



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

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SCIENCE & TECHNOLOGY

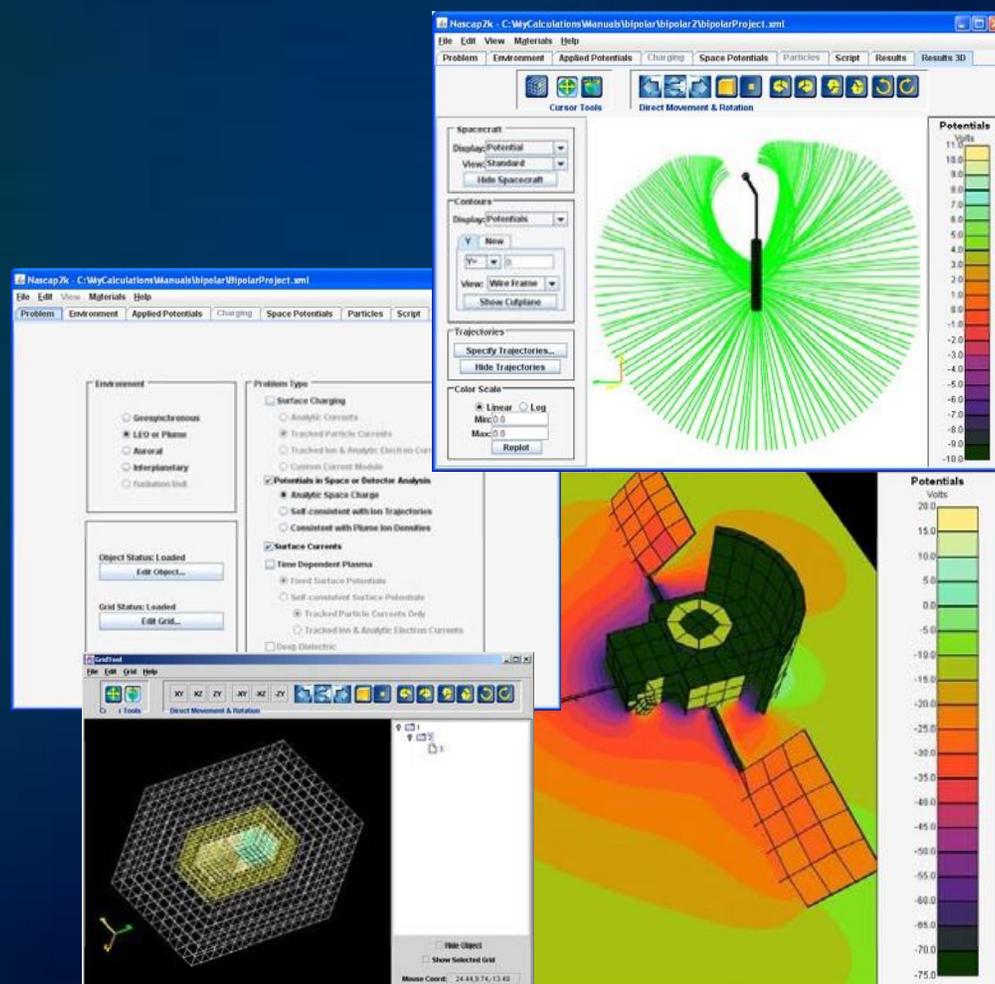
What Is *Nascap-2k*?

