Nascap-2k Spacecraft Surface Charging Code
(EAR-controlled, freely available to US citizens and companies)

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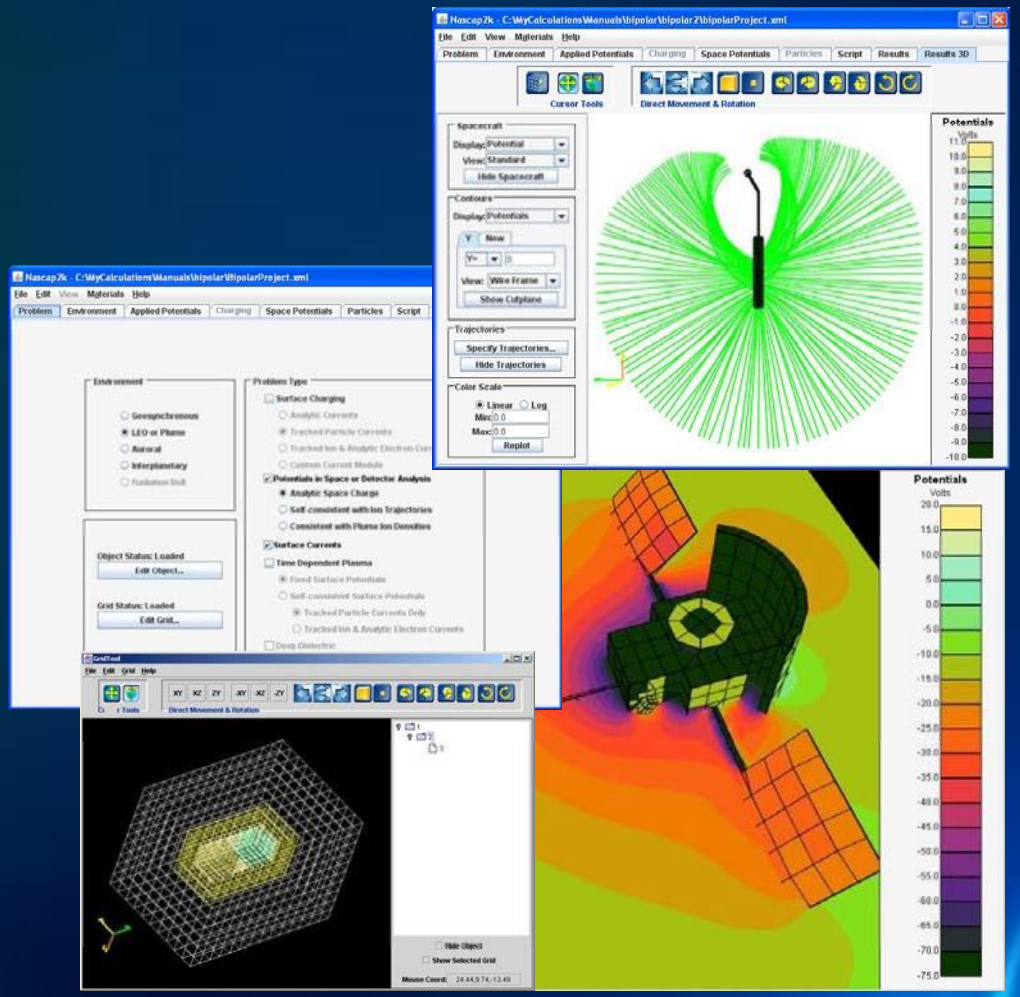
What Is *Nascap-2k*?

- *Nascap-2k* is a full 3-D fully GUI computer code to calculate the interactions of a spacecraft with its LEO, GEO, Polar, or interplanetary plasma environment. Interactions include:
  - Surface potentials
    - Charged particle spectra (electrons and ions)
    - Secondary electron emission
    - Photoemission
    - Bulk and surface conductivity
  - Current collection
    - Applied frame and distributed potentials
  - Perturbation of near-field environment
    - Space Potentials
    - Thruster plumes
    - Charge exchange ion flow
- Calculations are analytic where possible, PIC (particle-in-cell) where desired
- Code features
  - Object and grid definition
  - Simplified user interface for problem definition and execution
  - Graphical display of results
- Air Force Research Laboratory and NASA sponsorship
- Resides on your own computer, no web-login necessary

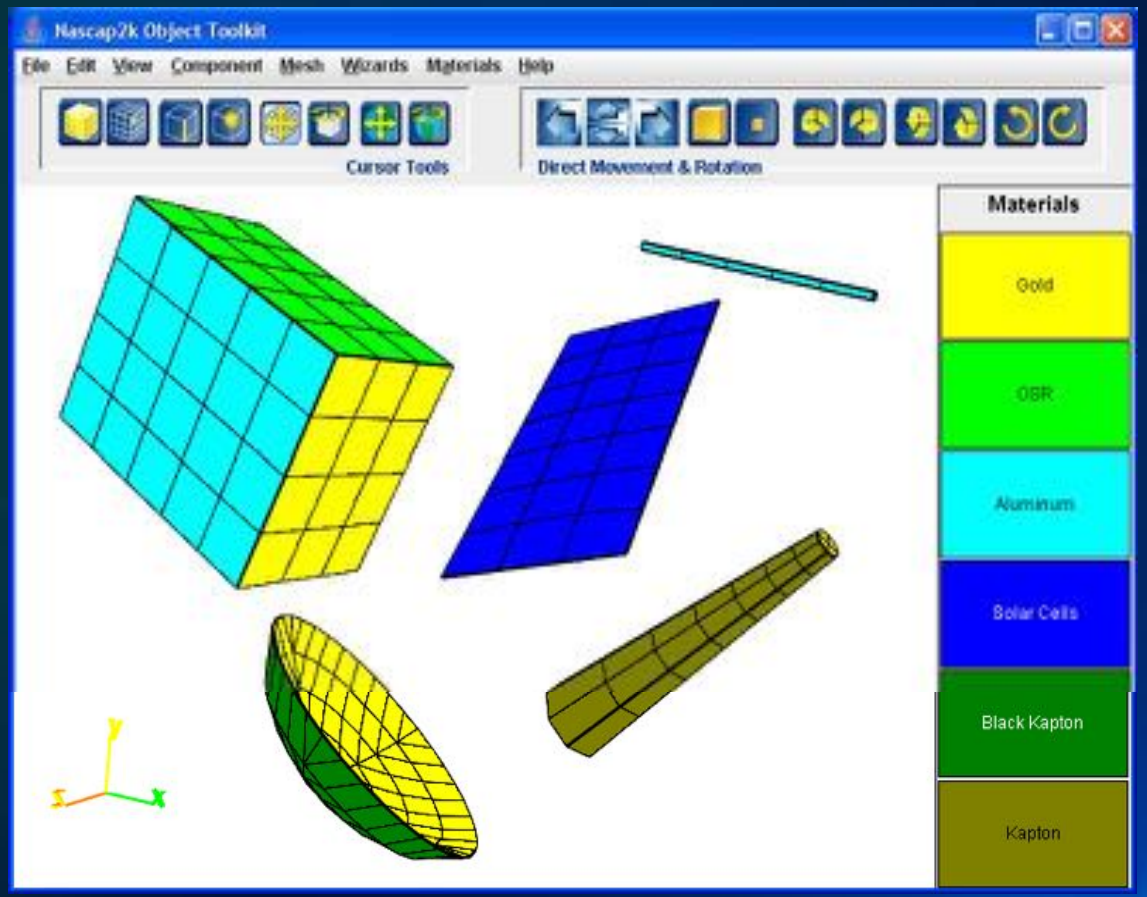
Nascap-2k Core Capabilities

- Defines spacecraft surface geometry
- Grids space surrounding spacecraft
- Calculates environmentally induced time-dependent surface potentials
- Calculates external potentials:
  - Analytic space charge (5 models)
  - Macroparticle space charge (4 models)
- Generates and tracks macroparticles
  - Uniform with boundary injection
  - Sheath generation
  - Charge exchange
- Post-processing:
  - Time-dependent surface potentials and currents
  - Time-dependent volume potentials, currents, and densities

