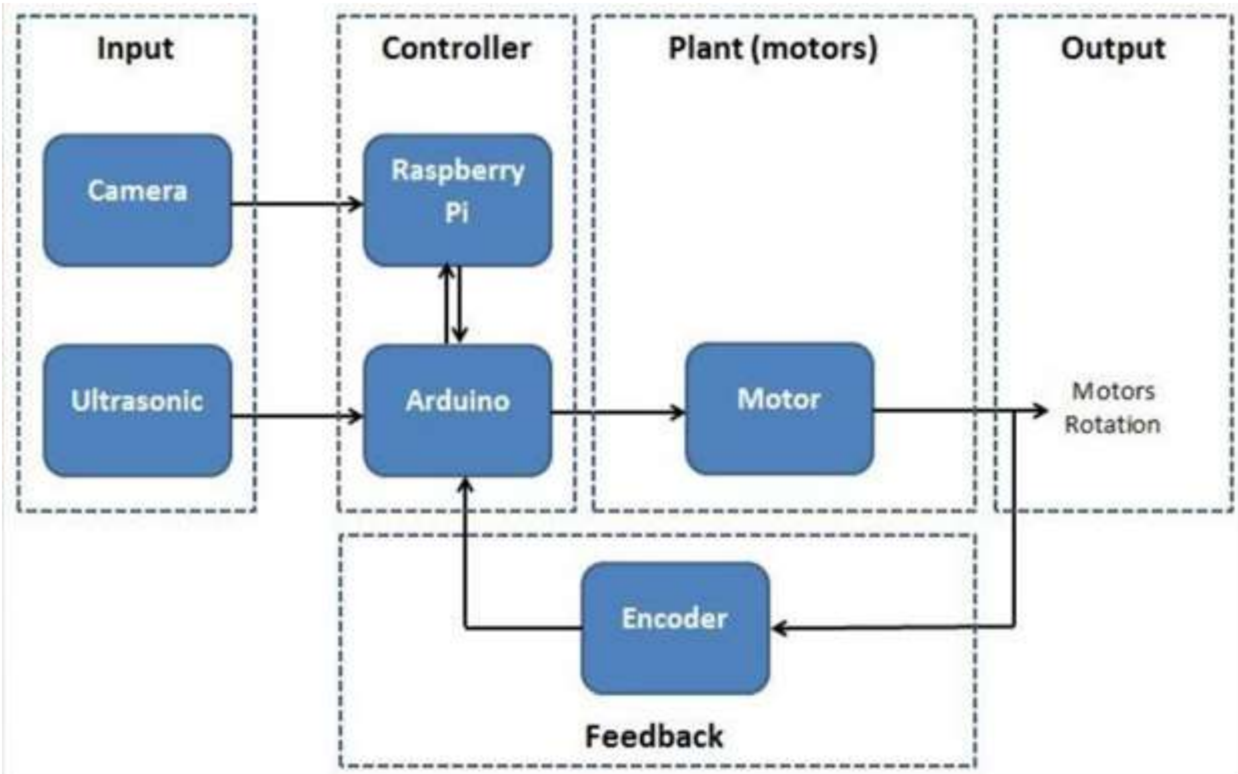


Figure 28: System block diagram

The system block diagram consists of 4 parts of functions which are input, controller, plant (motors), output and feedback. Below is the description lists of these functions:

1) Input:
   a. Gopro Hero 3 HD camera
      - Capture the image of the oil and gas field and reads the RGB colored images then passes it to the Raspberry Pi.
      - Record live video of the oil and gas plant
   b. Ultrasonic sensor
      - Measures the distance of the obstacles when encountered.

2) Controller:

   a. Arduino MEGA

      - Main microcontroller that stores and executes the main algorithm.
      - Read the ultrasonic sensor data.
      - Controls the speed of the motors.
      - Get the input signals from Raspberry Pi which required to reach at the desired destination.

   b. Raspberry Pi

      - Reads the input image from Gopro Hero 3 HD camera.
      - Perform the image processing for color detection and coordinates of the objects and obstacles.
      - Passes the output motion control signals to the Arduino.

3) Plant

   a. Motor

      - Reads the input control signals from the Arduino board and generates the required motor voltage.

4) Output

   a. Rotation of the motors

      - Speed of the rotation based on the voltage that have been generated by Arduino.

5) Feedback

   a. Encoder

      - Gets input signal from the rotation of the motor.
      - Measure the number of rotation of the motor.
      - Record the number of the rotation and passes it to the Arduino to know how much the distance that have been traveled by the robot.

4.7.2 Components and quantity

Table 16: main components

No	Components	Quantity
1	DC Motor	4
2	Servo motor	4
3	Raspberry Pi board	1
4	Arduino board	1
5	Motor driver	2
6	Ultrasonic sensor	4
7	Gopro Hero 3 HD camera	1
8	Wheel	4
9	Encoder	4
10	Dry battery	2
11.	Wifi Transmitter	1

4.7.2.1 Main Components justification

- Ultrasonic sensor

  4 units of ultrasonic sensors are used as motion detected sensor for the UGV. These sensors the author get from market and one of the effective sensors. The position of sensors will put on four side of UGV so the sensor can detect obstacle from 4 view.

