QinetiQ Space

*(Formerly known as **DERA**)*

- Over 30 years involvement in studying the space environment and its effects on spacecraft systems:
  - Radiation environment.
  - Radiation effects and shielding.
  - Spacecraft surface and internal charging.
  - Space debris.
- Examples of work carried out for ESA:
  - The development of Geant4 space modules.
  - Radiation effects analysis tools.
  - Support to ESA's XMM CCD radiation studies.
  - The development of internal charging analysis tools.
  - Study of S/C plasma interaction in LEO.
  - Participation in ESA space weather study program.

S/C – Plasma Interactions
Introduction

- Practical consequences:
  - ram/wake effects, spacecraft charging, solar array power loss, surface contamination, sputtering, e-m transmission, e-m interference, ion thruster characteristics
- Analysis tools must trade physical realism for computational speed.
- Low-Earth Orbit is particularly problematic.
- PIC codes are most realistic but very computer intensive.
  - Small physical scales, 1 or 2-d
- GRID techniques offer the possibility of more complicated, larger scale and 3-d simulations.

S/C – Plasma Interactions
Introduction continued

- Success depends on whether benefits of greater processing power outweigh the penalties of information exchange between different machines
- Aim: a physically simple but globally representative simulation
  - 3-D
  - large number of particles
  - motion under fully self-consistent electric fields
  - current collection to an absorbing surface
  - the minimum amount of physics to prove the principle i.e. will probably exclude the following:
    - Collisions, secondary particles, photo-emission, electromagnetic interactions

S/C – Plasma Interactions Activities

- Analyse high level requirements for particle-in-cell plasma simulations (URD)
- Design the intended plasma simulation (SRD)
  - Review, develop and specify methods for parallelisation of the PIC code (Tech Note)
  - Specify simulation inputs and intended output
- Develop prototyping implementation plan
  - Assess suitability of possible PIC codes
  - Select/adapt suitable code
- Specify preliminary hardware requirements of the needed GRID/LCMPP (Tech Note)

S/C – Plasma Interactions
UR approach

- Identify key tasks on PIC simulation e.g.
  - particle moving;
  - assignment of charge to the computational grid;
  - Poisson solution;
  - passing of field
  - the removal and injection of particles
  - monitoring of the simulation
  - object definition
- Identify key tasks associated with GRID implementation
  - study of parallelisation strategies
  - analysis of computational load
  - analysis of data transfer requirements

Radiation Transport
Introduction

- Radiation transport simulation
  - An indispensable tool in space engineering and science, but limited to simplified case and geometry
  - CPU intensive, but intrinsically suited for parallel processing

Aim: end-to-end simulation with full representatives of the spacecraft and its payload structure

Solution: massive parallelisation $\Rightarrow$ GRID

Radiation Transport
Geant4

- The result of collaboration between 40 institutes and >100 scientists.
- ESA a member of the collaboration, ensuring space as one of its core application area.
- Object-oriented approach in design and implemented in C++.
- Currently in excess of 1,000,000 lines of code and over 10,000 classes.
- Examples of space application: ESA Radiation shielding and effect analysis tools; XMM, INTEGRAL, GLAST, BepiColombo

Radiation Transport Requirement

- High level user requirements
  - Task creation, distribution
  - Data farming
- Software Requirement and Design
- Parallelisation of Geant4
  - Method and plan
  - Specification of the GRID/LCMPP
- Identify the prototyping task (a radiation shielding analysis tool) and draft the implementation plan

G4 Parallelisation

- Strategy: event level, track level or batch
  - parallelisation at event level is the favored option
- Repeatability and Reproducibility:
  - independent of number of processors
  - management of random number generator
- Implementation issues:
  - minimal or no impact to G4 kernel libraries.
  - exception handling.