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ROVER MOBILITY PERFORMANCE EVALUATION TOOL (*RMPET*): A SYSTEMATIC TOOL FOR ROVER CHASSIS EVALUATION VIA APPLICATION OF BEKKER THEORY

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ABSTRACT

With the current focus set on detailed investigation of the scientific hot spots on the surface of Mars, it has been noticed that the current range of autonomous robotic explorers are facing a grave problem in the form of highly hostile terrain. It has been the inefficiency of the mobility system that led the past Mars mission rovers Sojourner (Mars Pathfinder 1997) and MERs (2003-4) to traverse distance much less than their anticipated daily travel. This calls for a systematic investigation into the mobility/suspension systems for the Mars robotic rovers. In the view of investigating this problem, we have developed a software tool for evaluating the performance of a variety of rover chassis/mobility systems currently under investigation all over the world. The primary focus is on developing a tool called RCET (Rover Chassis Evaluation Tool), for ESA. The tool employs Bekker Theory into a solver engine to compute various mobility performance parameters, which in turn are governed by the choice of the vehicle geometry, nature of the mobility system and the type of terrain for navigation. Currently, there exists a choice of mobility systems available for the investigation within the scope of the tool namely, wheeled system, tracked system and legged system. Major emphasis is on incorporating the 3D design and simulation softwares in the shell of the solver engine, since different softwares are required for simulating wheeled, tracked and legged locomotion systems. This will allow an accurate performance analyses of the impact of different soils and surfaces, either terrestrial or extra-terrestrial on the performance of wheeled, tracked or legged robot.

1. INTRODUCTION

Investigating a mobility system for planetary rovers is a very trivial pursuit and often requires some kind of a database that can automatically updated during the calculation of the performance parameters for the system under investigation. These calculations involve a large number of terrain and vehicle parameters that have to be determined in advance. However, having known these parameters, generating a correct and accurate performance matrix for a particular system is of prime importance. This performance matrix is then used to rank the mobility system in accordance to their performance on a particular terrain.

The current state-of-practice in robotic locomotion design draws on knowledge of precedent robotic and conventional vehicles, intuition and experience, but rarely involves analysis and quantitative rationalization. Especially when a new robotic design is pursued, empirical approaches may result in ill-conceived designs that require redesign or reworks to achieve desired functionality. Moreover using current practices it is difficult to predict how much the paper designs will grow in physical and control complexity during development. Concurrent prototyping and testing is insufficient to address this challenge because a detailed performance evaluation is possible only after system-level tests have been carried out. The lack of quantitative methods to aid robotic locomotion designs makes it difficult to identify the engineering traits of significance to a specific design. As yet, there exists no theory, methodology or metrics for the systematic design of wheeled robotic configuration. Despite its significance, the process of configuration and design of locomotion for mobile robot performance has not been sufficiently addressed. As a result, robotic locomotion is a product of ad hoc speculation lacking rationalization and method, and ultimately performance [4].

An attempt was made during this study to develop a simple yet efficient calculation tool that can evaluate the performance of a particular system from the provided data. The tool has the most common and user-friendly Windows® interface as the front end and encompasses the *Bekker Theory* to calculate the performance parameters. The tool provides a choice of terrain to be used during the evaluation process depending upon the mission scenario. The presently available modules include the Martian Terrain (using the Martian Soil Simulant – MSS data), the Lunar Terrain (using the Lunar Soil Simulant – LSS data), the Terrestrial Surface (Earth's Hard Soil data) and the choice of creating a User Defined Surface.

2. SOFTWARE ARCHITECTURE

The Rover Performance Evaluation Tool (RPET) consists of two main modules namely:

(a) Rover Mobility Performance Evaluation Tool (RMPET)
(b) Mobility Synthesis (MobSyn)