Figure 29: Ultrasonic sensor

The specifications of the sensor are as follows:

Technical Info.	**Parameters**
Part number:	WPDS-140x
Wireless radio frequency:	2.4GHz
Communicate range:	100m
Wireless protocol:	ROSIM/Zigbee
Net capacity:	1 router/data collector per 20 sensors
Detection technology:	Magnetic and optic
Detection height:	0-80cm
Accuracy:	>99%
Reaction time:	3-5s
Power supply:	Battery
Battery life:	3year
Maintenance:	Device and battery all replaceable
Product size:	Diameter 143mm/Height 37mm
Load resistance:	20 tons for static
Protection:	IP68
Work condition:	All weather
Operation temperature:	-20 ~ 70℃
Storage temperature:	-20 ~ 70℃
Installation:	Surface mount
Application:	Indoor/Outdoor/Roadside parking

Figure 32: Specification of sensor

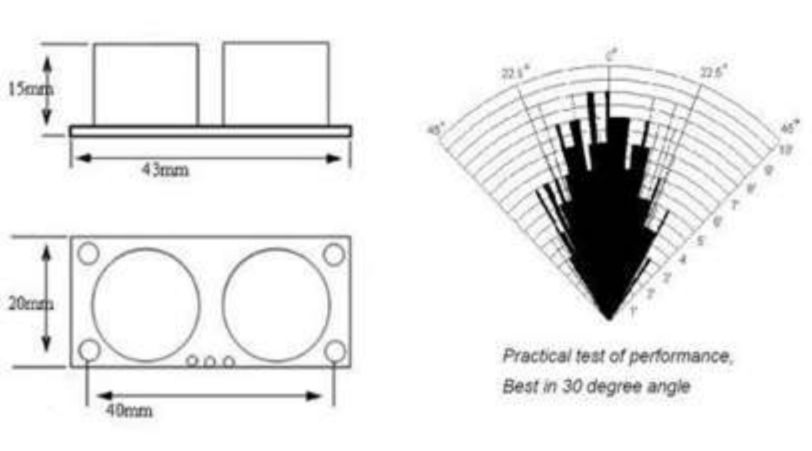


Figure 31: Ultrasonic sensor dimension

- **Camera**

This project will use Gopro Hero 3 HD camera for install in this UGV. The camera will attach at top side of UGV. The position of the camera is choose based on easily to assemble and best position to install it. The camera in HD so the view will become more clear and sharp to see plant area.

Figure 33: Go pro 3 HD

The specifications of the sensor are as follows:

VIDEO (NTSC/PAL)

Video Resolution	NTSC fps	PAL fps	STD Mode	Protune Mode	Field of View (FOV)	Screen Resolution/ Aspect Ratio
4K	15 fps	12.5 fps	NO	ONLY in Protune	Ultra Wide	3840x2160 16:9
4K Cin	12 fps	12 fps	NO	ONLY in Protune	Ultra Wide	4096x2160 17:9
2.7K	30 fps	25 fps	YES*	YES	Ultra Wide	2716x1524 16:9
2.7K Cin	24 fps	24 fps	YES*	YES	Ultra Wide	2716x1440 17:9
1080p	60, 48, 30, 24 fps	50, 48, 25, 24 fps	YES	YES	Ultra Wide, Medium, Narrow	1920x1080 16:9
1440p	48, 30, 24 fps	48, 25, 24 fps	YES	YES	Ultra Wide	1920x1440 4:3
960p	100, 48 fps	100, 48 fps	YES	YES	Ultra Wide	1280x960 4:3
720p	120, 60 fps	100, 50 fps	YES	YES	Ultra Wide, Narrow*	1280x720 16:9
WVGA	240 fps	240 fps	YES	NO	Ultra Wide	848x480 16:9

Note: *May require a firmware update on camera

- Video format: H.264 codec, .mp4 file format
- White Balance: auto and manual

PHOTO MODES

- 12, 7, 5MP resolutions
- Burst: 30 photos per second
- Continuous Photo: 3 photos per second, 5 photos per second, 10 photos per second
- Time-lapse: 0.5, 1, 2, 5, 10, 30, 60 second intervals
- Simultaneous Photo + Video:
  - 12MP + 1440p24 fps
  - 8MP + 1080p30 fps 8
  - 8MP + 720p60 fps

BATTERY & CHARGING

- 1050mAh rechargeable lithium-ion
- Charge via USB

AUDIO

- Mono, 48kHz, AAC compression w/ AGC
- Supports optional 3.5mm stereo mic adapter **

STORAGE

- Memory:
  - MicroSD class 10 or higher required
  - Up to 64GB capacity supported
- Record times will vary with resolutions and frame rates