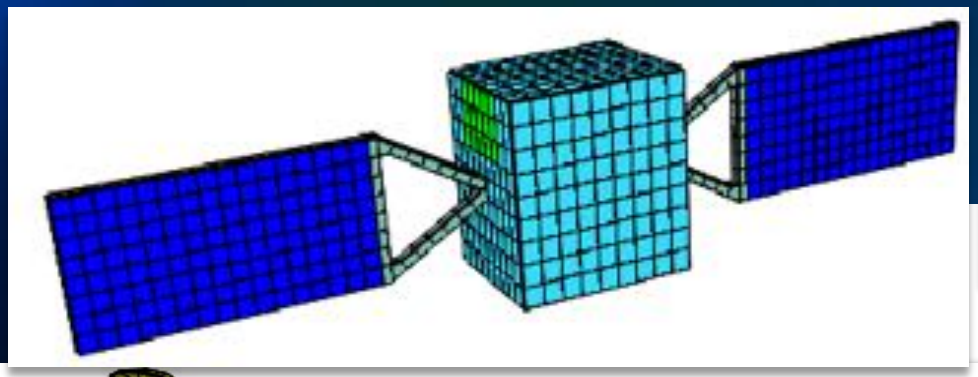


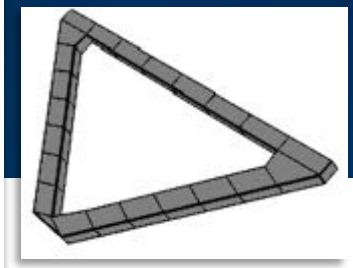
Object Toolkit

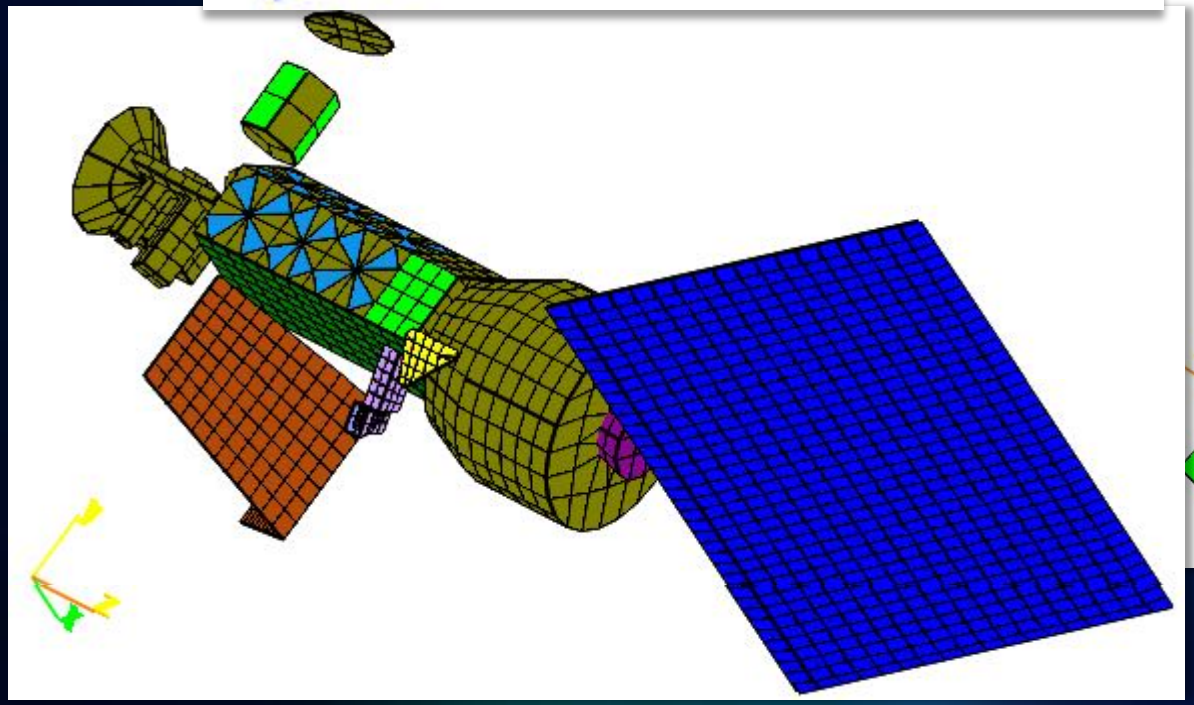
- Builds spacecraft surface models
- Uses intrinsic building blocks
- Imports from finite-element preprocessors
- Surface attributes from database or user-definable
  - Material name
    - Conductivity
    - Secondary electron emission
    - Thickness, etc.
  - Conductor number
- Customizable to other applications via an external file