- *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**



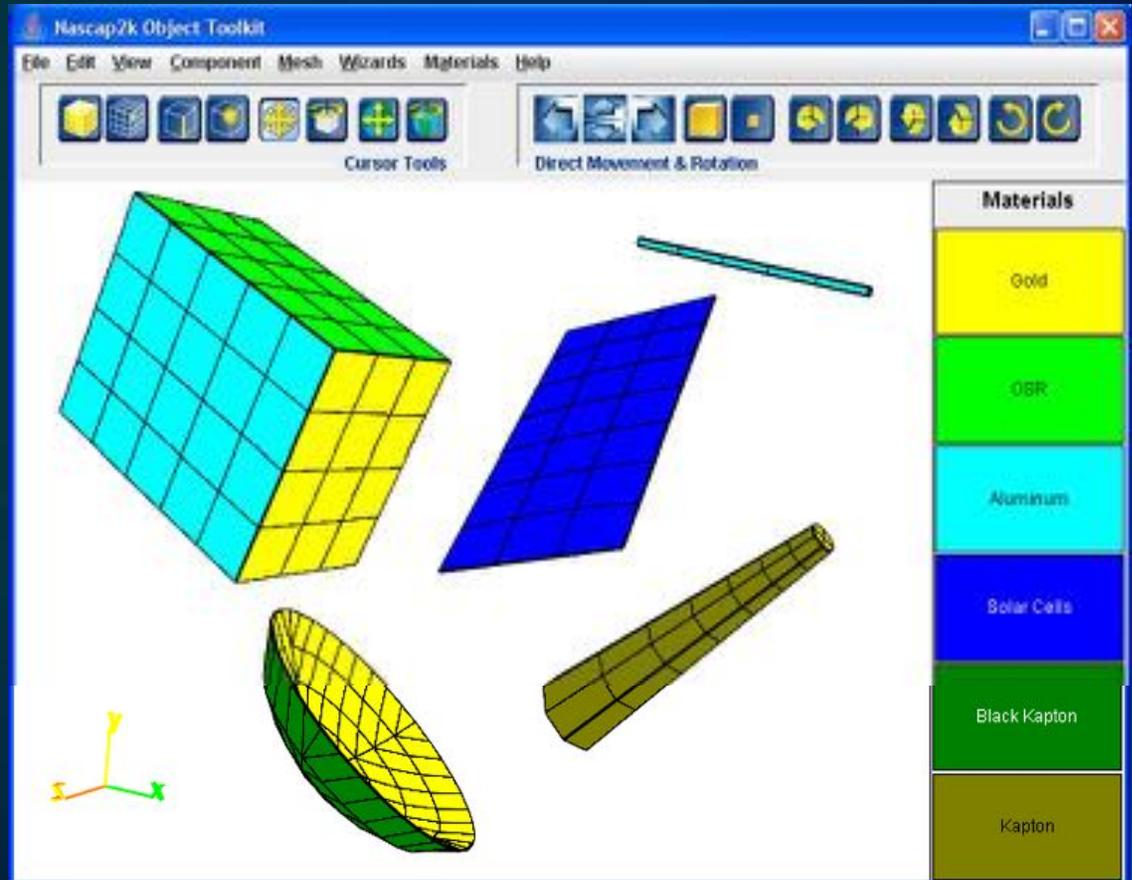
Nascap-2k Core Capabilities

- 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

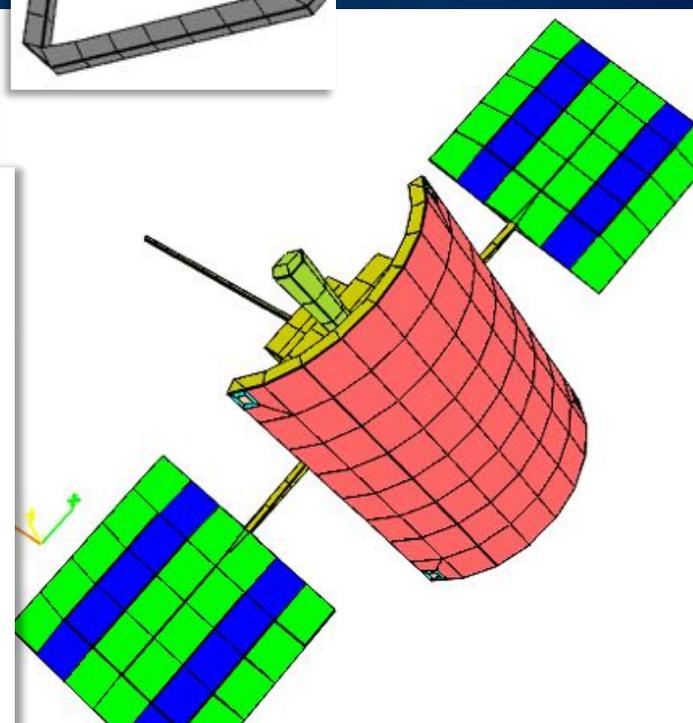
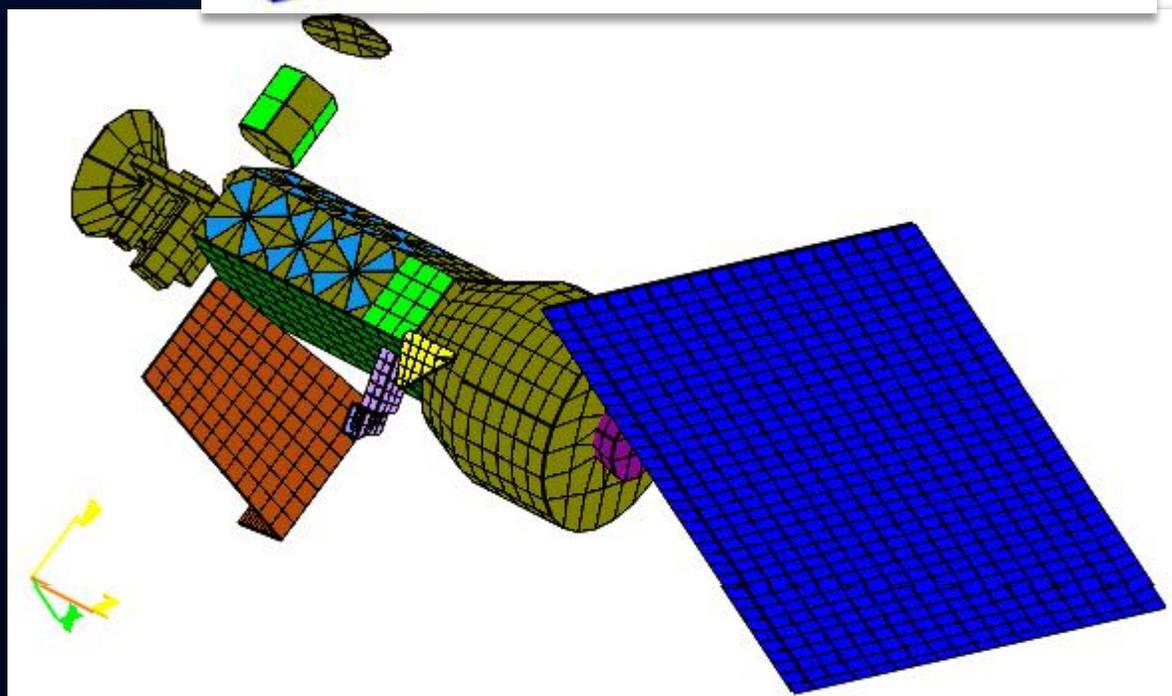
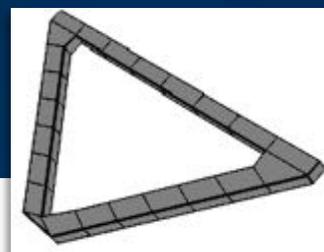
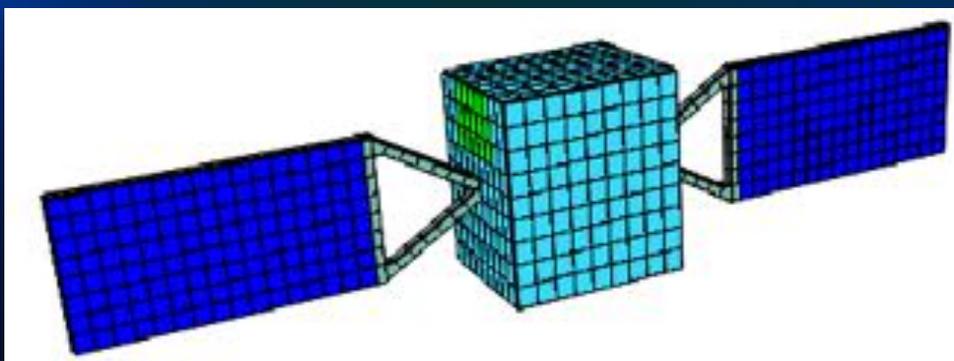


Object Toolkit

- 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



Nascap-2k GUI Input tabs

Problem

Environment

Charge Density Formulation

Particle Initialization and Tracking

Nascap-2k Results Tabs

Examine & Edit Script & Run Script

The screenshot displays the 'Script Editor' window with a list of script commands on the left and a script editor on the right. Below this, there are several smaller windows showing 'Potential' plots and data tables. One table shows a list of parameters and their values, and another shows a plot of potential energy over time.

Time	Potential
0	1000
100	500
200	200
300	100
400	50
500	20
600	10
700	5
800	2
900	1
1000	0