INCLUDED CABLES

- USB charging cable

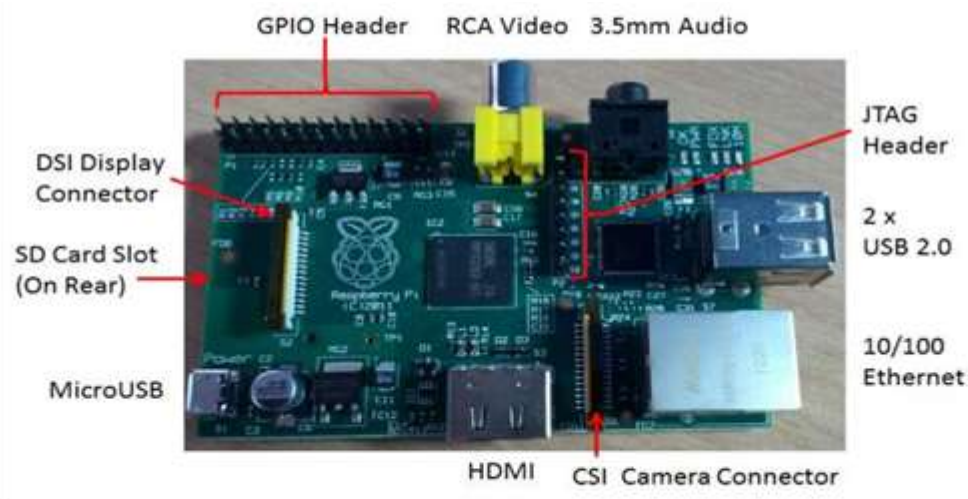
OPERATING SYSTEM

- Microsoft Windows® Vista, 7 and later

*Compared to HD HERO2 and HERO3 White and Silver Edition Cameras
**Optional accessories sold separately.

- Raspberry Pi

A microcontroller board that operates on Linux operating system where it is used to read the images from Gopro Hero 3 and perform image processing to identify the required colored object and coordinates for the objects and obstacles then sends the control signals input to the Arduino.



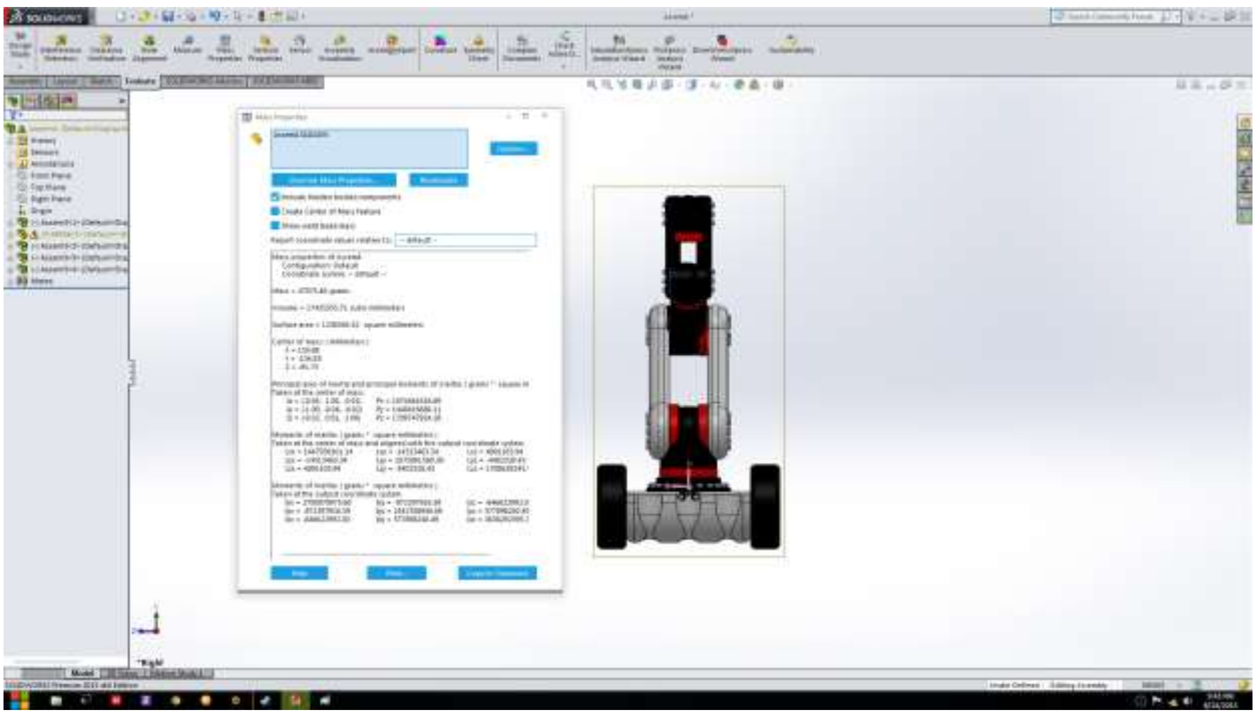
Specification	Raspberry PI Model B
Chip	Broadcom BCM2835 SoC full HD multimedia applications processor
CPU	700 MHz Low Power ARM1176JZ-F Applications Processor
GPU	Dual Core VideoCore IV® Multimedia Co-Processor
Memory	512MB SDRAM
Ethernet	onboard 10/100 Ethernet RJ45 jack
USB 2.0	Dual USB Connector
Onboard Storage	SD, MMC, SDIO card slot
Operating System	Linux
Video Output	HDMI (rev 1.3 & 1.4) Composite RCA (PAL and NTSC)
Audio Output	3.5mm jack, HDMI
Dimensions	8.6cm x 5.4cm x 1.7cm

- Motor (Vexta brushless DC motor)

  The author use Vexta brushless DC motor because this motor provide higher torque for rotational motion. When the author calculate estimate require torque, the motor must be higher than 39.65 N.m.