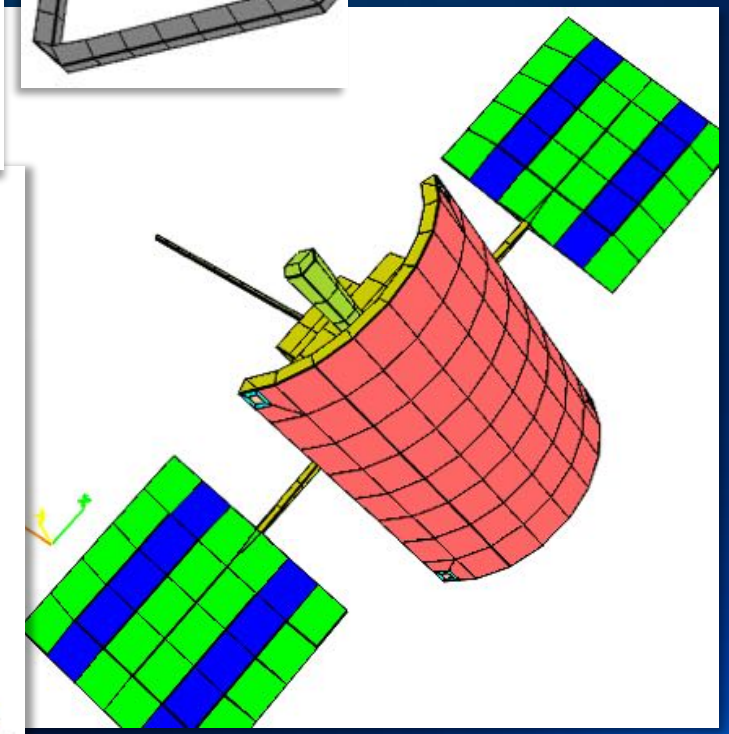


Object Toolkit Examples









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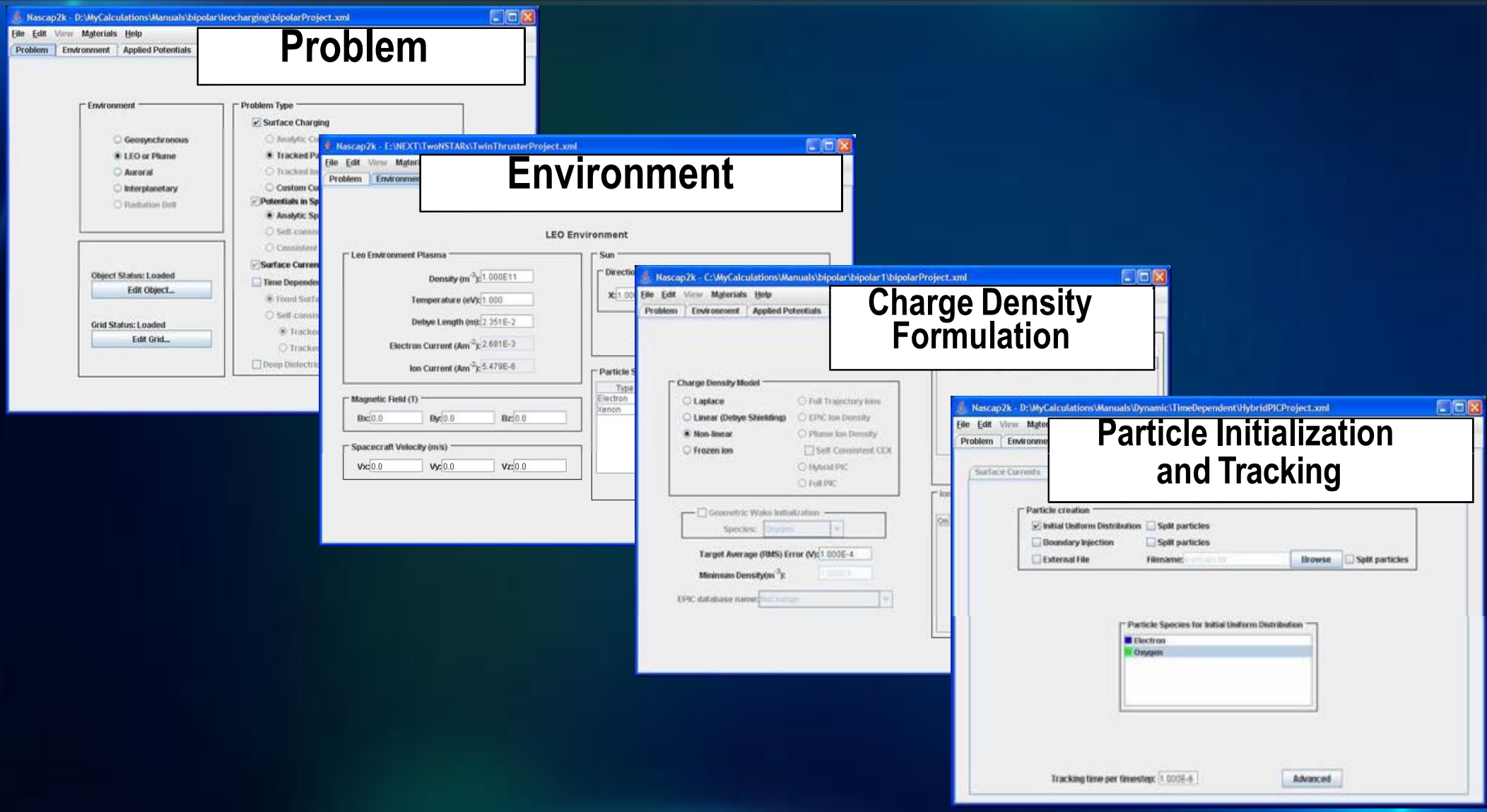
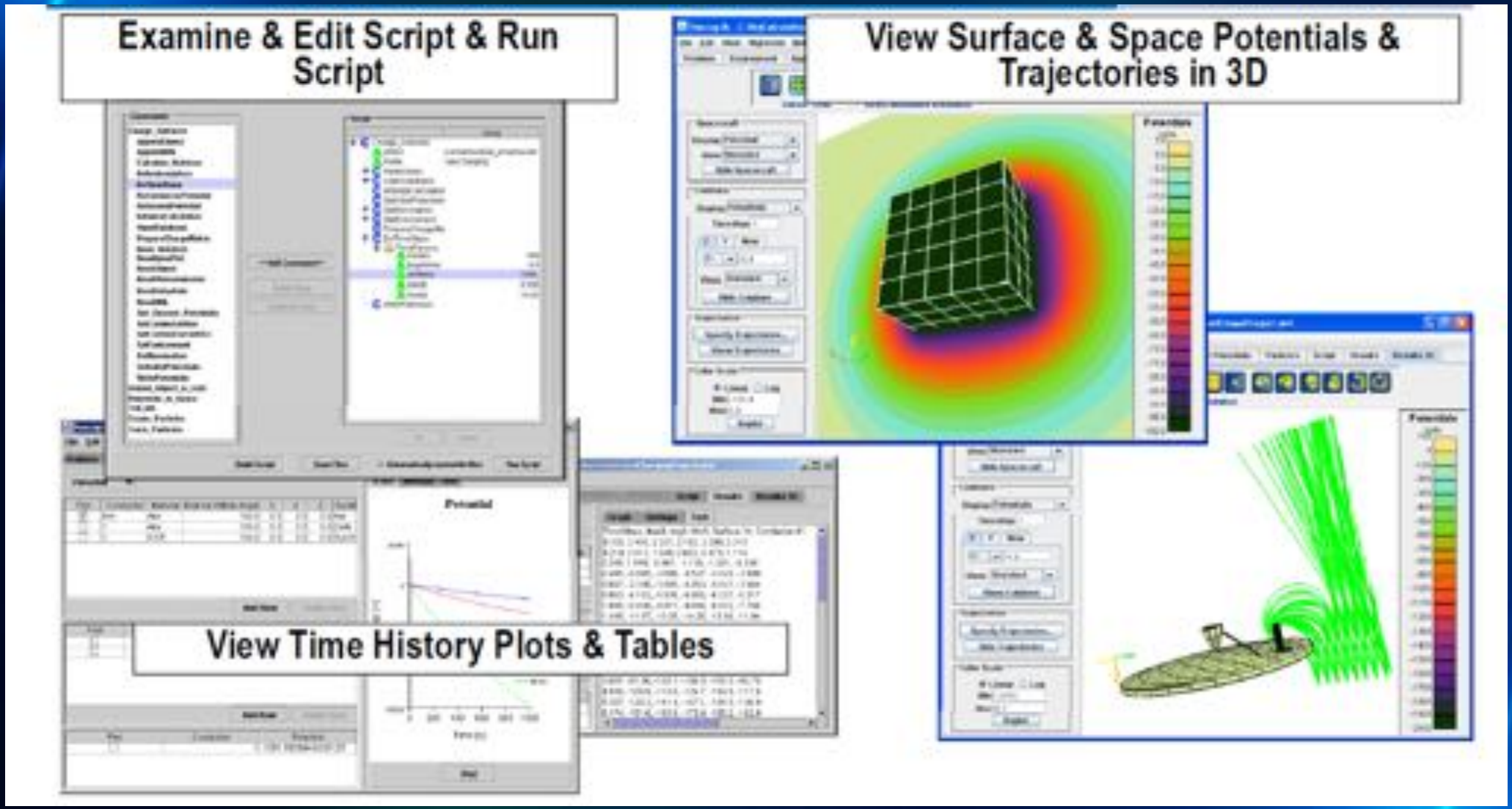
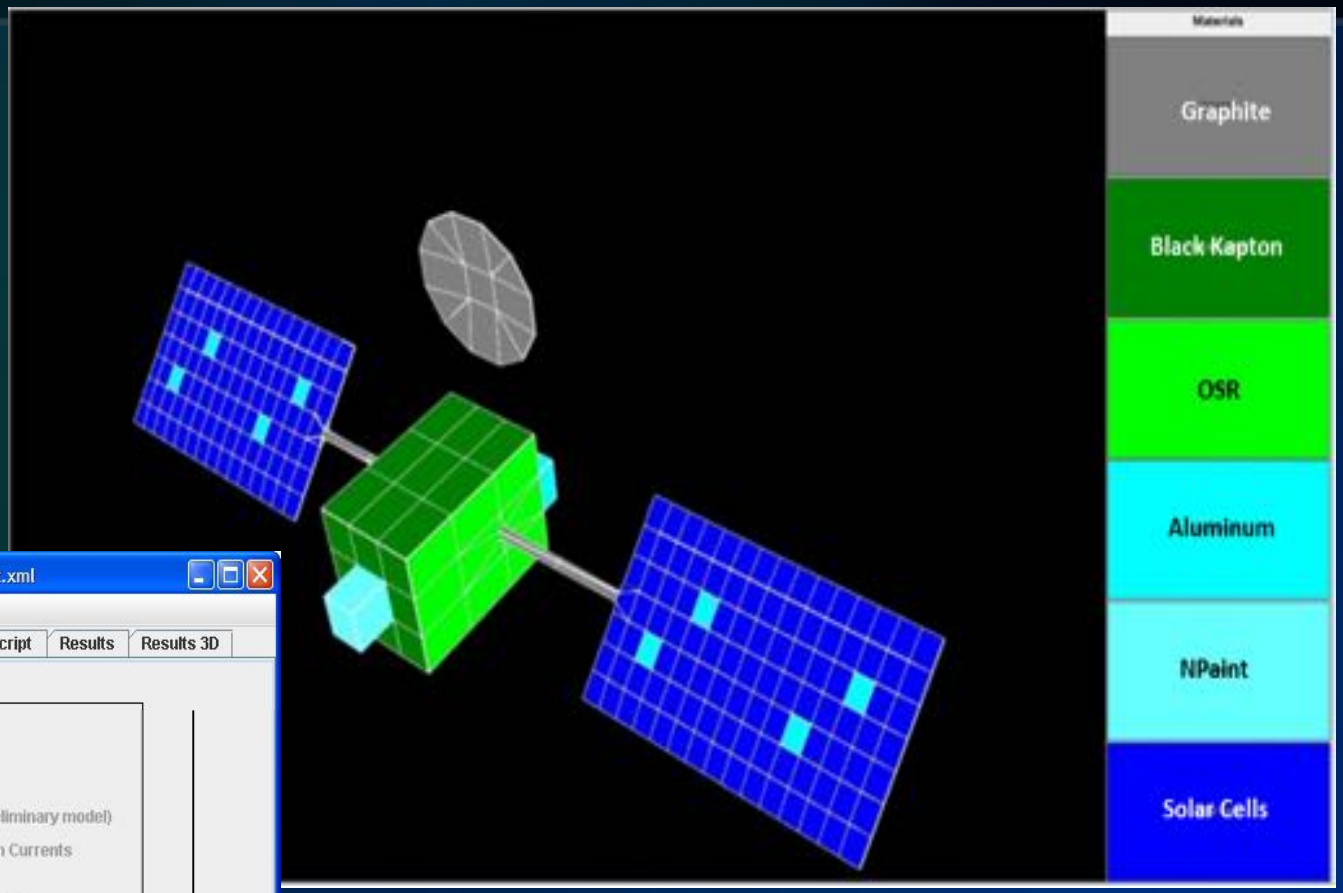
Nascap-2k GUI Input tabs