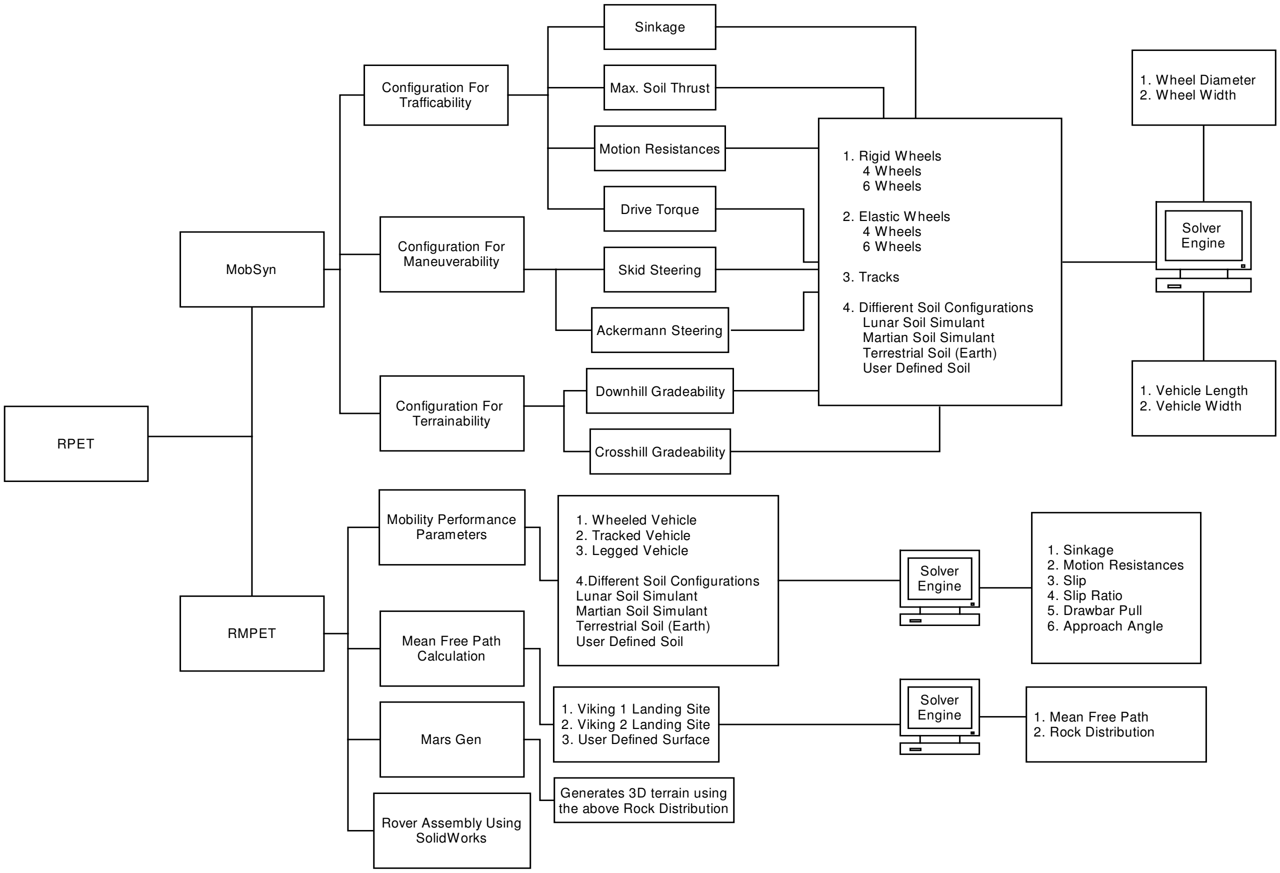


Fig. 1. RPET - Software Architecture/Data Flow

2.1 Rover Mobility Performance Evaluation Tool (*RMPET*)

The RMPET computes the mobility performance parameters such as drawbar pull, motion resistances generated, soil thrust, slippage and sinkage for a particular mobility system selected by the user for evaluation on a particular terrain. Currently there are a number of mobility systems available for investigation such as:

(a) Wheeled Mobility System
(b) Tracked Mobility System
(c) Legged Mobility System

Each of the above mobility systems can be evaluated for performance on a wide range of available terrain such as:

(a) Martian Terrain (using DLR soil simulant MSS-B)
(b) Lunar Terrain (using the Lunar soil simulant)
(c) Terrestrial Soil (Earth)
(d) User Defined Soil (customised soil with desired properties)

There are four sub-modules available in RMPET each having its own distinguished task:

(a) Compute Mobility Performance Parameters
(b) Compute Mean Free Path
(c) Generate 3D Martian Terrain using SolidWorks® (MarsGen)
(d) Generate & Simulate 3D Rover Assemblies using SolidWorks, COSMOS® (RoverGen)

2.2 Mobility Synthesis (*MobSyn*)

Mobility Synthesis (MobSyn) is similar to Locomotion Synthesis (LocSyn) developed by D. Apostolopoulos at Carnegie Melon University [4]. MobSyn computes the configuration equations for the chosen wheel/track type and outputs the ideal wheel/track width and wheel diameter for the desired performance parameters. The inputs to the system include desired motion resistances, power/torque availability, nature of terrain and other desired performance criteria. There are three sub-modules available in MobSyn each associated with determining the wheel diameter, wheel width or vehicle ground projected footprint depending upon the chosen constraint criteria.