  Below is the calculation of estimated torque requirement:

$$\text{Estimated Torque Requirement} = \frac{\text{Mass} \times \text{Wheel Radius}}{4}$$



Mass = 47kg

Whell diameter = 172mm

Whell radius = 86mm

$$\text{Torque require} = \frac{47(9.81)(0.086)}{4}$$

$$= 39.65 \text{ N.m}$$

Thus the torque for motor must be higher than 39.65 N.m

Figure 34: Vexta brushless DC motor

Future Planning:

The next step will continuous by master student from electrical department to do the control of this UGV. The detail design for all mechanism must be finish before fabricate. After that, in the future of this project this UGV will be fabricating. Besides fabricating the chassis, a controllable environment for oil and gas plant is importance. The author needs to make sure minimal damage is done on the UGV when run the project. More importantly, the author needs to ensure no individual will be harmed during the autonomous motion testing including the author itself.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Much is needed to be done as UGV technology has not yet been popularized in Malaysia. More research needs to be done on the suitable UGV monitoring method for a large oil and gas platform. Since the author is also new to this UGV field, much effort is required to determine the most suitable UGV to use in monitoring oil and gas plant.

As for the conclusion, the UGV was successfully design using CAD software and mathematically analyze to be able monitoring oil and gas plant. The author also manage to produce conceptual design based on the criteria needed in the design process. The author also able to define the problem statement and achieved the objective.

It is recommended that the author must design simple mechanism and system for the UGV, it will easy for the user to control the UGV. The user also don't need higher skill for control the UGV. The author have to do many analysis before arrive fabrication stage, so it will be no mistake and problem when come to fabrication. The author need to understand in depth regarding the project that will conducted and able identify the best option for monitoring oil and gas plant. The author must understand how mechanical design, chassis design and locomotion system effect outcome result of the project.