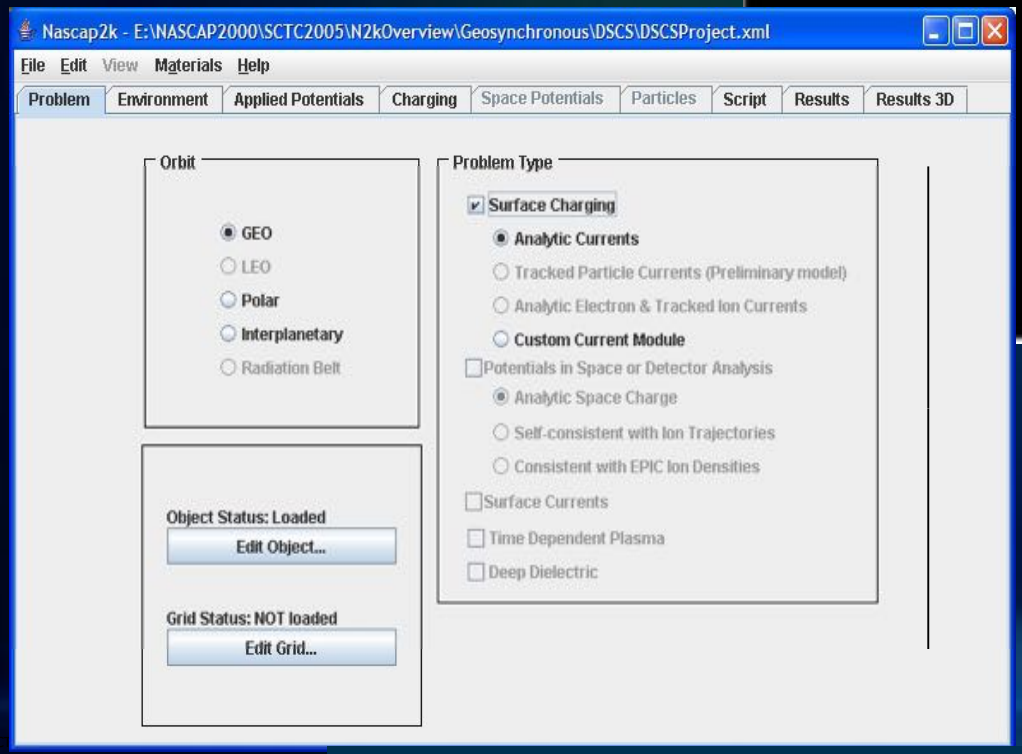


Nascap-2k Results Tabs

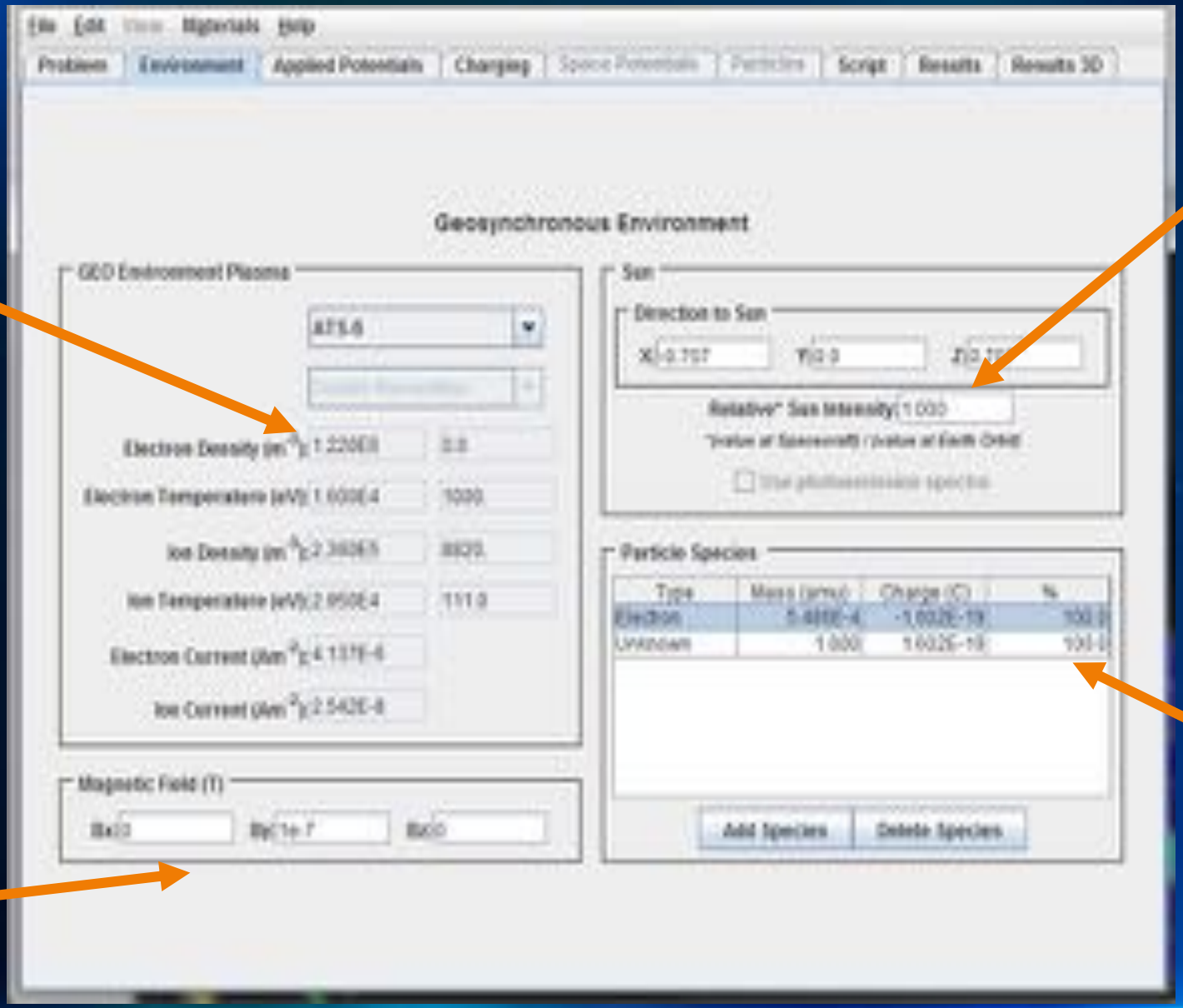


Example 1 – GEO Spacecraft Model – 3-axis stabilized
Defining the Problem and Surface Materials





Example - Environment Input for *Nascap-2k*



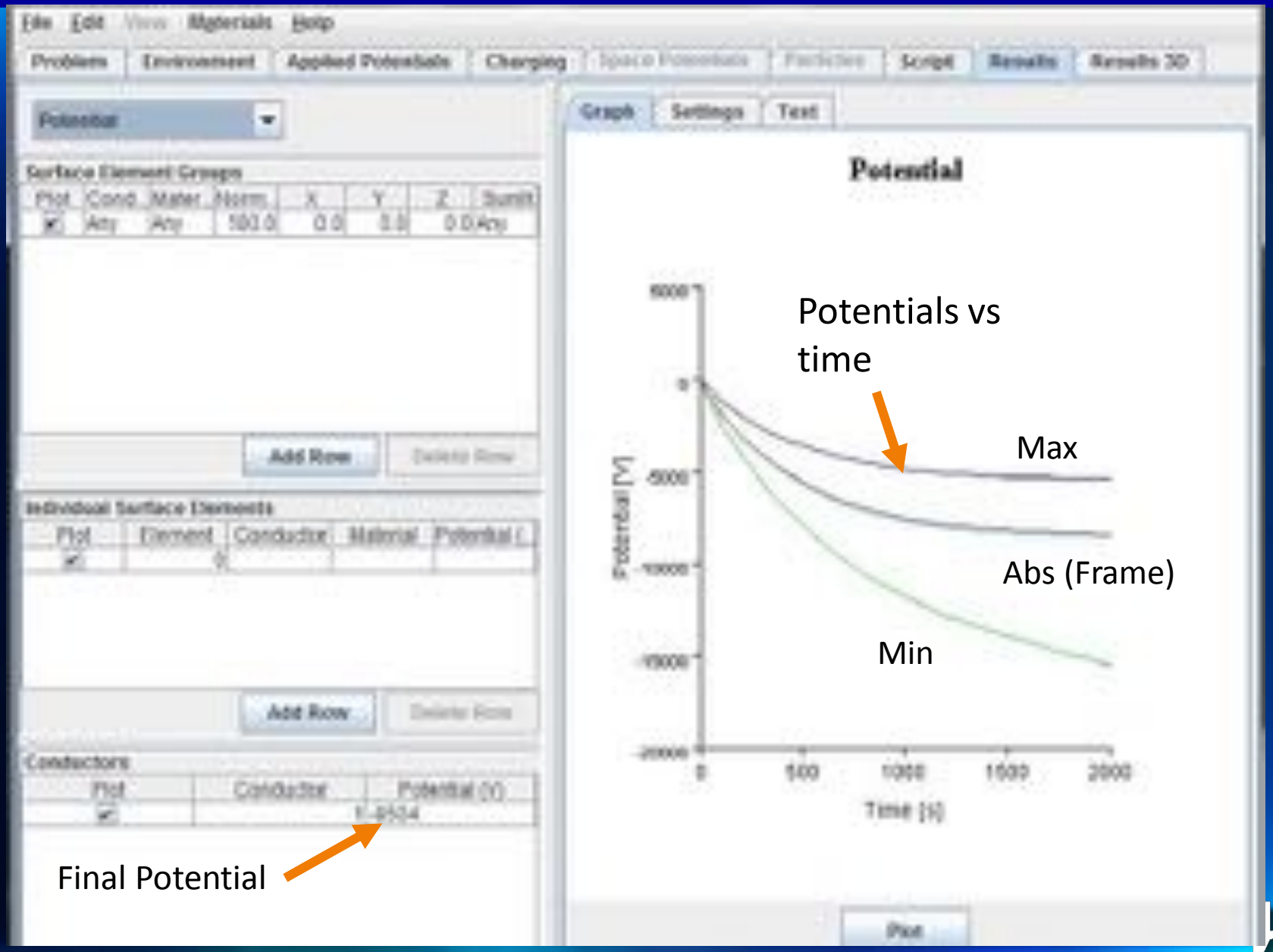
May be single or double Maxwellian or Kappa distribution