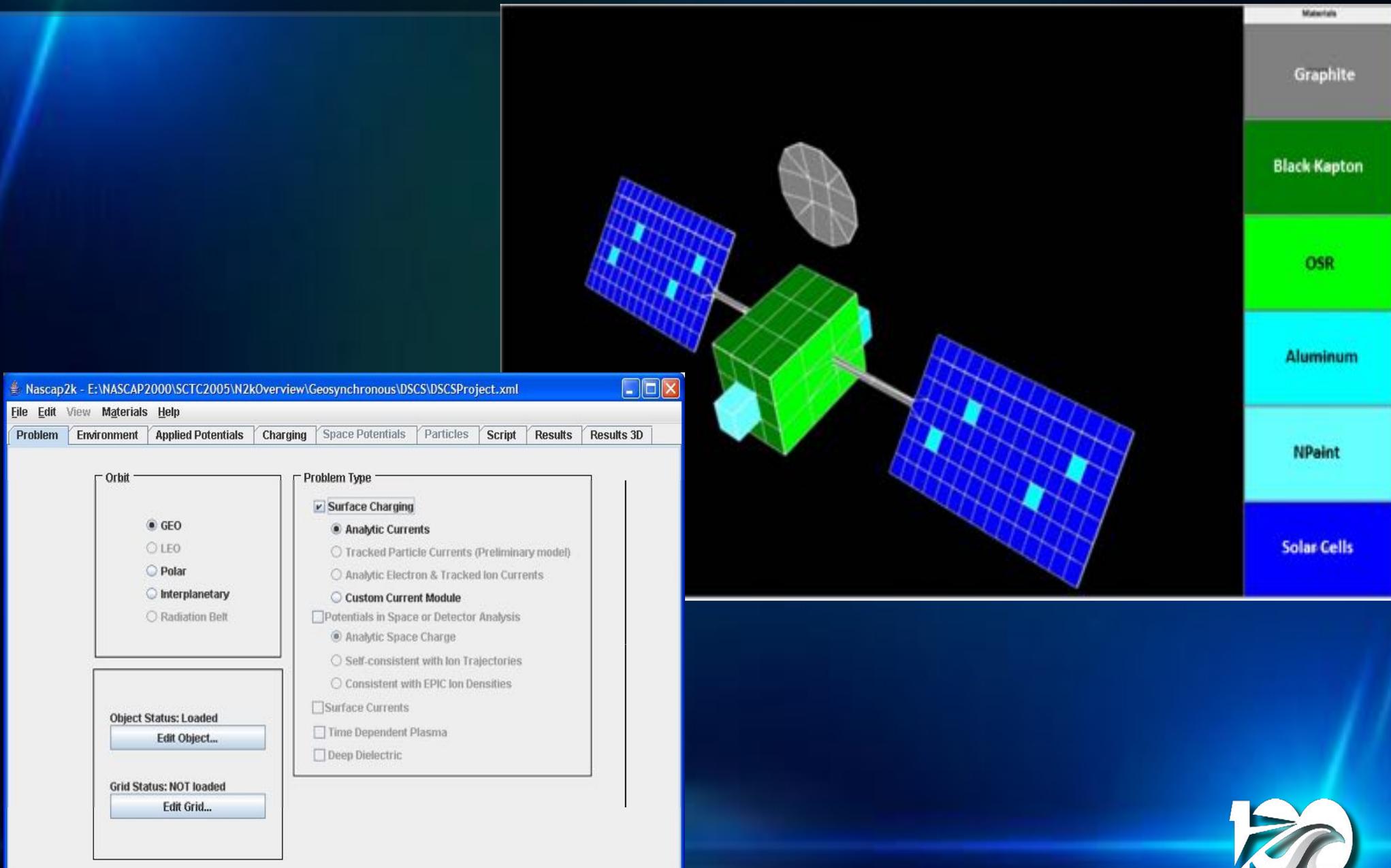
View Surface & Space Potentials & Trajectories in 3D

The screenshot shows a 3D visualization of a satellite's potential field. A green cube is positioned in the center, surrounded by a color-coded potential field. A color scale on the right indicates potential values from 0 to 1000. Below this, there is a 3D plot of trajectories showing a satellite's path and its associated potential field.

View Time History Plots & Tables

Example 1 – GEO Spacecraft Model – 3-axis stabilized

Defining the Problem and Surface Materials



The image displays the Nascap2k software interface for defining a spacecraft model. The main window shows a 3D model of a spacecraft with a central body and two large solar panel arrays. The spacecraft body is colored green, and the solar panels are blue. A material configuration panel on the right lists the materials used in the model: Graphite, Black Kapton, OSR, Aluminum, NPaint, and Solar Cells. The software window also shows the 'Materials' menu and the 'Problem' tab, which is currently selected. The 'Problem' tab contains several sub-sections: 'Orbit' (with radio buttons for GEO, LEO, Polar, Interplanetary, and Radiation Belt), 'Object Status' (Loaded), 'Grid Status' (NOT loaded), and 'Problem Type' (with checkboxes for Surface Charging, Analytic Currents, Tracked Particle Currents, Analytic Electron & Tracked Ion Currents, Custom Current Module, Potentials in Space or Detector Analysis, Analytic Space Charge, Self-consistent with Ion Trajectories, Consistent with EPIC Ion Densities, Surface Currents, Time Dependent Plasma, and Deep Dielectric).

Materials

- Graphite
- Black Kapton
- OSR
- Aluminum
- NPaint
- Solar Cells

Problem

Orbit

- GEO
- LEO
- Polar
- Interplanetary
- Radiation Belt

Object Status: Loaded

Edit Object...

Grid Status: NOT loaded

Edit Grid...

Problem Type

- Surface Charging**
- Analytic Currents
- Tracked Particle Currents (Preliminary model)
- Analytic Electron & Tracked Ion Currents
- Custom Current Module
- Potentials in Space or Detector Analysis
- Analytic Space Charge
- Self-consistent with Ion Trajectories
- Consistent with EPIC Ion Densities
- Surface Currents
- Time Dependent Plasma
- Deep Dielectric



Example - Environment Input for *Nascap-2k*



File Edit View Materials Help

Problem Environment Applied Potentials Charging Space Potentials Particles Script Results Results 3D

Geosynchronous Environment

GEO Environment Plasma

475.6

Electron Density (cm^{-3}): 1.220E8 3.3

Electron Temperature (eV): 1.600E4 1000

Ion Density (cm^{-3}): 2.380E5 3300

Ion Temperature (eV): 2.950E4 1110

Electron Current (Am^{-2}): 4.137E-4

Ion Current (Am^{-2}): 2.542E-8

Magnetic Field (T)

Bx:0 By:1e-7 Bz:0

Sun

Direction to Sun

X:0.707 Y:0 Z:0.707

Relative* Sun Intensity(1.000)

*Value at Spacecraft / Value at Earth Orbit

Use photoionization spectra

Particle Species

Type	Mass (amu)	Charge (C)	%
Electron	5.488E-4	-1.602E-19	100.0
Uranium	1.000	1.602E-19	100.0