(a) Configuration for Trafficability
- Using Sinkage/Wheel loading area
- Using Motion Resistances
- Using Soil Thrust/Max. Tractive force generated
- Using Available drive torque

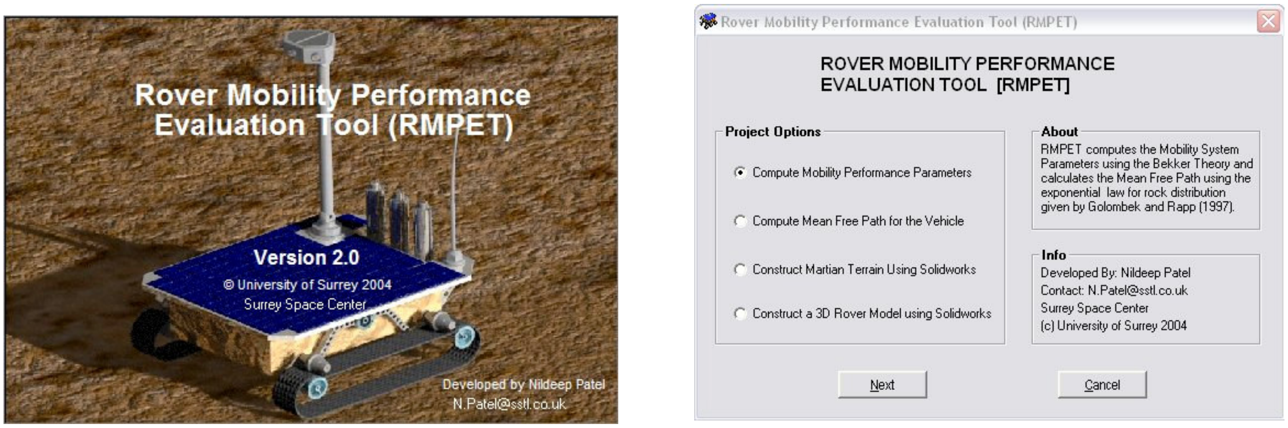
(b) Configuration for Maneuverability
  - For Skid Steering
  - For Ackermann Steering

(c) Configuration for Terrainability

Sub-module (a) computes the configuration equations and outputs the ideal wheel diameter and wheel width whereas, the sub-modules (b) and (c) output the ideal ground projected footprint i.e. vehicle length and width to safely and successfully manoeuvre the vehicle whilst operating in the desired operating environment. This module is not covered in greater detail within the scope of this document.

3. ROVER MOBILITY PERFORMANCE EVALUATION TOOL (RMPET)

The primary goal for a planetary rover is the capability to navigate in an unknown, hostile terrain, recognize and negotiate obstacles, deploy scientific instruments and acquire samples from scientific targets. These goals must be attained within minimum mass and minimum volume within tight mobility, power, thermal and communications constraints. The mobility system is characterized by a number of parameters - wheel-base, footprint, drive wheel number, drive wheel torque, wheel design (dimensions, stiffness, grouser placement, construction material), power requirements, suspension and stability. Performance is generally quantified in terms of vehicle Drawbar Pull (DP – defined as the difference between soil thrust and motion resistance) and power requirements. Resistance to motion comprises a number of components – rolling resistance, compaction resistance, bulldozing resistance, resistance due to wheel flexure, and resistance due to slippage. Locomotion requires traction to provide forward thrust on the ground. The mobility system must provide robust mobility with maximum payload capacity for scientific instruments.



ROVER MOBILITY PERFORMANCE
EVALUATION TOOL [RMPET]

● Compute Mobility Performance Parameters
○ Compute Mean Free Path for the Vehicle
○ Construct Martian Terrain Using Solidworks
○ Construct a 3D Rover Model using Solidworks

RMPET computes the Mobility System Parameters using the Bekker Theory and calculates the Mean Free Path using the exponential law for rock distribution given by Golombek and Rapp (1997).

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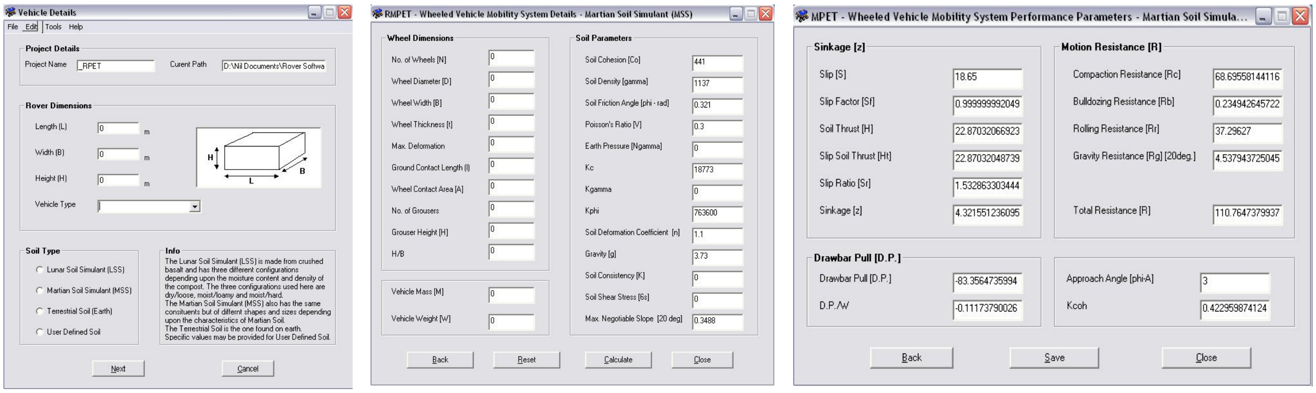
Fig. 2. RMPET – Start Up Screen and Task Selection Screen

This analysis tool is of invaluable importance in determining the direct performance effects for comparing mobility performance with variations in the mobility system parameters without the complexities of generating 3D models or scaled real vehicles. All values are quoted in SI units – all tabulated results assume that all other parameters not represented in the tables are constant.