Sun or shade

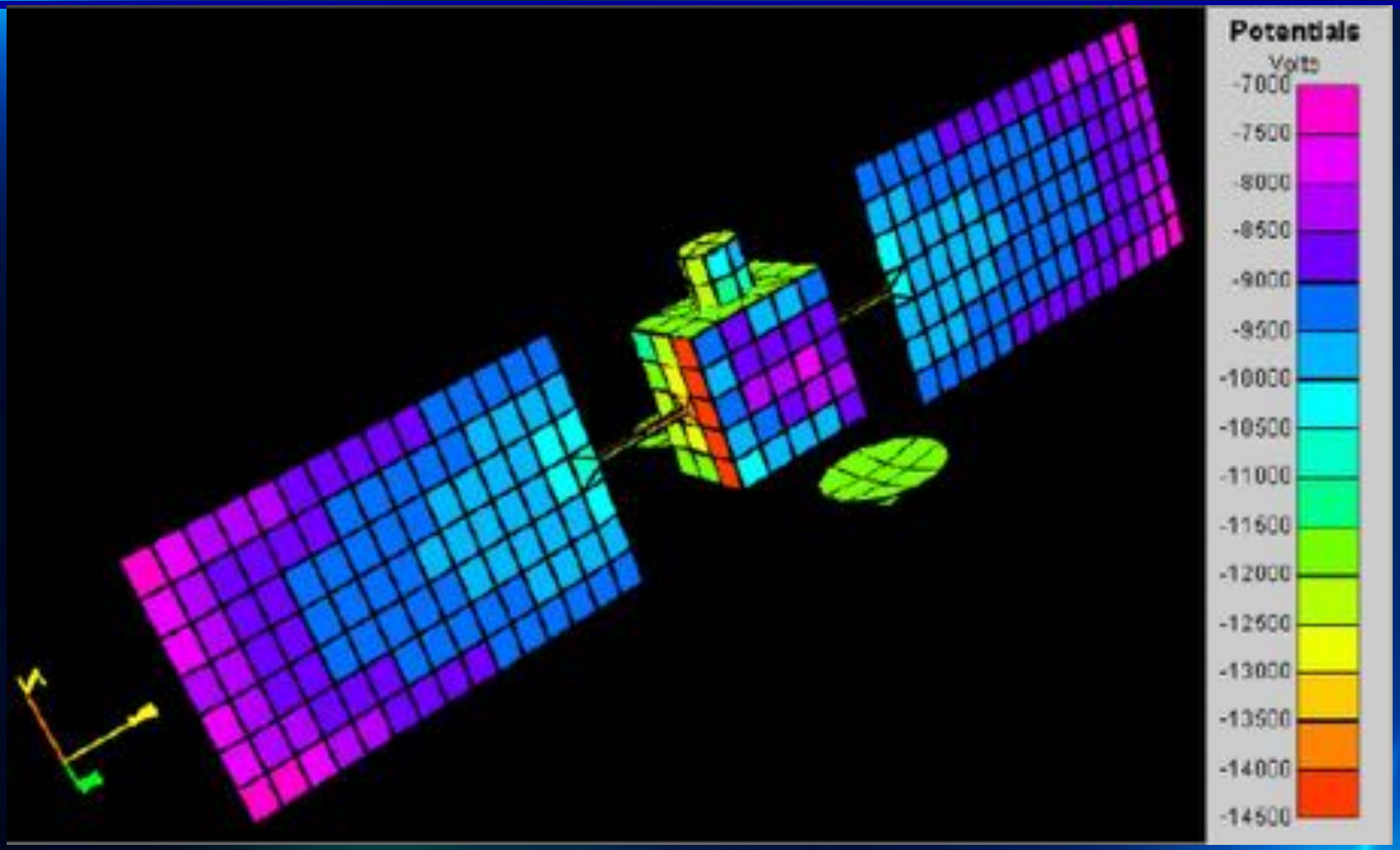
Ion species

B field

Example - Charging History from *Nascap-2k*

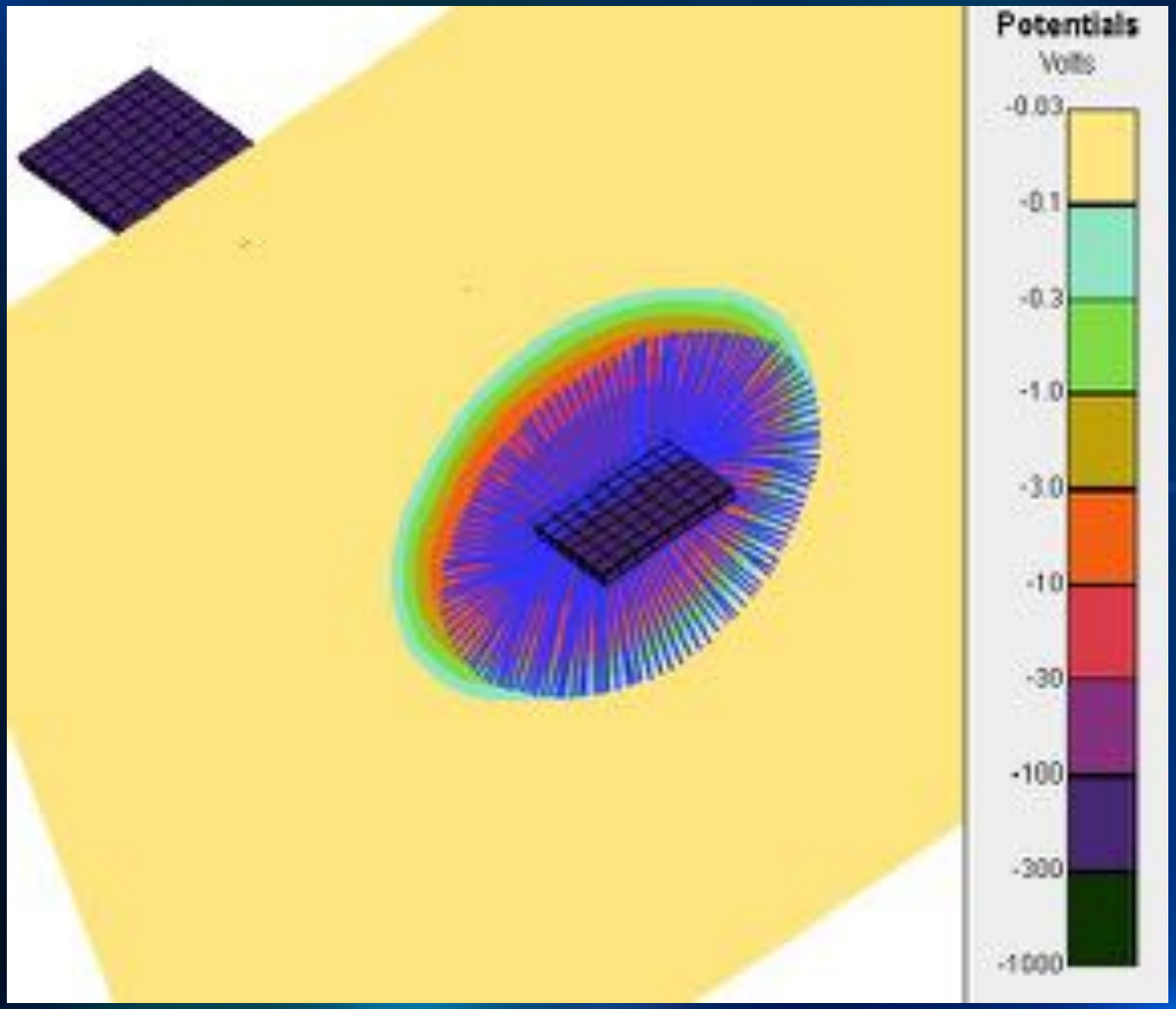


Example - Surface Charging from *Nascap-2k*



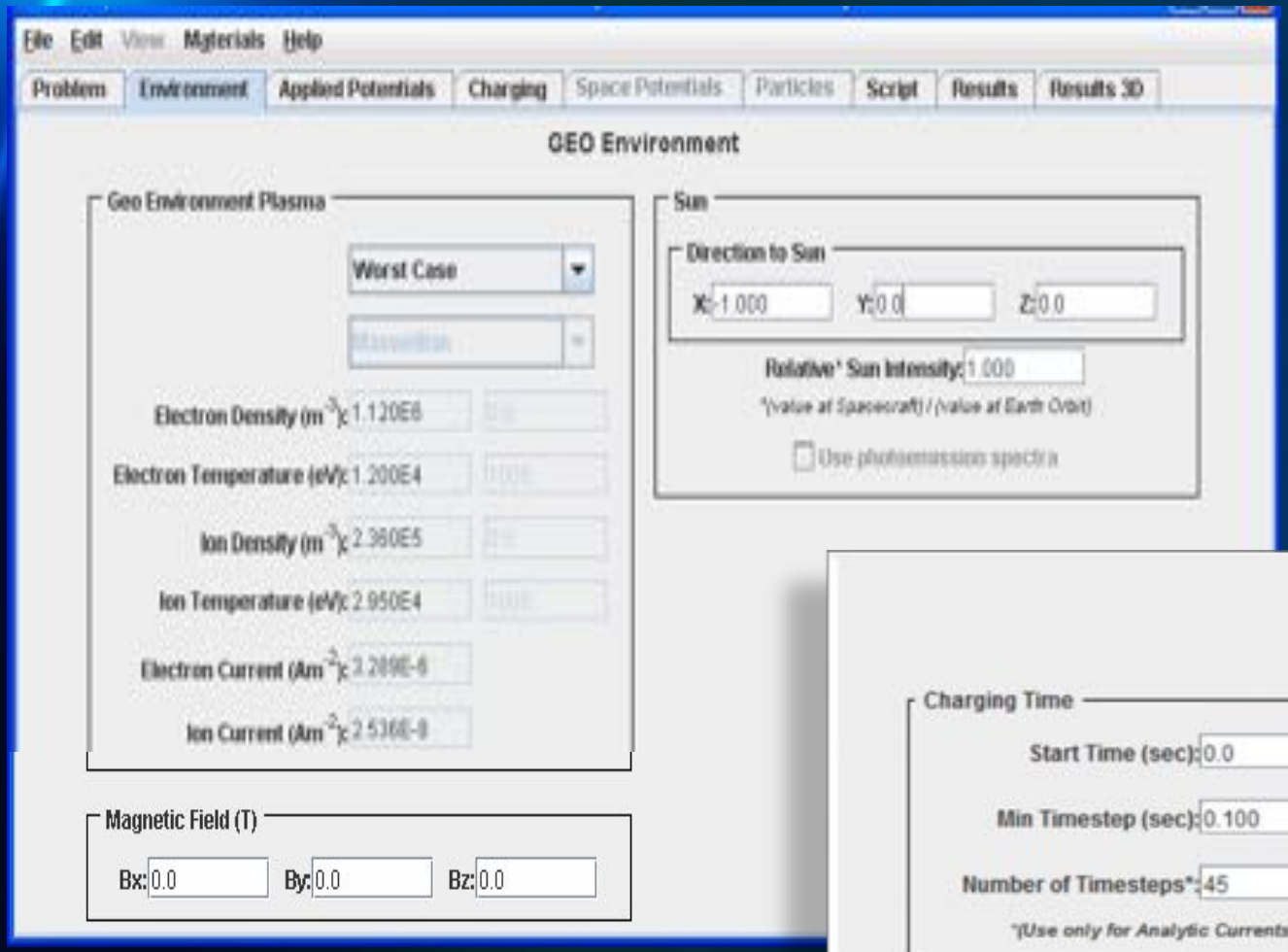
3-D Results Display

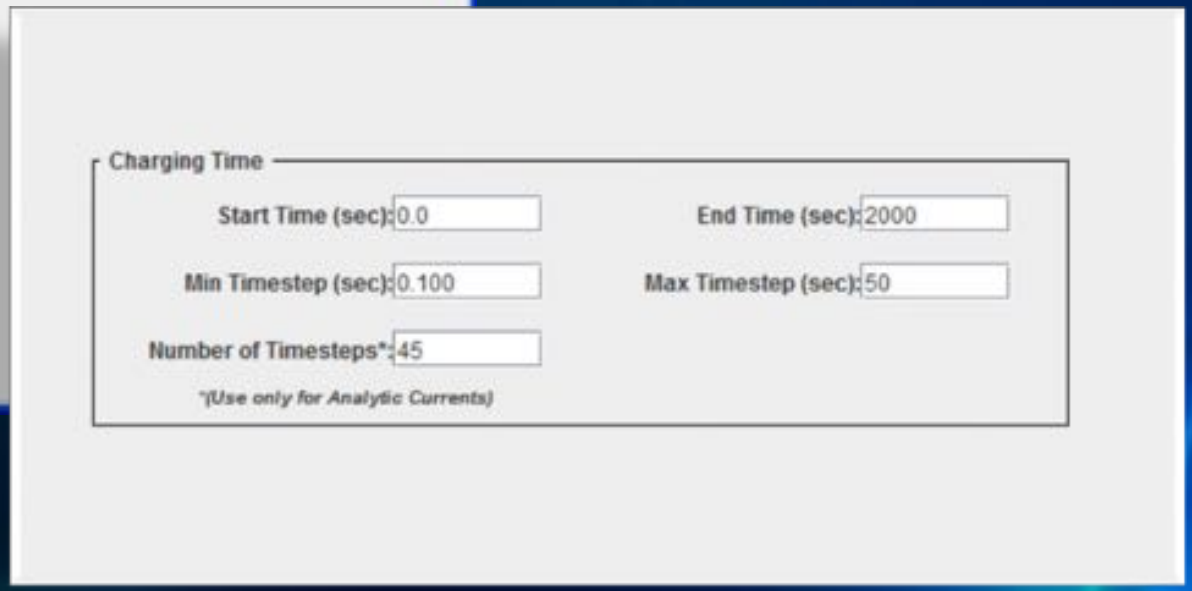