Add Species Delete Species

May be single or double Maxwellian or Kappa distribution

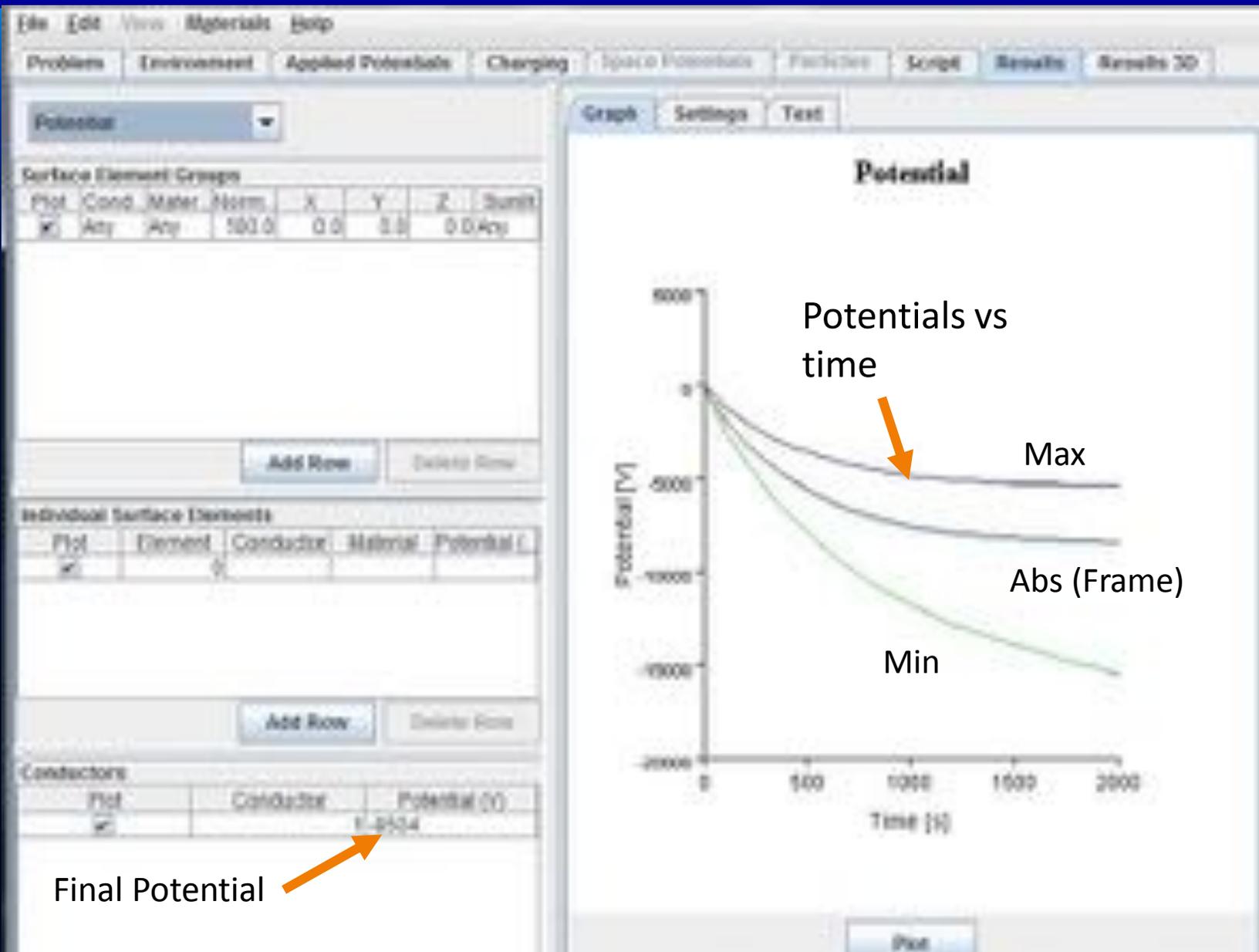
Sun or shade

B field

Ion species

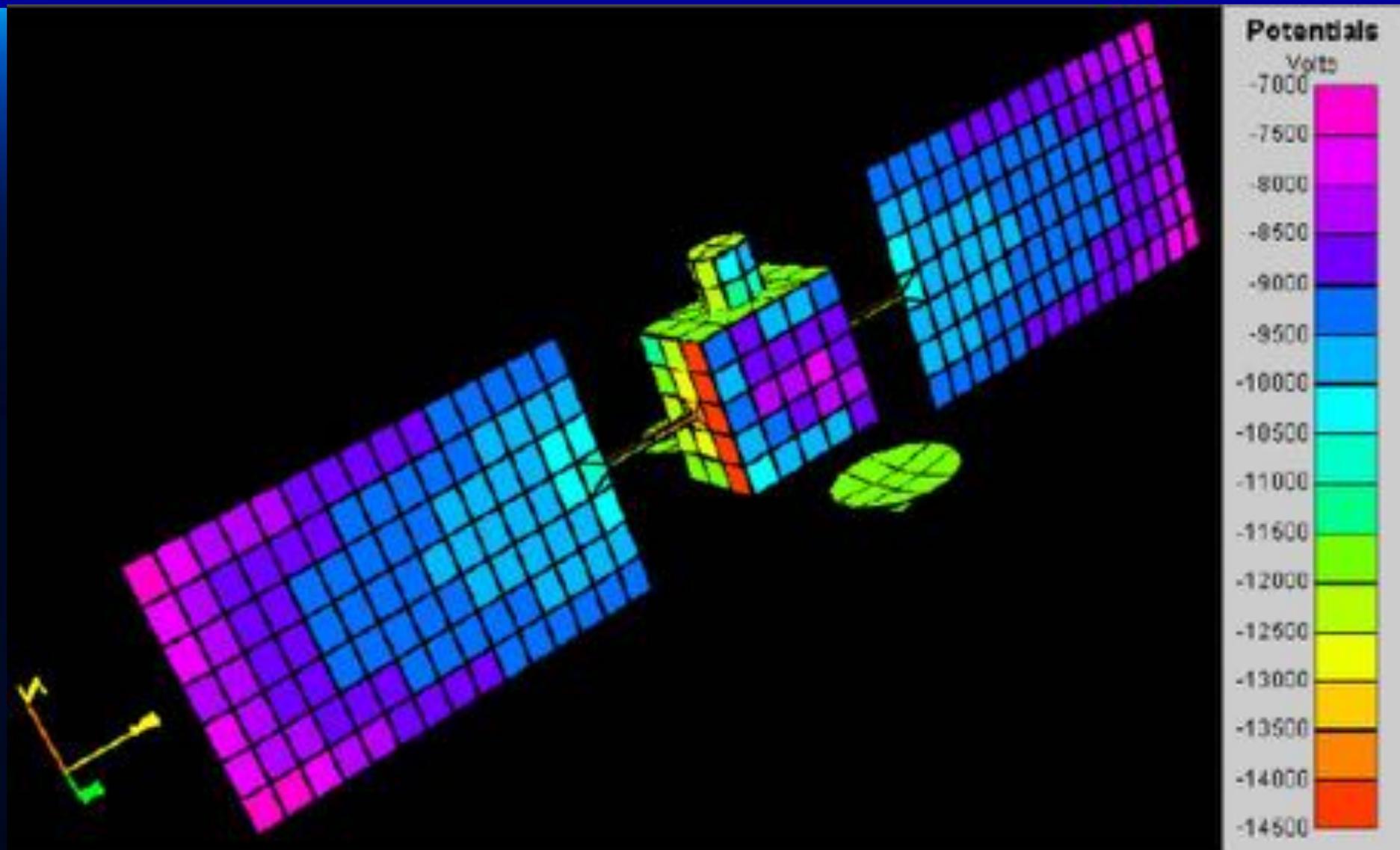


Example - Charging History from Nascap-2k





Example - Surface Charging from *Nascap-2k*

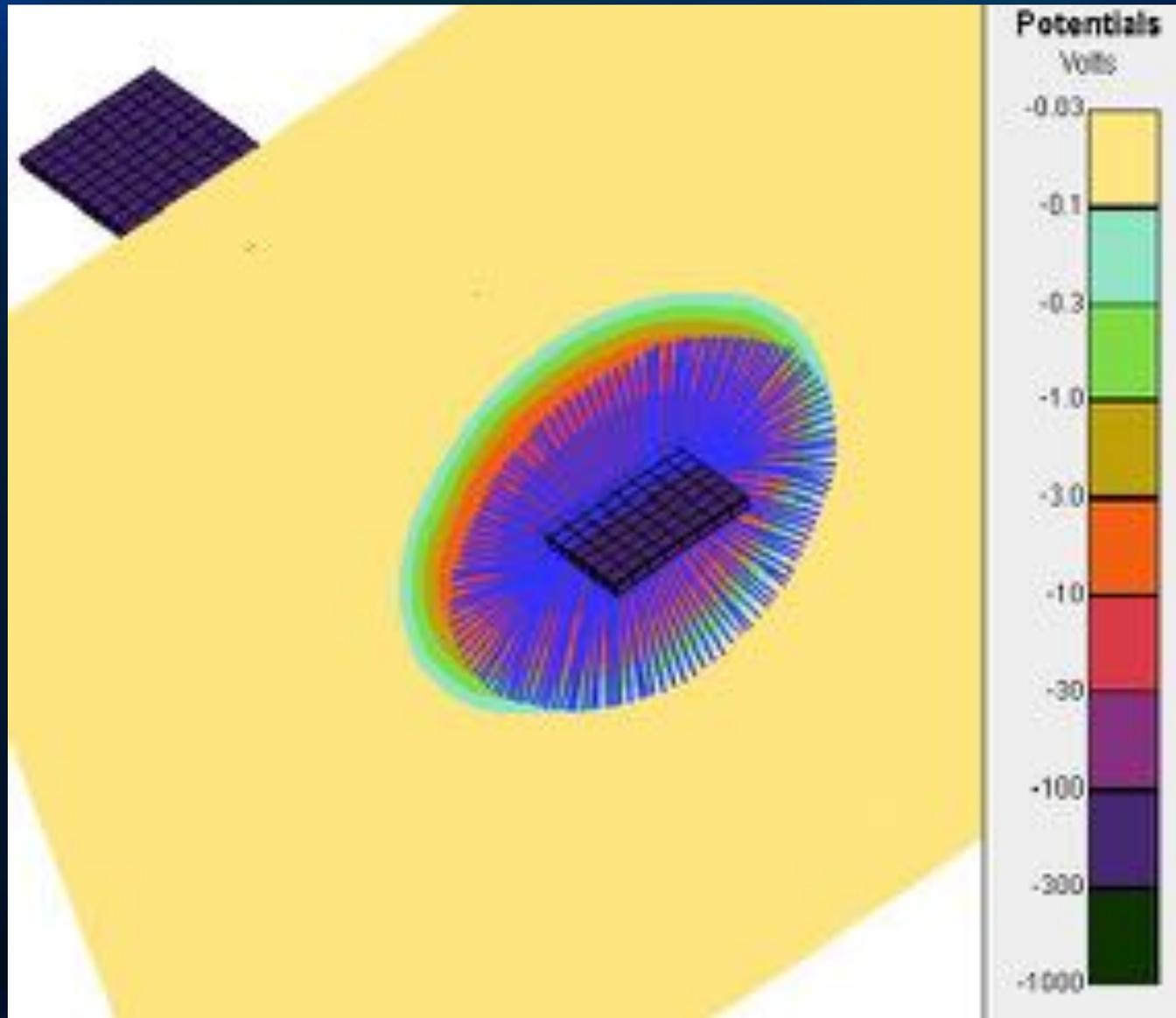


Distribution A: Approved for public release; distribution unlimited



3-D Results Display

Surface Potentials, Space Potentials, and Ion Trajectories



Distribution A: Approved for public release; distribution unlimited



Geosynchronous Orbit Charging Environment and Timestepping Specifications



File Edit View Materials Help