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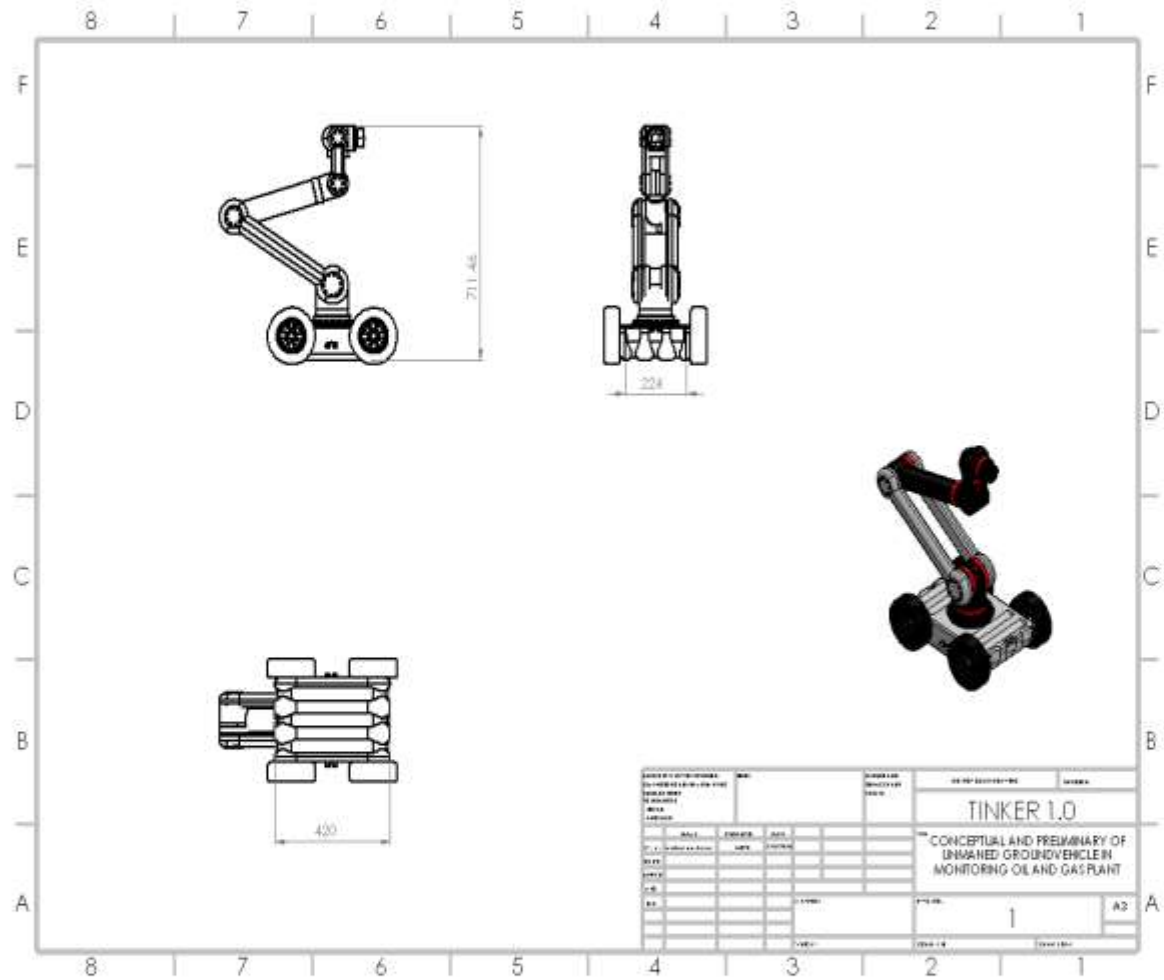
Appendices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CONCEPTUAL AND PRELIMINARY OF UNMANED GROUNDVEHICLE IN MONITORING OIL AND GAS PLANT
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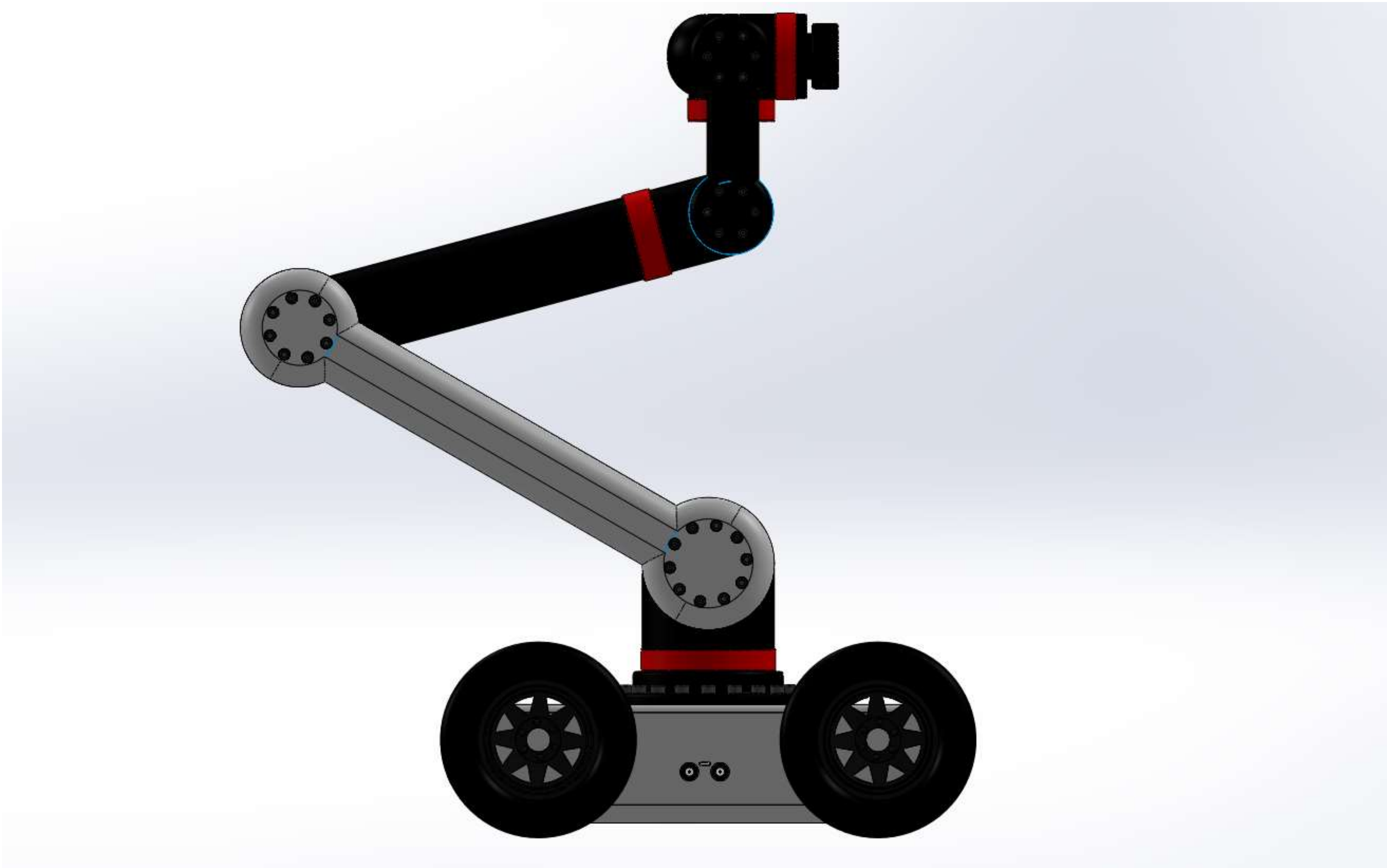