Surface Potentials, Space Potentials, and Ion Trajectories



Geosynchronous Orbit Charging

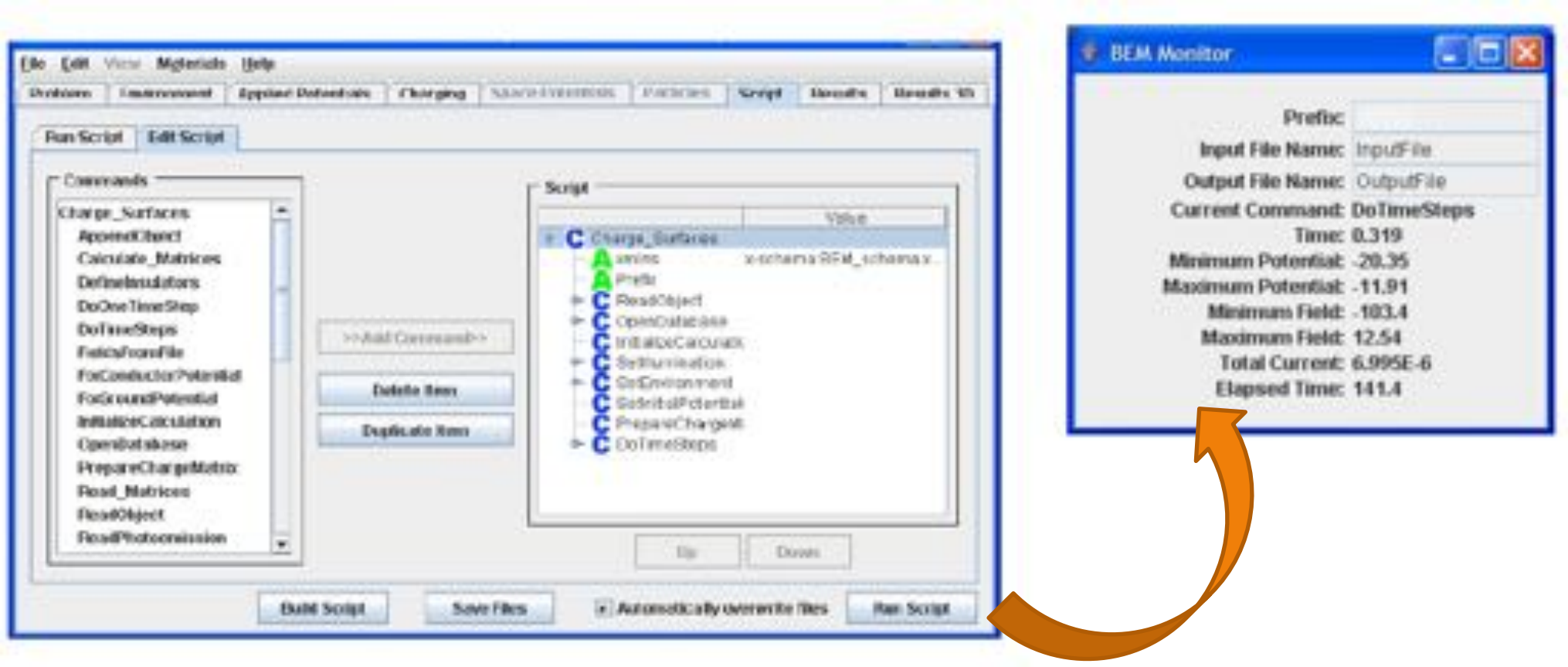
Environment and Timestepping Specifications





- Environment tab sets geosynchronous environment distribution function–here a Maxwellian
- Charging tab sets timestep parameters