Problem Environment Applied Potentials Charging Space Potentials Particles Script Results Results 3D

GEO Environment

Geo Environment Plasma

Worst Case

Maxwellian

Electron Density (m^{-3}): 1.120E6

Electron Temperature (eV): 1.200E4

Ion Density (m^{-3}): 2.360E5

Ion Temperature (eV): 2.950E4

Electron Current (Am^{-2}): 3.289E-8

Ion Current (Am^{-2}): 2.536E-8

Magnetic Field (T)

Bx: 0.0 By: 0.0 Bz: 0.0

Sun

Direction to Sun

X: 1.000 Y: 0.0 Z: 0.0

Relative* Sun Intensity: 1.000
*(value of spacecraft) / (value of Earth Orbit)

Use photoionization spectra

Charging Time

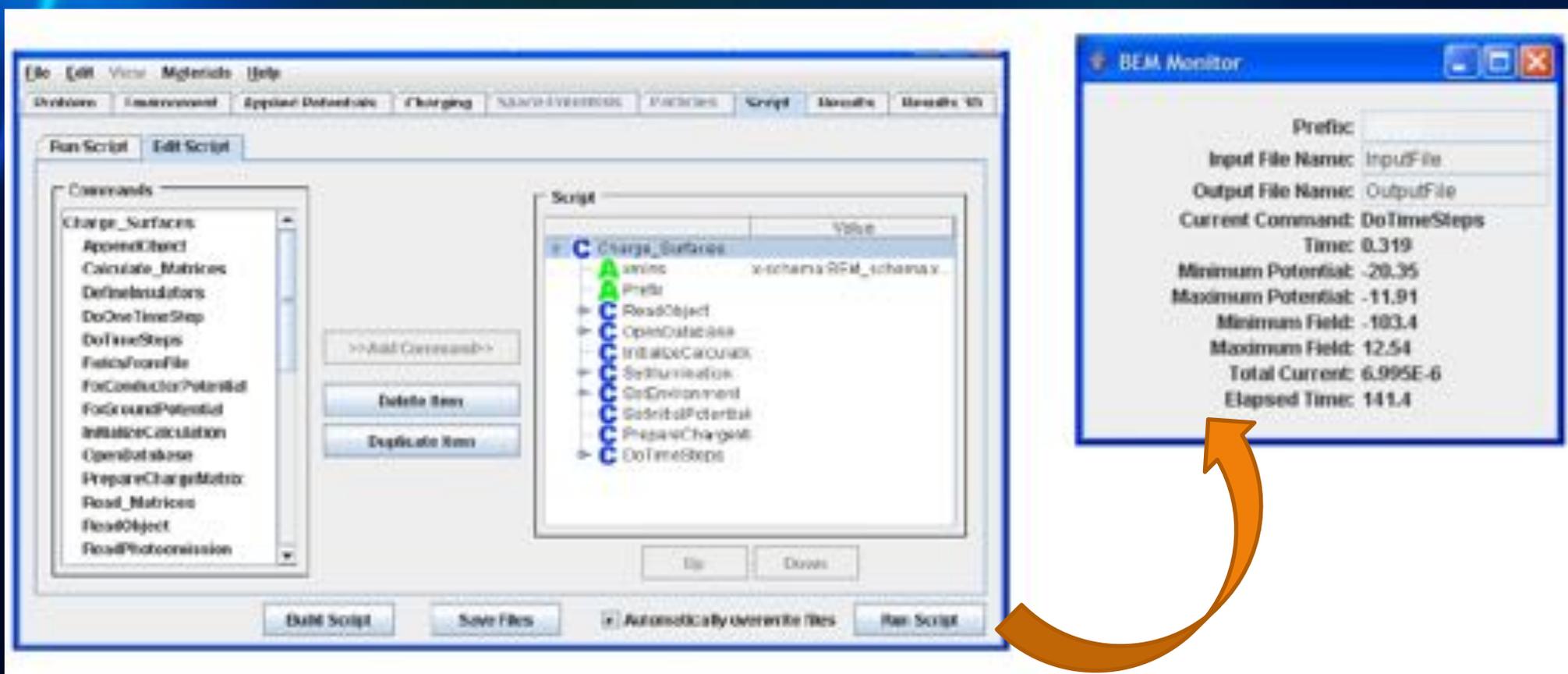
Start Time (sec): 0.0 End Time (sec): 2000