Vehicle Details

Project Details
Project Name _RPET
Curent Path D:\Nil Documents\Rover Softwa

Rover Dimensions
Length (L) 0 m
Width (B) 0 m
Height (H) 0 m
Vehicle Type

Soil Type
○ Lunar Soil Simulant (LSS)
○ Martian Soil Simulant (MSS)
○ Terrestrial Soil (Earth)
○ User Defined Soil

Info
The Lunar Soil Simulant (LSS) is made from crushed basalt and has three different configurations depending upon the moisture content and density of the compost. The three configurations used here are dry/loose, moist/loamy and moist/hard.
The Martian Soil Simulant (MSS) also has the same consituents but of differnt shapes and sizes depending upon the characteristics of Martian Soil.
The Terrestrial Soil is the one found on earth.
Specific values may be provided for User Defined Soil.

RMPET - Wheeled Vehicle Mobility System Details - Martian Soil Simulant (MSS)

Wheel Dimensions
No. of Wheels [N] 0
Wheel Diameter [D] 0
Wheel Width [B] 0
Wheel Thickness [t] 0
Max. Deformation 0
Ground Contact Length (l) 0
Wheel Contact Area [A] 0
No. of Grousers 0
Grouser Height [H] 0
H/B 0

Vehicle Mass [M] 0
Vehicle Weight [W] 0

Soil Parameters
Soil Cohesion [Co] 441
Soil Density [gamma] 1137
Soil Friction Angle [phi - rad] 0.321
Poisson's Ratio [V] 0.3
Earth Pressure [Ngamma] 0
Kc 18773
Kgamma 0
Kphi 763600
Soil Deformation Coefficient [n] 1.1
Gravity [g] 3.73
Soil Consistency [K] 0
Soil Shear Stress [6s] 0
Max. Negotiable Slope [20 deg] 0.3488

MPET - Wheeled Vehicle Mobility System Performance Parameters - Martian Soil Simula...

Sinkage [z]
Slip [S] 18.65
Slip Factor [Sf] 0.999999992049
Soil Thrust [H] 22.87032066923
Slip Soil Thrust [Ht] 22.87032048739
Slip Ratio [Sr] 1.532863303444
Sinkage [z] 4.321551236095

Motion Resistance [R]
Compaction Resistance [Rc] 68.69558144116
Bulldozing Resistance [Rb] 0.234942645722
Rolling Resistance [Rr] 37.29627
Gravity Resistance [Rg] [20deg.] 4.537943725045
Total Resistance [R] 110.7647379937

Drawbar Pull [D.P.]
Drawbar Pull [D.P.] -83.3564735994
D.P./W -0.11173790026

Approach Angle [phi-A] 3
Kcoh 0.422959874124

Fig. 3. RMPET - Data Entry and Results Screen

3.1 Mobility Performance Parameters

***Soil Shear Strength*:** Soil shear strength is characterised by soil cohesion C_0 and internal friction angle ϕ quantified by the Mohr-Coulomb law such that the shear stress parallel to the plane of failure will be given as:

$$\tau = C_0 + \sigma \tan\phi \tag{1}$$

Soil Thrust and Slip: The soil thrust provides the tractive effort. When the forces of the wheels, tracks, or legs push on the soil, the resulting force from the soil is called the soil thrust. However, soil thrust is modified by the slip of the wheel, track, or leg against the soil and is basically the difference between the vehicle's translational velocity and wheel/track rotational velocities (or leg movement velocity). At low velocity we can compute the slip [4,6] as:

$$H = H_0\left(1 - e^{-sl/\kappa}\right) \tag{2}$$

For n-wheeled and n-legged vehicles, soil thrust is given by:

$$H_0 = n\left(blC_0 + W\tan\phi\right) \tag{3}$$

For tracked vehicles, the soil thrust is increased due to the greatly increased ground contact area. For double tracks, soil thrust is given by:

$$H_0 = 2(blC_0 + W\tan\phi) \tag{4}$$

Grousers: The Mean Maximum Pressure (MMP) drops when the number of wheels on a rover is increased. MMP is a heuristic performance parameter that quantifies the ground pressure distribution on the soil by the vehicle [7]. The addition of grousers increase the soil thrust because of the added traction on each wheel/track. Sojourner wheels had 16 x 0.127 mm thick cleats per wheel that protruded 1 cm. For grousered, n-wheeled vehicle, the soil thrust is given by:

$$H_0 = \tfrac{d}{2} n\left(T_0 + W\tan\phi\right) \tag{5}$$

The addition of grousers improves the Drawbar Pull with a minimal impact on mass overheads. Their most important use is in improving performance in unfavourable soils. Grousers on tracks dramatically increase the soil thrust, more than doubling it from a smooth track. For a double tracked vehicle with N_g grousers (with height 'h') per track:

$$H_0 = 2\left(N_g blC_0\left(1 + \tfrac{2h}{b}\right) + W\tan\phi\left(\tfrac{h}{b}\cot^{-1}\tfrac{h}{b}\right)\right) \tag{6}$$