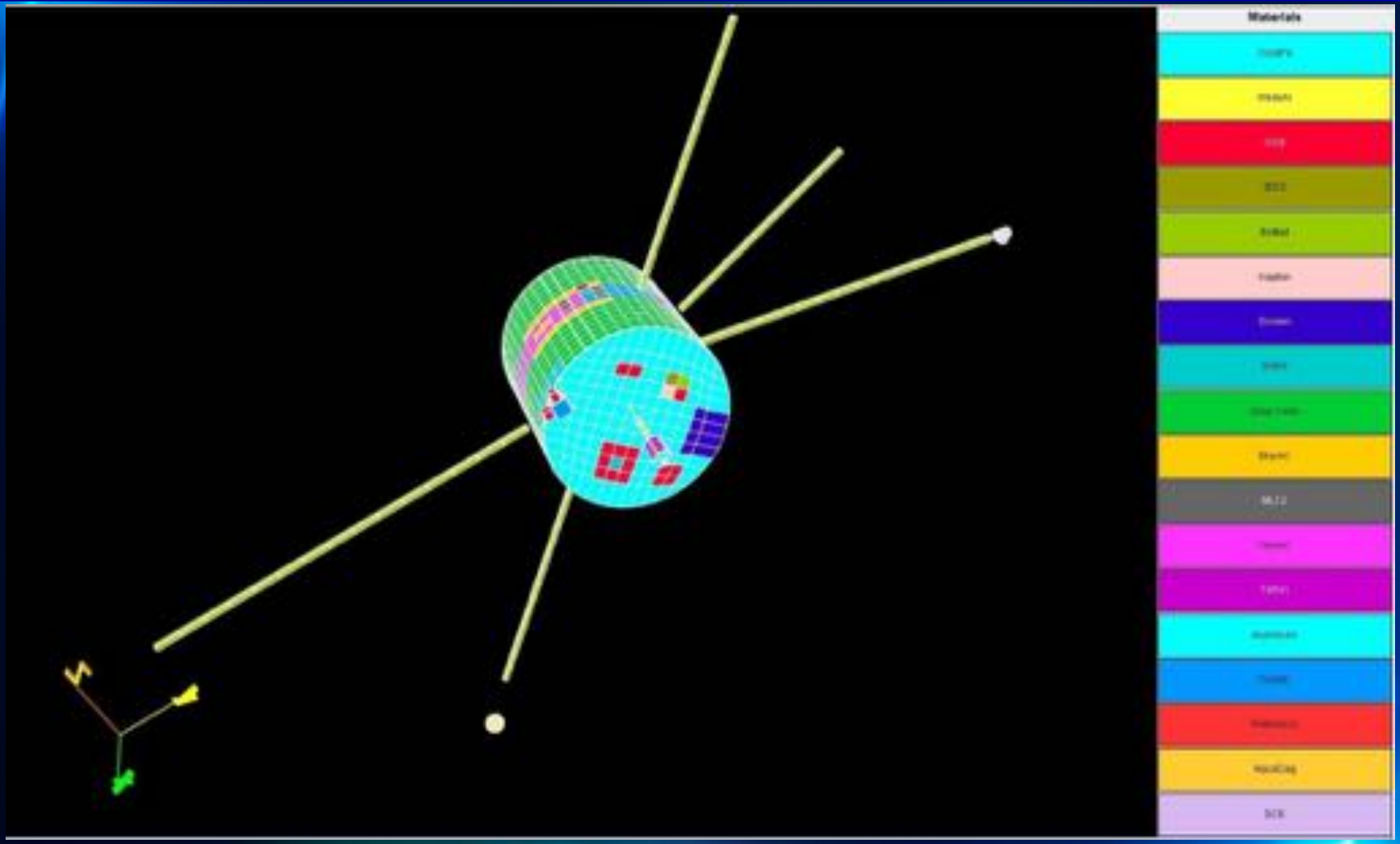
Geosynchronous Orbit Charging



- Script (automatically generated) specifies calculation steps
  - Script can be edited internally or externally
  - Can do eclipse entry and exit, dynamic plasmas, spacecraft rotation, distributed array voltage
- Monitors progress of calculation
- Results in ~10 minutes on workstation

Example - Charging of Spinning Spacecraft

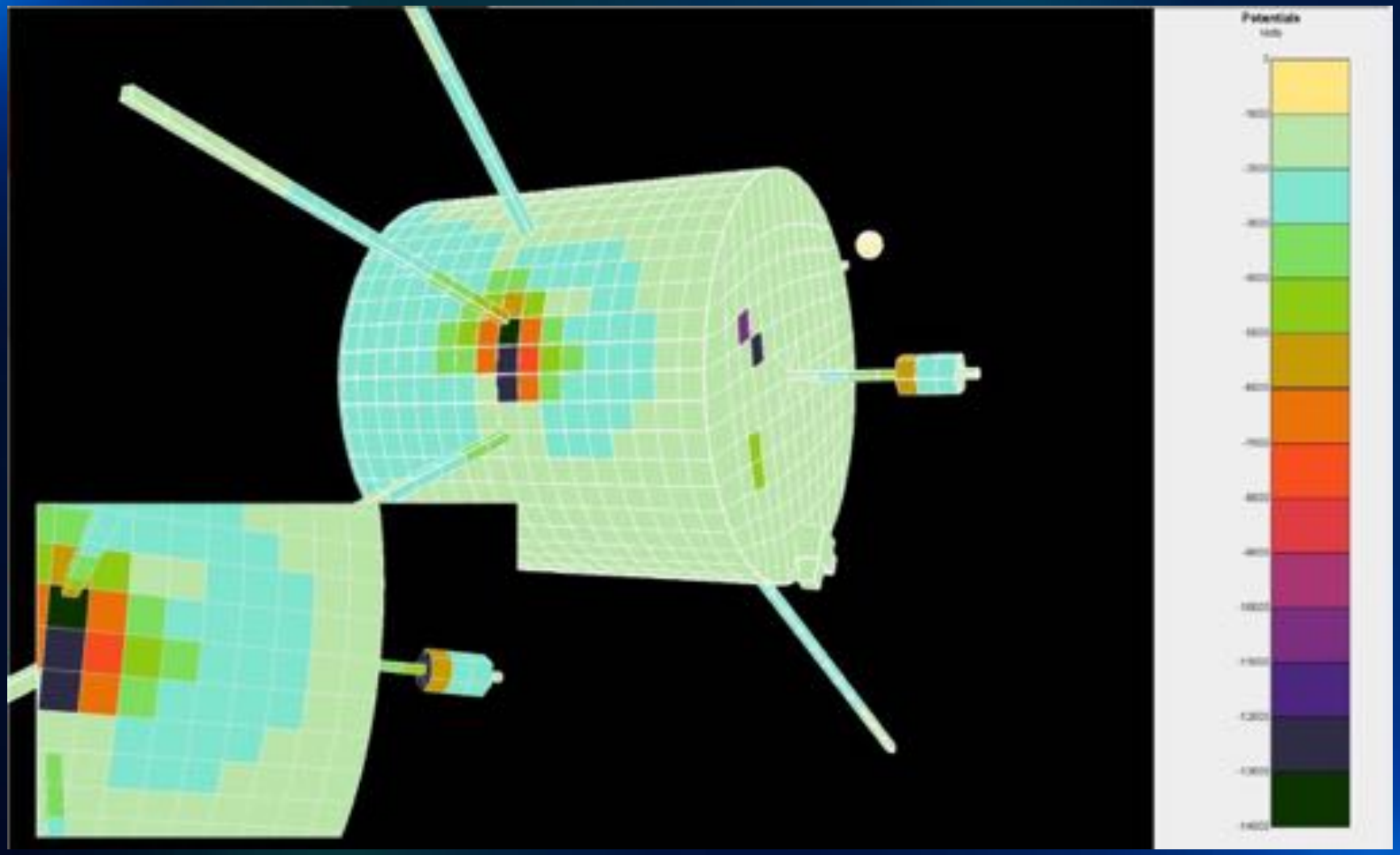
Nascap-2k Model of SCATHA



False color *Nascap-2k* surface-materials model of SCATHA

Charging of Spinning Spacecraft

Nascap-2k Results for SCATHA

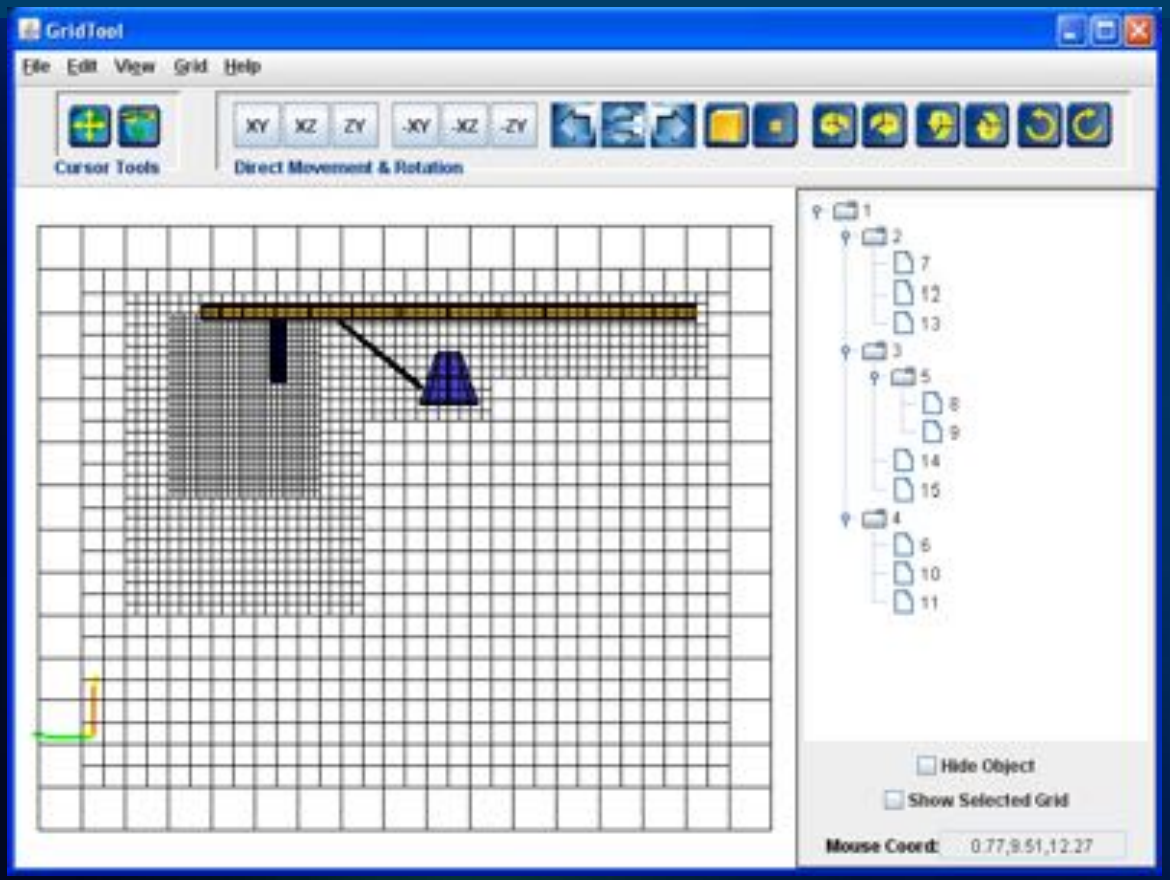


Potentials after 2010 seconds, ATS-6 environment, rotating at 1 rpm. Inset at lower left shows the bottomside of the Teflon cylindrical antenna cover, from which ions are partially blocked