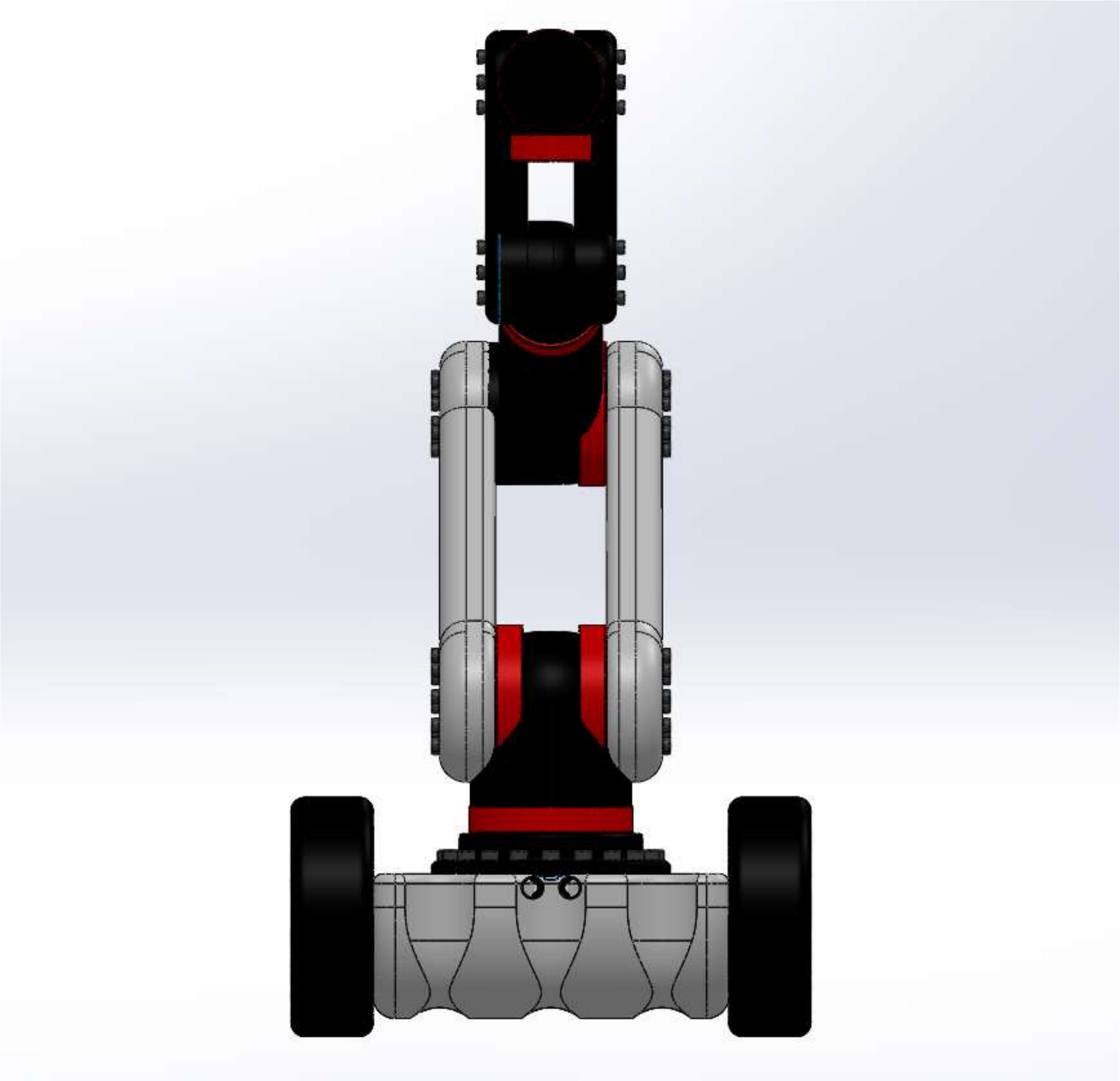

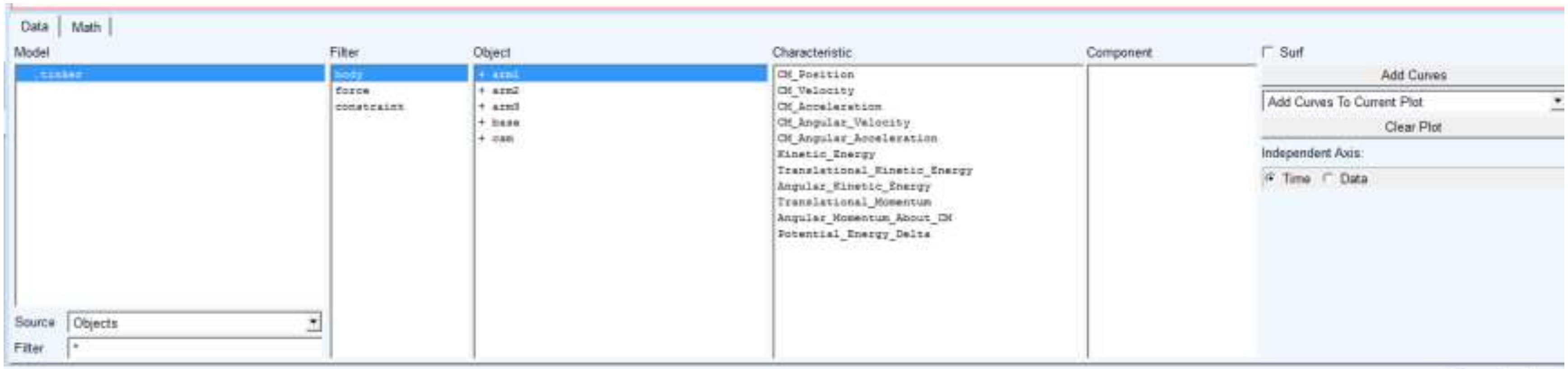
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CM_Angular_Acceleration
Kinetic_Energy
Translational_Kinetic_Energy
Angular_Kinetic_Energy
Translational_Momentum
