COMPARISON OF THE NASCAP/GEO, SEE INTERACTIVE CHARGING HANDBOOK, AND NASCAP-2K.1 SPACECRAFT CHARGING CODES

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Abstract: *The NASA Charging Analyzer Program (NASCAP) spacecraft charging software developed by Maxwell Technologies has been widely used for the past fifteen to twenty years in satellite design and investigation of spacecraft charging related anomalies. NASCAP/GEO, the version used for geostationary orbiting satellites, solves the Poisson-Vlasov system for currents and densities taking into account the limited speed and memory of computer systems standard for the day. In addition, use of this charging model requires individual input files that are not readily transported into the various families of charging codes to facilitate comparison of results by the user.*

This paper presents comparison of spacecraft charging results obtained for a hypothetical satellite using the current versions of NASCAP/GEO, SEE Handbook, and NASCAP 2K/GEO. The model satellite is constructed of materials typically used for building geosynchronous satellites. Comparison of the codes is accomplished by using the same hypothetical satellite model in all three charging codes. Differences and similarities of the resulting output for each of the three codes will be presented, along with a discussion of the computational efficiency and ease of use for each of the codes.

1.0 Introduction

For over twenty years, the NASA / Air Force Charging Analyzer Program (NASCAP) has been one of the primary tools available to scientists and engineers for predicting the charging of spacecraft surfaces at geosynchronous altitudes. Because of its validation using flight data and long history of acceptance by the spacecraft charging community, it is the yardstick to which two new charging programs will be compared.

The release of the Space Environments and Effects (SEE) Handbook charging code, along with the recent development of NASCAP 2K/GEO, are two significant new contributions to the suite of charging analysis programs available to the spacecraft charging analyst. The SEE Handbook was written for multi-platform usage using a web browser as the computer interface. The SEE Handbook uses a simplified charging model and incorporates single and multiple material routines for geosynchronous and polar orbits. In addition, software is included to estimate the impact of energetic particles on bulk charging of dielectric materials. NASCAP 2K is the NASA and Air Force charging codes of the future using a highly developed boundary element method of solving for the correct physical environments. It also incorporates a user-friendly three-dimensional object tool kit for building complex satellite models.

This paper will compare and contrast the NASCAP program with two new programs: SEE Interactive Charging Handbook and NASCAP 2K/GEO (beta release). Each program will be discussed including the mathematics used to calculate results. For ease of reading, the paper is divided in three sections corresponding to the three programs. Each program will be used to evaluate a hypothetical satellite design. Comparison of the results will take place in a further section.

2.0 NASCAP/GEO Model Description

NASCAP development began in the mid- to late- 1970s. In depth discussions of its capabilities can be found in [Katz, et al., 1978]. NASCAP was validated by comparing data to that gathered by the SCATHA (Spacecraft Charging AT High Altitude) (P78-2) [Stannard, et al., 1982]. Spacecraft are modeled in NASCAP in terms of thin booms, parallelepipeds, trapezoids, or flat plates [Mandell, et al., 1984]. The resulting geometrical object must fit within a 16 x 16 x 32 grid. This results in a maximum resolution of 1/32 of the object length. This limitation can be prohibitive when trying to analyze charging effects on small scientific payloads mounted on large geostationary satellites. The object is limited to no more than 1250 surfaces and a maximum of 15 different materials and 15 distinct electrical conductors. These conductors can be connected with either a fixed bias or by capacitive coupling [Stannard, et al., 1982]. It is up to the user to correctly implement the placement of each object, in relation to other building block and in terms of the coding language. For a beginner, defining the model can be the most frustrating part. Time and experience is needed to become proficient.

Figures 1 and 2 show the hypothetical model as it was written in NASCAP/GEO.

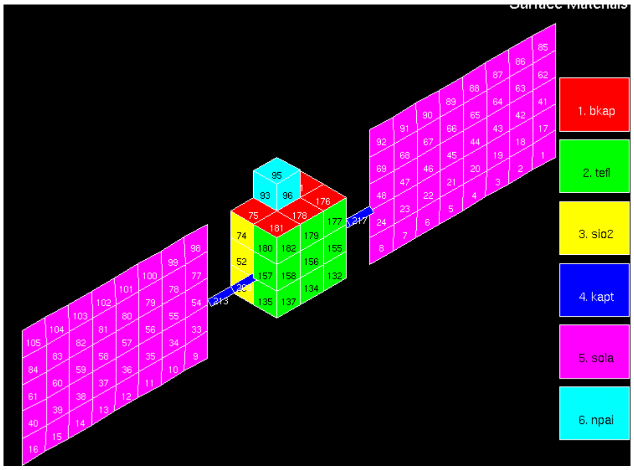

Figure 1. Solar array view of the hypothetical NASCAP/GEO model.