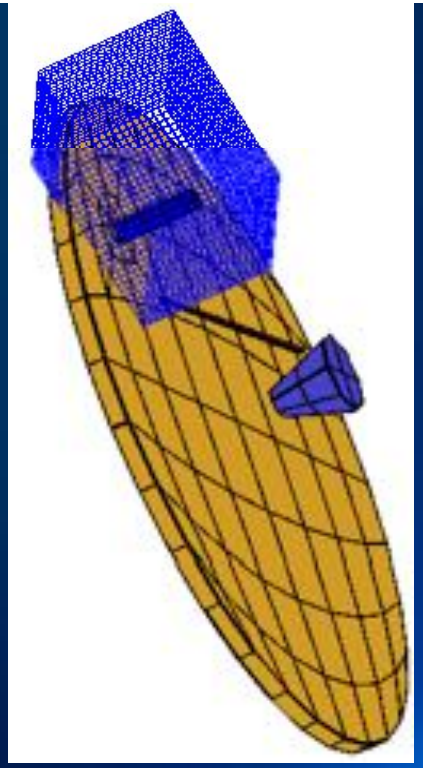
Example - LEO Current Collection

Spatial Gridding with *GridTool*

Charging Hazards and Wake Studies Experiment (CHAWS)



Fine resolution around probe and near edge of disk

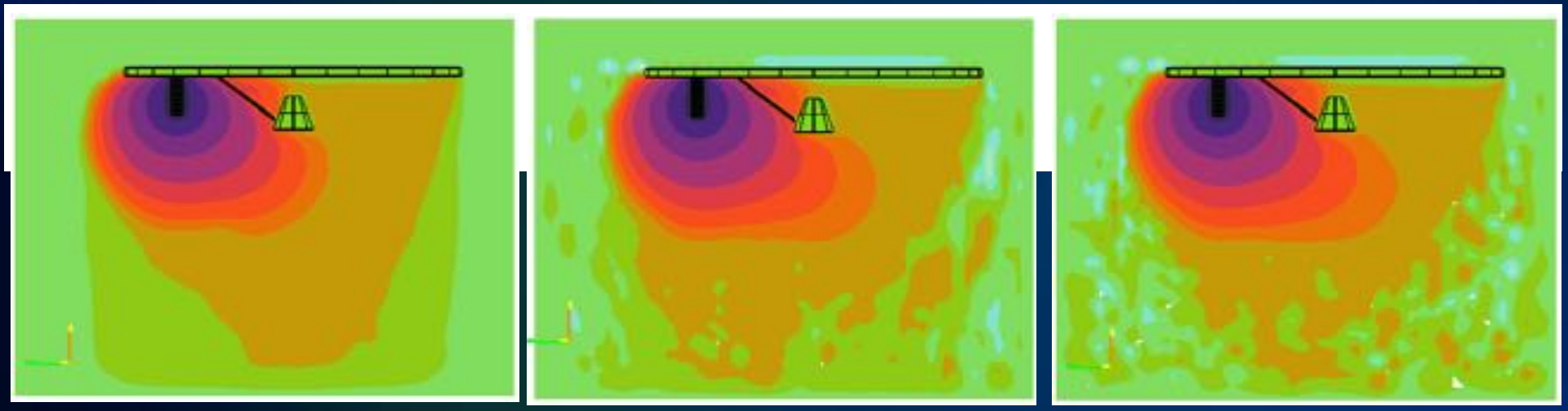


Multiply nested cubic grids with “special” elements containing object for computational speed

LEO Current Collection

Orbit Averaged Particle-In-Cell

- Macroparticle charge distributed over trajectory sub-steps, allows longer timesteps in dynamic calculations



Full Trajectory (steady-state)	Particle-in-Cell (dynamic)	Orbit averaged
Macroparticles carry current	Macroparticles carry charge	Macroparticles carry charge
Share *current* × *sub-step time* to grid *each sub-step*	Share *charge* to grid at end of *timestep*	Share $charge \times \frac{sub\text{-}step\,time}{timestep}$ to grid *each sub-step*
10 iters (with sharing) in 2 hours	900 2-μs timesteps in 140 hours	90 20-μs timesteps in 12 hours

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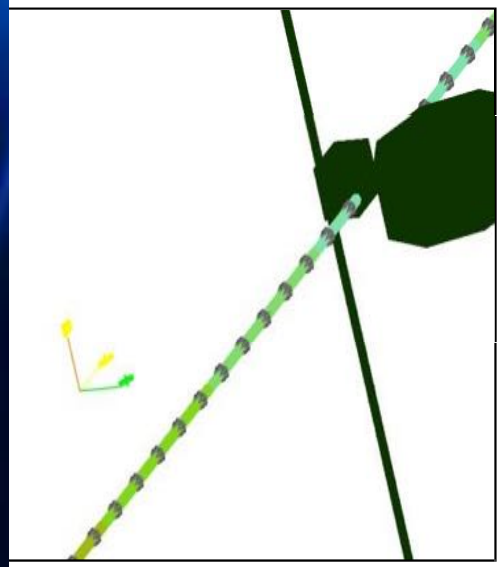
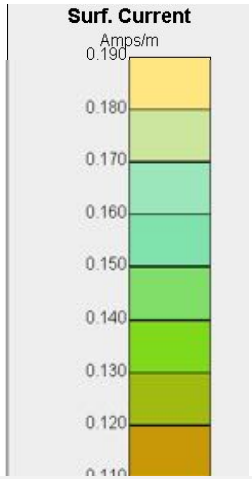
Potentials in Thruster Plumes

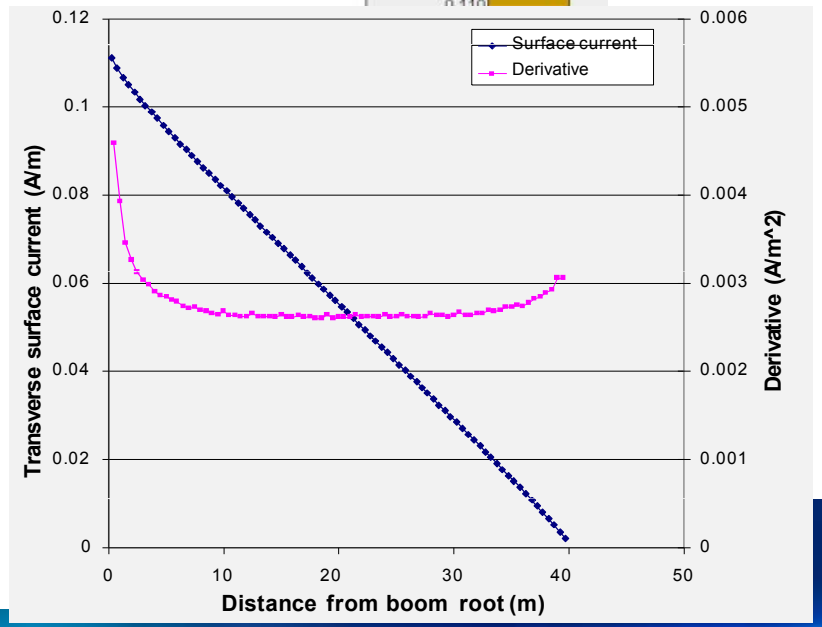
- Thruster plumes
  - Produce potentials that modify contaminant trajectories
  - Produce charge-exchange ions that lead to enhanced plasma density around the spacecraft
  - Interact with spacecraft surfaces
  - Interact with other thruster plumes
- Import plume ion densities from external file
  - Densities created by *PlumeTool*, part of EPIC *(*Electric Propulsion Interactions Code, a NASA SEE (Space Environments Effects) product)
- Calculate potentials self-consistently with charge exchange ion generation and transport

Antenna-induced Currents

Surface Currents - DSX







- Cones indicate direction of current
- Colors indicate magnitude of current
- Numeric results show capacitive loading near boom root and tip

Summary

- *Nascap-2k*
  - User-friendly integrated code
  - Study and analysis of a wide variety of spacecraft-plasma interactions
  - Variety of important space environments.
  - Uses efficient algorithms
  - Builds on heritage going back to late 1970s
- Examples presented
  - Charging in geostationary orbit
  - Current collection in low-Earth orbit
  - Charge exchange generation and potentials in thruster plumes
  - Surface and volume currents generated by antennae
- *Nascap-2k* is supported by Air Force Research Laboratory and the NASA Space Environments and Effects program
  - Distributed through http://see.msfc.nasa.gov