Motion Resistances: Acting in opposition to the soil thrust is the resistances to motion. Such a resistance is dominated by soil compaction and bulldozing of the soil – it can absorb between 5-35% of gross engine power depending on the soil and vehicle speed.

Soil Compaction due to Sinkage: Sinkage (z) and compaction resistance decrease with increasing footprint size, as a larger footprint would resist sinkage. The adoption of tracks significantly reduces compaction resistance due to sinkage because of the very large footprint of each track. The general sinkage equation is as follows:

$$z = \left(\frac{W}{A(k/b)}\right)^{1/n'} = \left(\frac{p}{k/b}\right)^{1/n'} \tag{7}$$

Track sinkage for dual tracks is given by:

$$z = \frac{1}{2}\left(\frac{W}{kl}\right)^{1/n'} \tag{8}$$

Wheel sinkage for an n-wheeled vehicle is given by:

$$z = \frac{1}{n}\left(\frac{3W}{(3-n')k\sqrt{d}}\right)^{2/(2n'+1)} \tag{9}$$

The dominant source of resistance for wheeled and legged vehicles is compaction resistance (R_c), but this is minimal for tracked vehicles given their very high soil thrusts. The most effective means to reduce compaction resistance is to increase the footprint size. Soil compaction resistance for wheeled and legged vehicles is determined through the following:

$$R_c = n\left(\frac{k}{n'+1}\right)z^{n'+1} \tag{10}$$

Bulldozing Resistance: Bulldozing occurs for the front wheels only as the rearward wheels typically follow in the tracks made by the forward wheels. Bulldozing resistance (R_b) becomes a problem when wheel sinkage exceeds around 0.06 times the wheel diameter. Narrow wheels suffer less from bulldozing as significant portions of the soil are pushed to the sides of the wheel. Bulldozing for wheeled vehicles involves all the terms but for tracked vehicles, only the first term is relevant (as the other terms determine the impact of the following wheels in the path created by the first, a situation not encountered by a tracked vehicle).

$$R_b = \frac{B\sin(\alpha+\varphi)}{2\sin\alpha\cos\varphi}(2zC_0k_c + \gamma z^2 k_\gamma) + \left[\frac{\pi\gamma l^2(90-\varphi)}{540} + \frac{\pi C_0 l^2}{180} + C_o l^2 \tan(45 + \varphi/2)\right] \tag{11}$$

Bulldozing resistance offers lower resistance to motion compared with compaction resistance for both wheeled and tracked vehicles. Bulldozing resistance is affected by changes in both wheel/track diameter and wheel/track width – narrow wheels reduces bulldozing resistance significantly while a decrease in wheel width increases the bulldozing resistance to a much lesser degree.

Gravitational Resistance: The rover experiences gravitational resistance (R_g) while negotiating the slopes. The maximum slopes that must be negotiable on Mars are the inner slopes of recent craters that may reach up to 30-40^o but wheeled vehicles are generally limited to gradients < 25^o. We have adopted a maximum value of 20^o.

$$R_g = W\sin\theta \tag{12}$$

Drawbar Pull: Drawbar pull (DP) is the difference between soil thrust (H) and motion resistance (R) and it defines trafficability. This is the most important value in the development of a vehicle, as it defines the ability (or inability) of a vehicle to traverse over a specified terrain. In order for a vehicle to negotiate terrain, it must have a positive Drawbar Pull.

$$DP = H - R = H - \left(R_c + R_b + R_g + R_{other}\right) \tag{13}$$

3.2 Mean Free Path

Mean Free Path is defined as expected distance that the vehicle can traverse in a straight line before it encounters a non-traversable hazard. Martian surface is very rocky with rocks occupying up to 16% of areal coverage for rocks over 3 cm in diameter. However, the problem of reliance on such statistical models was exemplified by Sojourner's difficulties in traversing the rock garden which had an areal coverage of 24.6% of rocks over 3 cm diameter. A model of the Martian rock distribution is used to determine the mean free path (MFP) which is a function of both the rock distribution and the vehicle geometry. When expressed in units of vehicle scale (e.g.: vehicle turning circle diameter), a large Mean Free Path (e.g.>>1) means the terrain is sparsely populated with rocks. Whereas, when the mean free path is small (e.g. <<<1), then the terrain is effectively non-traversable for the vehicle [8,9,10]. If the mean free path is moderate (e.g. ~ 1) then successful navigation will require elaborate sensing of terrain and a sophisticated navigation algorithm. If the Mean Free Path were monotonically increasing with scale then it would be desirable to build large rovers. If it were monotonically decreasing it would be desirable to build small rovers. If it is non-monotonic then there might be an optimum size or alternatively, an undesirable range of scales. It is desirable to design rovers which have as large an intrinsic mean free path as possible for the expected terrain within mass and cost constraints.