Min Timestep (sec): 0.100 Max Timestep (sec): 50

Number of Timesteps*: 45
*(Use only for Analytic Currents)

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

Geosynchronous Orbit Charging

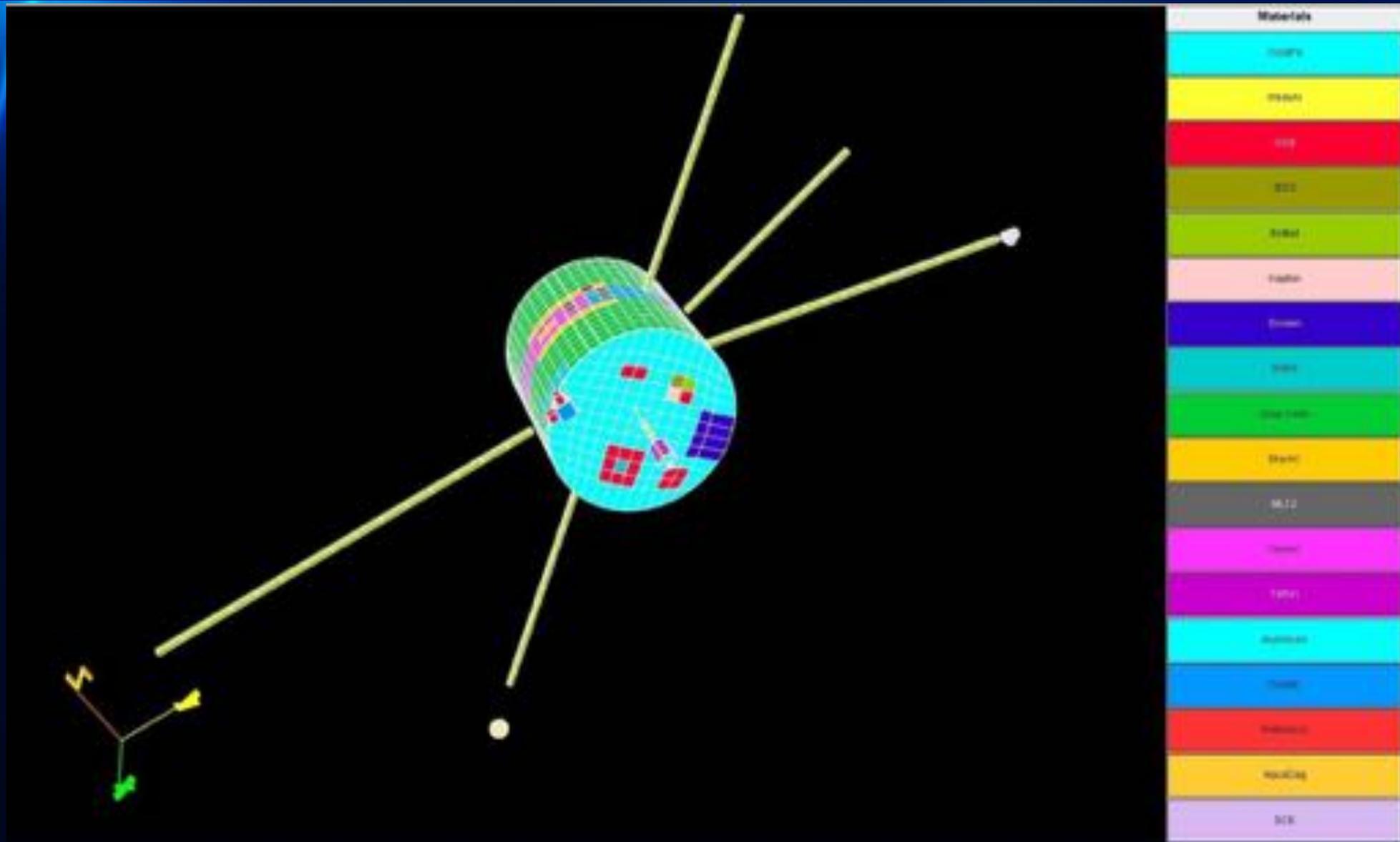


- Script (automatically generated) specifies calculation steps
 - Script can be edited internally or externally
 - **Can do eclipse entry and exit, dynamic plasmas, spacecraft rotation, distributed array voltage**
- Monitors progress of calculation
- Results in ~10 minutes on workstation