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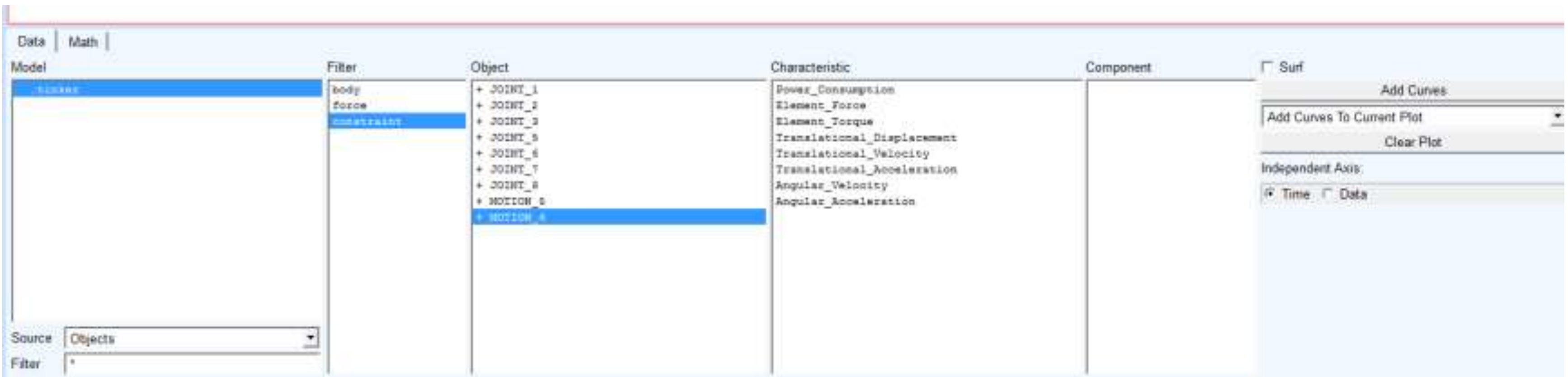
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+ MOTION_5
Power_Consumption
Element_Force
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Translational_Displacement