Assume that the vehicle is resting on a hazard-free surface and moves forward by a distance "x". We wish to compute "x" such that the product of the expected number of non-traversable hazards in the swept area of the vehicle out to "x" is unity. At this stage, i.e. "x", the vehicle is said to have reached its mean free path. Hazards are distributed randomly, uniformly and independently, so the distribution of hazard in any area of terrain is a Poisson's Process, with expected value proportional to the area. Lets consider a vehicle with length (L) and width (W) preparing to move a distance (x).

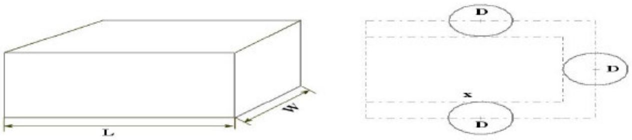


Fig. 4. Mean Free Path Schematic

The number of rocks for Viking Landers sites 1 and 2 is given by Golombek & Rapp's (1997) exponential law:

$$N(D) = Le^{-sD} \tag{14}$$

L = cumulative number of rocks of all sizes/m^2

L_{VL1}=5.61, L_{VL2}=6.84

s_{VL1}=12.05, s_{VL2}=8.30

The frequency of rock coverage for Viking Lander sites 1 and 2 is given by a similar relation,

$$F(D) = Ke^{-qD} \tag{15}$$

K = cumulative fractional area covered by rocks of all sizes

K_{VL1}=0.069, K_{VL2}=0.176

q_{VL1}=4.08, q_{VL2}=2.73

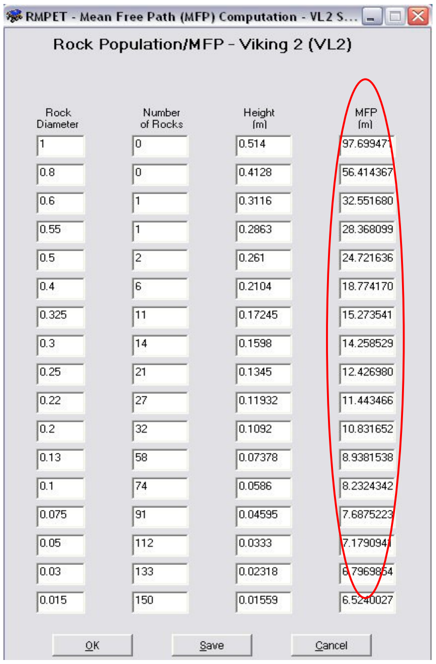
This model represents the most accurate, predictive model available with a 96% correlation with actual Mars data of rock size distribution [5]. This exponential law computes the frequency distribution of rocks according to diameter for both VL1 and VL2 sites. The rock frequency distribution may be utilised to compute the MFP - rocks of diameter D. Rocks are assumed to be distributed randomly according to a Poisson distribution. MFP may be defined as the product of the areal coverage of the rover's trajectory of (x+D/2), and the areal density of rocks of diameter D [Wilcox et al. 1997]. For rocks larger than D_0:

$$\int_{D_0}^{\infty} (x + D/2)(r + D)\rho(D).dD = 1 \tag{16}$$

where,

$\rho(D) = Ke^{-qD}$ =probability density of rock centres/m^2 for rocks between D and D+δD.

MFP is determined by the rock vertical height rather than rock diameter due to embedding in the soil. The average rock height may be determined by [Golombek & Rapp 1997] – this will give a proper value of limiting rock diameter D_0:



Rock Population/MFP - Viking 2 (VL2)

Rock Diameter	Number of Rocks	Height [m]	MFP [m]
1	0	0.514	97.699471
0.8	0	0.4128	56.414367
0.6	1	0.3116	32.551680
0.55	1	0.2863	28.368099
0.5	2	0.261	24.721636
0.4	6	0.2104	18.774170
0.325	11	0.17245	15.273541
0.3	14	0.1598	14.258529
0.25	21	0.1345	12.426980
0.22	27	0.11932	11.443466
0.2	32	0.1092	10.831652
0.13	58	0.07378	8.9381538
0.1	74	0.0586	8.2324342
0.075	91	0.04595	7.6875223
0.05	112	0.0333	7.1790941
0.03	133	0.02318	6.7969854
0.015	150	0.01559	6.5240027