Example - Charging of Spinning Spacecraft

Nascap-2k Model of SCATHA



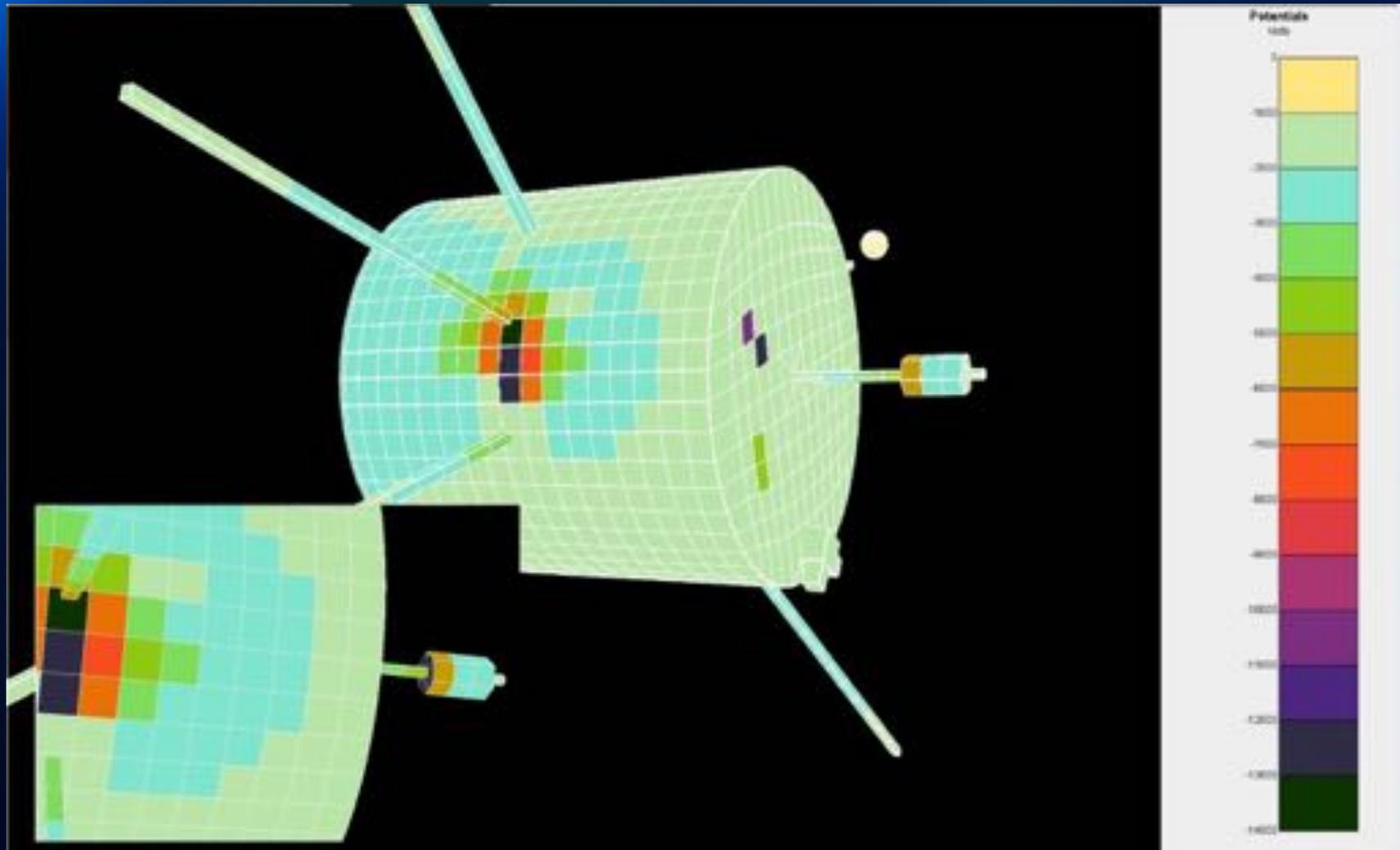
False color *Nascap-2k* surface-materials model of SCATHA

Distribution A: Approved for public release; distribution unlimited



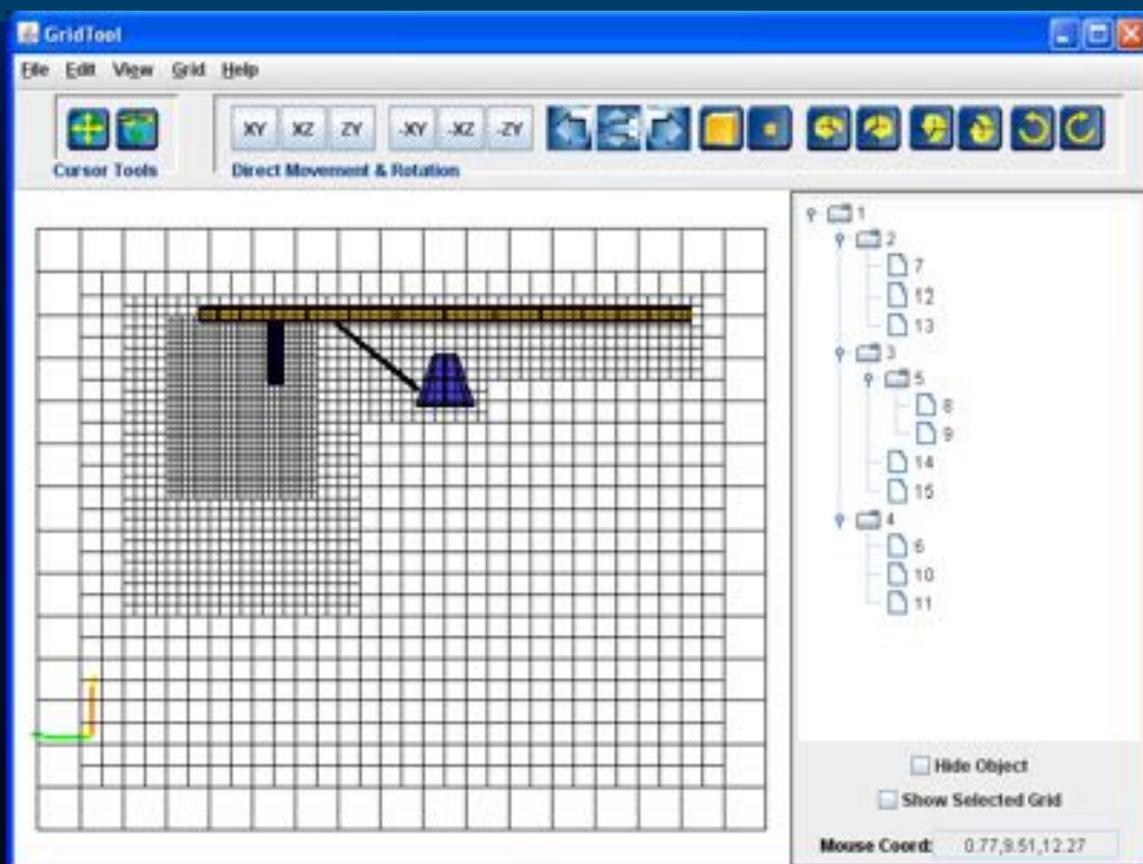
Charging of Spinning Spacecraft

Nascap-2k Results for SCATHA

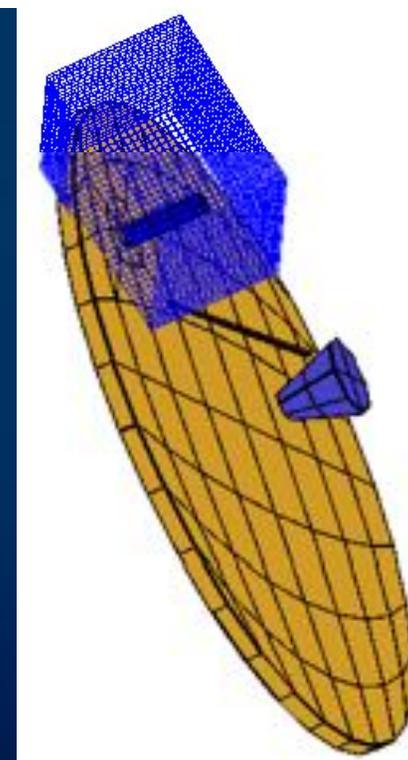


Potentials after 2010 seconds, ATS-6 environment, rotating at 1 rpm. Inset at lower left shows the bottomside of the Teflon cylindrical antenna cover, from which ions are partially blocked

Example - LEO Current Collection Spatial Gridding with *GridTool* *Charging Hazards and Wake Studies Experiment (CHAWS)*



