Executive Summary (ES)

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2-6	Shortened version and typo corrections

Table of Contents

1 Introduction

1.1 Purpose and scope

The purpose of this document is to prove a brief and concise final report of the DPEM project and an executive summary.

The main goals of the DPEM project was [RD1] "*to set the foundations for the development of a comprehensive suite of near surface dusty plasma environment models applicable in particular (but not only) to airless bodies of interest for future exploration missions such as asteroids, the Moon, Phobos and Deimos, etc … These models shall allow the definition of charged dust environment specifications to assess the effects of dusty plasmas on near surface or surface exploration units (spacecraft, payload, lander, astronaut) in a surface-spacecraft-dust environment system.*".

These goals were obtained by divided the work into five tasks [RD1]:

- Task 1 (T1): Consolidation of dusty plasma near-surface environments requirements
- Task 2 (T2): Review of existing literature and data sources
- Task 3 (T3): Modelling of near surface dusty plasmas
- Task 4 (T4): Definition of Environments Specifications
- Task 5 (T5): Analysis of gaps in the current knowledge, roadmap for further developments

In this document the summary of the project is given by going through the results task by task and giving the basic conclusions and results.

1.2 Acronyms & Abbreviations

Acronym	Meaning
PIC	Particle-in-Cell
MC	Monte Carlo
DSMC	Direct simulation Monte Carlo. In this document DSMC is abbreviated as MC, for briefly.
DPEM	Dusty Plasma Environments: Near-Surface Characterisation and Modelling
DPEM model	The name of the modeling suite (MC, hybrid, PIC) prepared at the DPEM-project

1.3 References

1.3.1 Applicable Documents

Reference	Document
[AD01]	DPEM-TN-1-Dust plasma environment literature review - Ref. DPEM_IRF_UBe_DPEM-DS-0001-I2R0.pdf
[AD02]	DPEM-TN-1-Planetary Mission Database with Dust Experiment - Ref. DPEM-TN-0001-I1R0_Issue_1.pdf
[AD03]	DPEM-TN-1-Review of harmful effects - Ref. ARQ_12107_ETN_002_Issue_01.pdf
[AD04]	DPEM-TN-2-Moon Mission Database with Dust Experiment - Ref. DPEM-TN-0002-I1R0_Issue_1.pdf
[AD05]	DPEM-TN-2-Digital data library based on a 3D MHD model – Ref. MHDlibrary_Issue_10.pdf
[AD06]	DPEM-TN-2-Dust plasma environment digital library - Ref. DPEM-TN-0003-I1-R0_Issue_1.pdf
[AD07]	DPEM-TN-3-Models definition - Hybrid and DSMC manual - Ref. DPEM-DS-0002-I1R0.pdf
[AD08]	DPEM-TN-3-Models definition - Monte Carlo manual- Ref. DPEM-DS-0003-I1R1_Issue1_Rev1.pdf
[AD09]	DPEM-TN-3-Models definition – PIC model - Ref. DPEM-TN3-PIC_I01.pdf (
[AD10]	DPEM-TN-4-Environment Specification Definition - Ref. DPEM-TN-0003-I1-R0_Issue_1.pdf
[AD11]	DPEM-TN-5-Analysis of gaps in the current knowledge, further roadmap developments - Ref. DPEM-TN05_Issue_1.pdf
[AD12]	DPEM-Software with specification models - PIC manual - Ref DPEM-PIC Manual_Issue_10.pdf
[AD13]	DPEM-MRAD-Modeling Requirements and the Preliminary Model Architecture - Ref. DPEM-FMI-MRAD-002_Issue_1.0.pdf

1.3.2 Reference Documents

Reference	Document
[RD1]	Dusty plasma environments: near-surface characterisation and modelling, Document Type Statement of Work; Reference: GSP-SOW-10-665, Appendix 2 to AO/1-6996/11/NL/CO

2. Consolidation of dusty plasma near-surface environments requirements (T1)

The goal of this task was to collect important information related to the dust near-surface environments, especially, taking into account the dust simulation activities done in the project. The collected data contained information about (WP 1.01) harmful effects, (WP 1.02) relevant parameters for dusty plasma and environments modelling and (WP 1.03) requirements for dusty plasma near surface environment specifications and models. The results of the task are described in documents [AD01] - [AD03].

3. Review of existing literature and data sources (T2)

The second task in the project was to review existing literature and data sources. In addition to the digital libraries about lunar missions with dust experiments and dust plasma environment digital library, a new database was generated based on a 3D MHD model which contained plasma and field parameters near the lunar orbit.

Moreover, the task identified modelling requirements and designed the preliminary model architecture. The results of the task 2 are described in documents [AD04]-[AD06].

4. Modelling of near surface dusty plasmas (T3)

In this task the science requirements from the previous tasks were used to develop three kinetic models for the DPEM modelling suite: (1) 3D Hybrid model, (2) a 2D electrostatic full kinetic Particle-in-Cell (PIC) model, and (3) 3D Monte Carlo (MC) model. The results of the task are described in documents [AD07] - [AD09] and [AD12]- [AD13].

5. Definition of environments specifications (T4)

The purpose of this task 4 was to give examples of results of runs made for airless objects by the DPEM modelling suite which contains 3D hybrid model 1D/2D full kinetic PIC model and 3D Monte Carlo (MC) model. In the DPEM project these activities were performed in WP 4.01 “Environment specification models definition: Global (3D) Hybrid and DSMC models” and in WP 4.02 “Environment specification models definition: Local (1D & 2D) PIC model”. The modelling suite was used to study three different objects of different sizes, masses and escape velocities [AD01]: (1) Near-Earth asteroid RQ36, (2) Martian moon Phobos and (3) The Moon. Results of this task are described also in documents [AD07]-[AD09].

6. Analysis of gaps in the current knowledge, roadmap for further developments (T5)

The developed modelling suite makes it possible to study numerous dust environment situations for different objects and different conditions. However, the developed models can be seen just as a first step towards a comprehensive unified model. In addition, numerous important physical parameters have to be determined. Therefore, more comprehensive dust modelling and observations are called for in the future. Recommendations for the future dust modelling research were listed in task 5 in the document [AD11].

7. Summary: A concise description of the achievements

The DPEM (Dusty Plasma EnvironMents: near-surface characterisation and modelling) project has developed a modelling suite near surface dusty plasma environment and applicable to airless bodies of interest for future space exploration missions such as asteroids, the Moon, and the Martian moon Phobos.

The project developed three kinetic models which are linked together: (1) a 3D hybrid model, (2) a 1D/2D electrostatic full kinetic Particle-in-Cell (PIC) model, and (3) a 3D Direct Simulation Monte Carlo (DSMC) model. These models make it possible to study dusty plasmas for various space and time scales. The local PIC model simulates properties of charged particles and electric fields near the surface of the studied surface within and near the Debye layer while the DSMC gives the global properties of the dust. The 3D hybrid model provides the required solar wind parameters near the surface of an object.

The developed DPEM modelling suite allows the definition of charged dust environment specifications to assess the effects of dusty plasmas on near surface of various Solar System bodies.