Fig. 5. Mean Free Path Results Screen

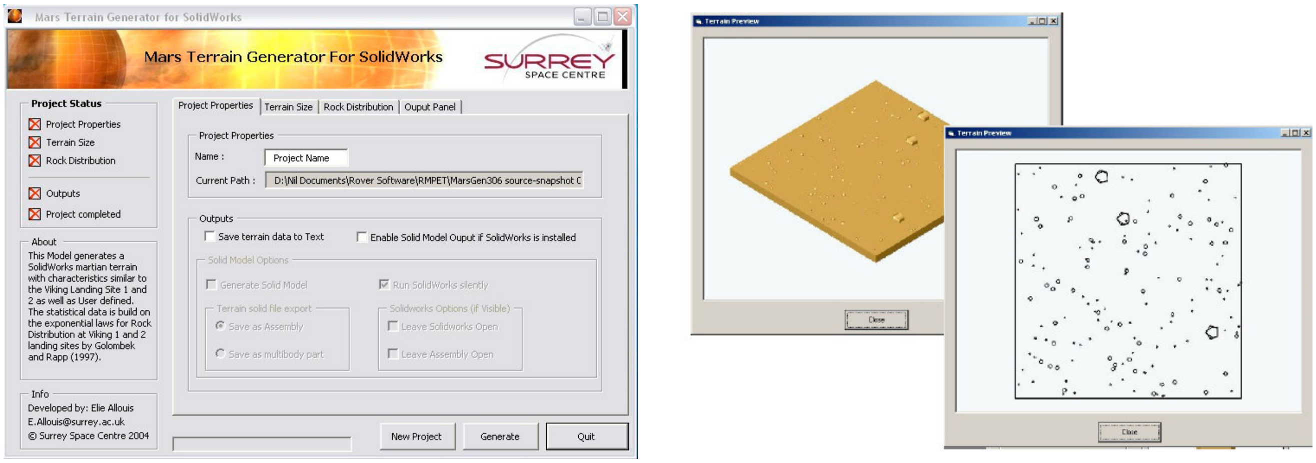
H=0.365D+0.008 assuming that the rock height for VL1 is 3/8 the rock diameter
H=0.506D+0.008 assuming that the rock height for VL2 is ½ the rock diameter

The largest diagonal of the vehicle is r=$\sqrt{l^2+w^2}$ where l = vehicle length, w = vehicle width assuming that the vehicle can turn in place which may be related to the limiting rock size for negotiation. This is assumed to be the case with skid steering capability or with appropriate double Ackermann steering. The solution for MFP is given by:

$$x=\frac{1-(r/2)\int_{D_0}^{\infty}D\rho(D)dD-(1/2)\int_{D_0}^{\infty}D^2\rho(D)dD}{r\int_{D_0}^{\infty}\rho(d)dD+\int_{d_0}^{\infty}D\rho(D)dD} \tag{17}$$

3.3 Mars Terrain Generator (MarsGen)

To investigate rover mobility, navigation and obstacle avoidance systems, two-dimensional representations of a terrain may provide little insight of the relation of the vehicle with respect to its environment. An enhanced view of the resultant terrain is inevitable to run the simulations for establishing the suitability of a particular rover mobility system to operate in the desired environment. This resulted in a study investigating the development of a software tool to generate representative models of the Martian surface using the methodology explained in section 3.2.



Project Status

☒ Project Properties
☒ Terrain Size
☒ Rock Distribution
☒ Outputs
☒ Project completed

About

This Model generates a SolidWorks martian terrain with characteristics similar to the Viking Landing Site 1 and 2 as well as User defined. The statistical data is build on the exponential laws for Rock Distribution at Viking 1 and 2 landing sites by Golombek and Rapp (1997).

Info

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Project Properties

Name : Project Name
Current Path : D:\Nil Documents\Rover Software\RMPET\MarsGen306 source-snapshot C

Outputs

☐ Save terrain data to Text
☐ Enable Solid Model Ouput if SolidWorks is installed

Solid Model Options

☐ Generate Solid Model
☑ Run SolidWorks silently

Terrain solid file export

● Save as Assembly
○ Save as multibody part

Solidworks Options (if Visible)

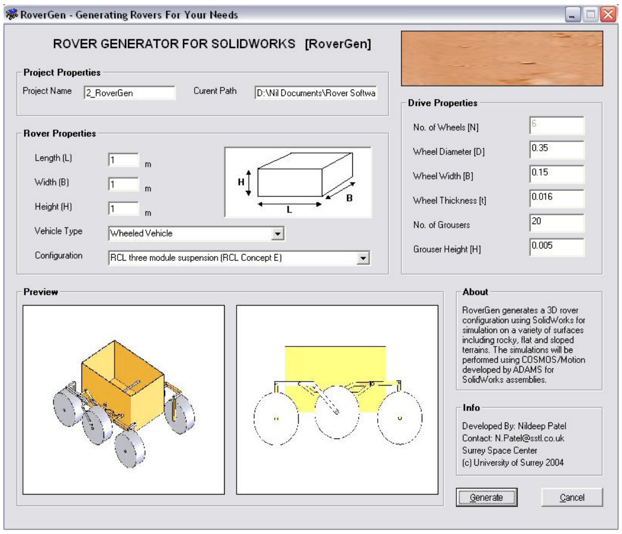
☐ Leave Solidworks Open
☐ Leave Assembly Open