Fine resolution around probe and near edge of disk

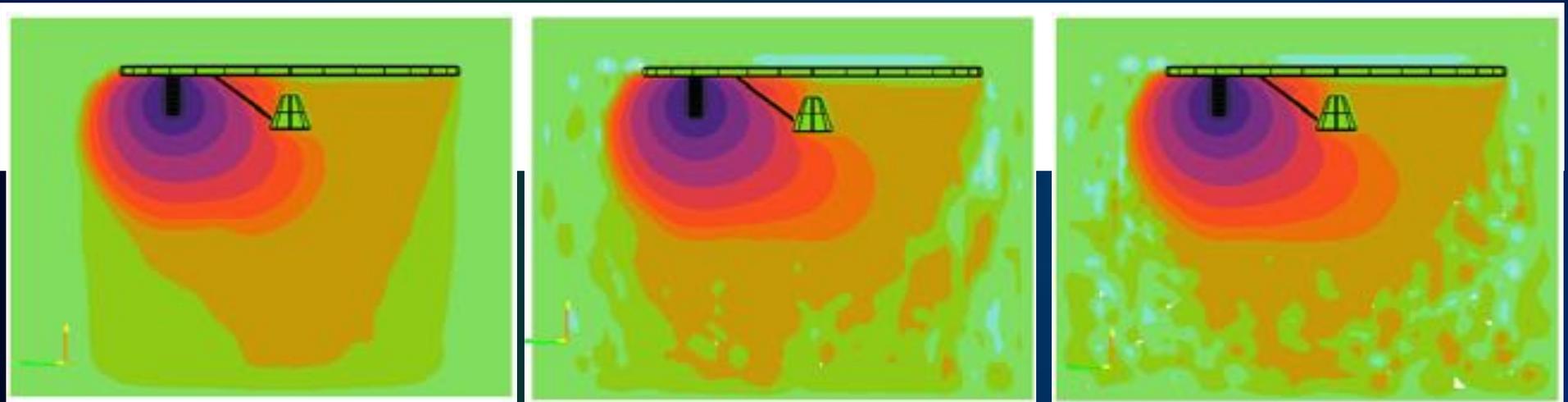


Multiply nested cubic grids with “special” elements containing object for computational speed

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)

Macroparticles carry current

Share *current* \times *sub-step time*
to grid *each sub-step*

10 iters (with sharing) in 2 hours

Particle-in-Cell (dynamic)

Macroparticles carry charge

Share *charge* to grid at end of
timestep

900 2- μ s timesteps in 140 hours

Orbit averaged

Macroparticles carry charge

Share *charge* \times $\frac{\textit{sub-step time}}{\textit{timestep}}$
to grid *each sub-step*

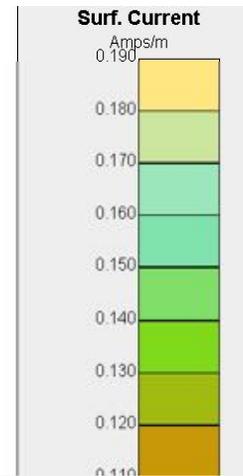
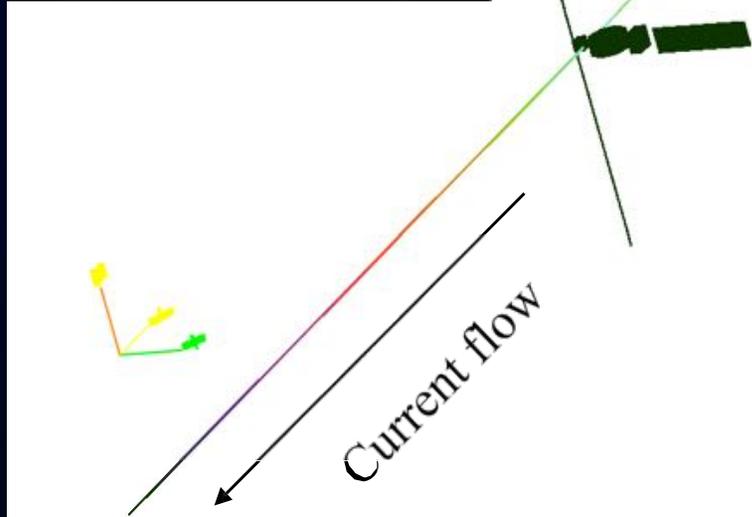
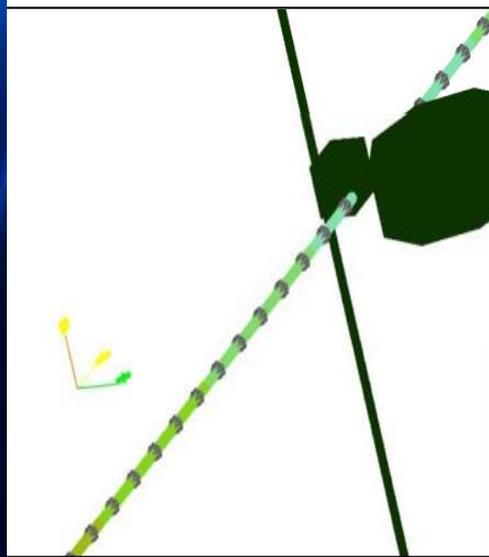
90 20- μ s timesteps in 12 hours

Potentials in Thruster Plumes

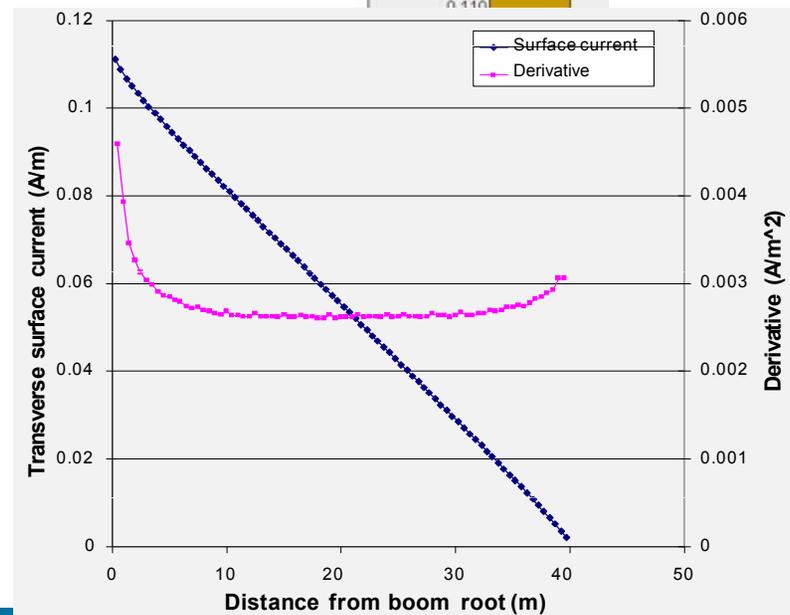
- Thruster plumes
 - Produce potentials that modify contaminant trajectories
 - Produce charge-exchange ions that lead to enhanced plasma density around the spacecraft
 - Interact with spacecraft surfaces
 - Interact with other thruster plumes
- Import plume ion densities from external file
 - Densities 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>