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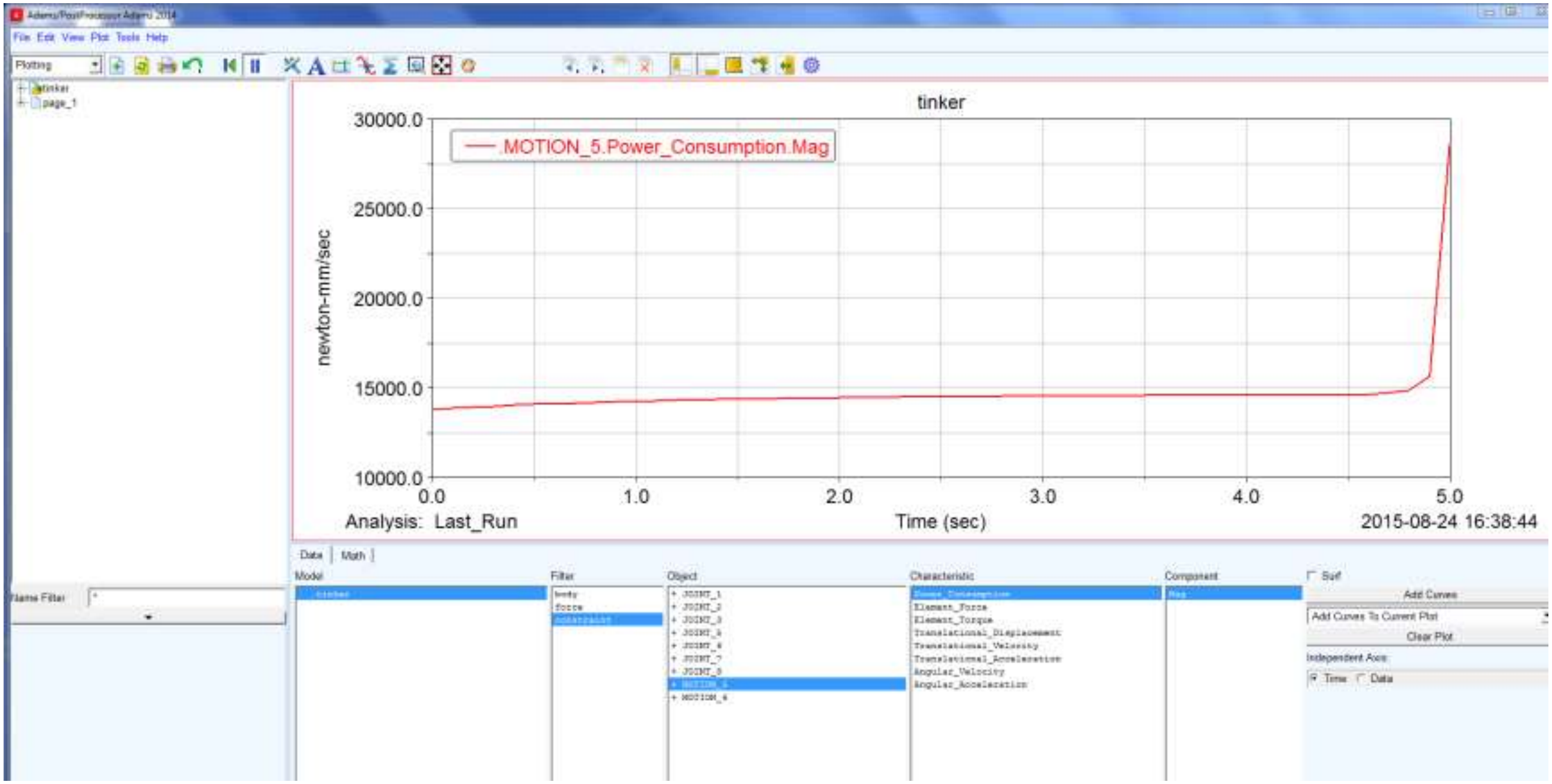
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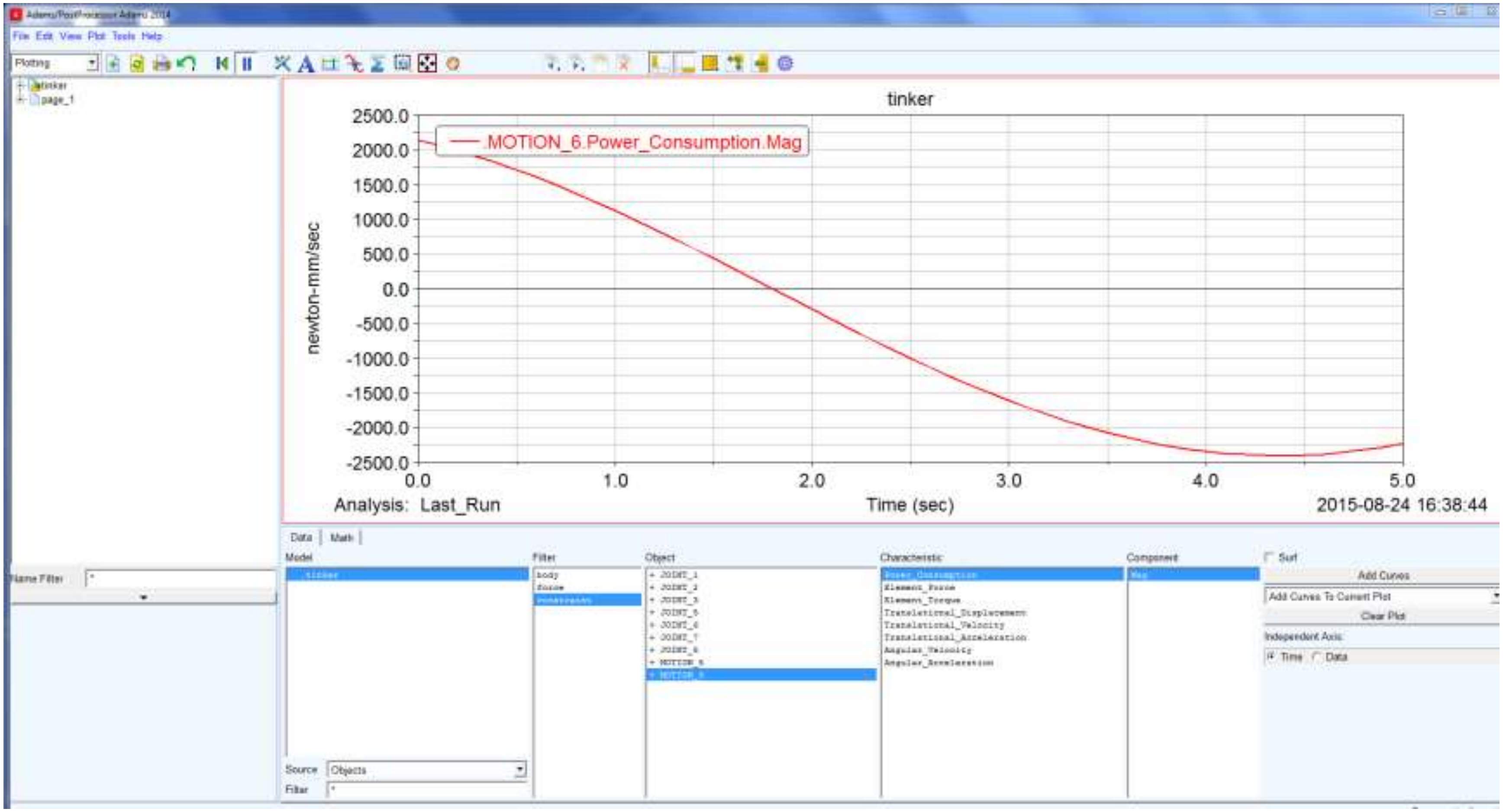
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Analysis: Last_Run
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