Fig. 6. MarsGen Data Input Screen and Terrain Preview Screen

3.4 Rover Generator and 3D Simulator (RoverGen)

RoverGen is a 3D simulator for SolidWorks designs developed as a part of the RMPET tool. The simulator uses COSMOS/Motion developed by ADAMS®. There exists capability of controlling the design and simulation software running in the background silently without the hassle of going through the software manuals or expensive training programs to get acquainted with using the complex simulators. All the desired parameters are inputted in the front-end interface, which are directly transmitted to the simulator for conducting a simulation run using those user-defined parameters. There exists a choice of models to be simulated using the tool provided by selecting from the drop-down box to facilitate comparison between several designs to generate a performance matrix. This performance matrix gives an indication of the capability of an individual concept to perform on a predefined terrain under a fixed set of operating environmental parameters. There exists a possibility of importing several different terrains for performing a simulation run. Currently there are three different types of terrains available:
(a) Flat Surface, (b) Sloped Surface (1^{o} onwards) and (c) User Defined Surface (Terrain Generated using MarsGen, Imported from other CAD software, etc.)

The post-processing module is currently under development to facilitate direct or indirect comparison between different designs simulated using RoverGen. Ideally, a post-processing module will allow the user to create the plots of the desired quantities for desired components within the model to analyze the performance of the system during the simulation run. There exits a possibility of creating individual plots for each quantity of each component with simulation time as the X-axis or another quantity of the same component as X-axis. Alternatively, the data may be exported in form of a text file or a spreadsheet. In order to load a model and simulate it, it is a required to have the CAD models stored in the "Models Library".



Project Name: 2_RoverGen
Curent Path: D:\Nil Documents\Rover Softwa
Length (L): 1 m
Width (B): 1 m
Height (H): 1 m
Vehicle Type: Wheeled Vehicle
Configuration: RCL three module suspension (RCL Concept E)
No. of Wheels [N]: 6
Wheel Diameter [D]: 0.35
Wheel Width [B]: 0.15
Wheel Thickness [t]: 0.016
No. of Grousers: 20
Grouser Height [H]: 0.005

RoverGen generates a 3D rover configuration using SolidWorks for simulation on a variety of surfaces including rocky, flat and sloped terrains. The simulations will be performed using COSMOS/Motion developed by ADAMS for SolidWorks assemblies.

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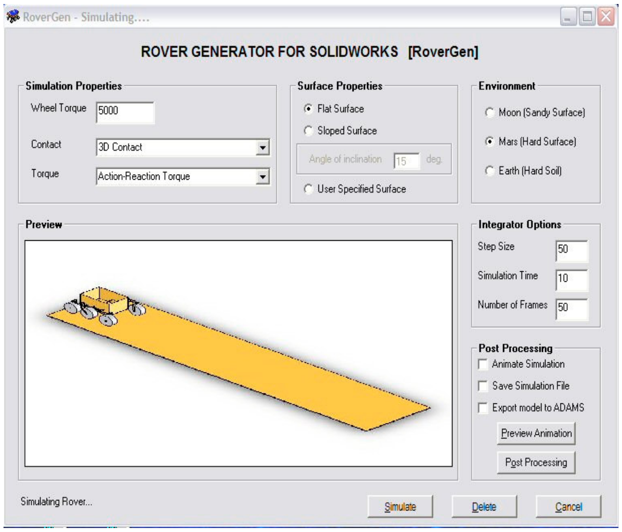
Fig.7. RoverGen – Load Model Screen



Wheel Torque: 5000
Contact: 3D Contact
Torque: Action-Reaction Torque

● Flat Surface
○ Sloped Surface
Angle of inclination 15 deg.
○ User Specified Surface

○ Moon (Sandy Surface)
● Mars (Hard Surface)
○ Earth (Hard Soil)

Step Size: 50
Simulation Time: 10
Number of Frames: 50

☐ Animate Simulation
☐ Save Simulation File
☐ Export model to ADAMS

Simulating Rover...

Fig. 7. RoverGen – 3D Simulator Set-Up Screen

4. CONCLUSION

The RPET provides the user with a very simple, user friendly and highly accurate tool to perform preliminary analysis for the various configurations of the desired planetary rover. The performances can be determined from the results computed by the RMPET and can be utilized further to perform advanced analysis either using the theoretical equations or by incorporating them in the form of 3D simulation engine. Either way, the RMPET reduces the time consumption in computing these basic and most fundamental parameters as far as mobility systems are concerned.

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