A simple model was specifically chosen so that direct comparisons for all three models could be accomplished. Here bkap is black Kapton®. This is not a predefined material for NASCAP/GEO. However, defining a material is accomplished in the same file as with the model definition and is three lines of input. Tefl is Teflon®. Sio2 is silicon oxide which corresponds to OSR used in the other codes. Kapt is Kapton®. Sola is a NASCAP defined material used on solar arrays. Npaint is a non-conductive paint. A cube covered in the non-conductive paint was used to represent the dish antenna. There is no “dish” in NASCAP and as such, for a one cell wide antenna a rectangle had to be used.

The 90% worst case environment as given in Purvis, et al., [1984] and shown in Table 1 was used for the charging runs in this paper. The charging time used with in NASCAP/GEO is on the order of 6700 seconds. It took the program one hour and thirty minutes to run on an antiquated Sun Sparc.

	Temperature (keV)	Density (cm^{-3})
Ions	29.5	.236
Electrons	12	1.12

Table 1. 90% worst case environment for geosynchronous orbits used for all charging runs as defined in Purvis, et al., [1984].

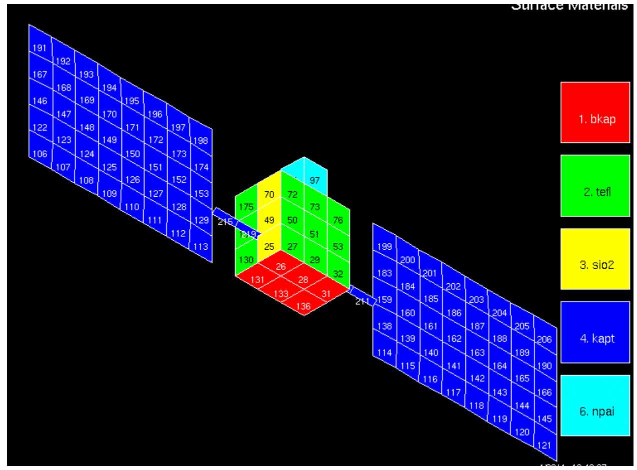

Figure 2. View of hypothetical satellite in NASCAP/GEO highlighting the eclipse side view.

The net electrical currents to the spacecraft surface are calculated from the various charged particle fluxes (including backscattered particles, secondary electrons, and photoelectrons). Over an interval of time, these currents cause the accumulation of charge. This resultant surface charge distribution is used to calculate the surface potentials and fields on the object.

NASCAP utilizes a finite element method to calculate the potential in three-dimensions around the object. A conjugate gradient method is used to solve Poisson's equation to determine the surface potentials [Katz, et al., 1977].

3.0 SEE Handbook Model Description

The Spacecraft Charging Interactive Handbook (referred herein as the SEE Handbook) was developed by SAIC (formerly Maxwell Technologies Systems Division) for the NASA Space Environments and Effects Program (SEE Program) Office at the George C. Marshall Space Flight Center (http://see.msfc.nasa.gov/). The purpose of the Handbook is to provide a compilation of the most up-to-date information on spacecraft charging as well as updated design guidelines. A web browser-based model, it is intended for spacecraft designers and spacecraft charging researchers. [Maxwell, 1998] The SEE Handbook provides an update to charging guidelines contained in Purvis, et al. [1984] and interactive spacecraft charging calculation tools for initial assessment of spacecraft design. These tools include calculations for both surface and deep dielectric charging. [Gardner, et al.] The hypothetical model written with the SEE Handbook can be seen in Figure 3. Charging time was 5000 seconds with timesteps of ten. It took less than two minutes for this program to complete on a 486/32 MB of RAM personal computer.

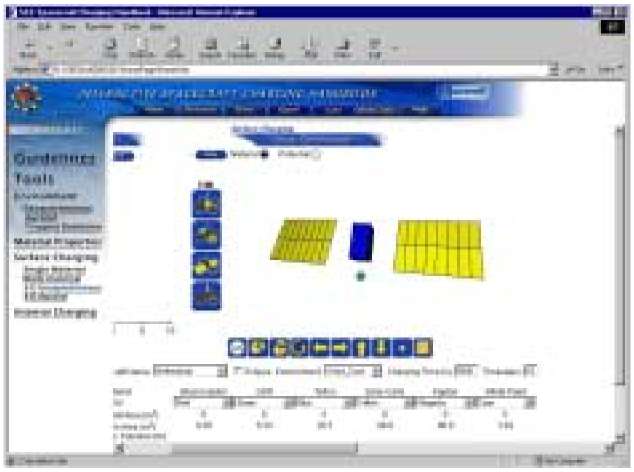

Figure 3. View of SEE Handbook hypothetical satellite highlighting the solar cells view.

4.0 NASCAP 2K/GEO Model Description

NASCAP 2K/GEO is a model now under development by SAIC (formerly Maxwell Technologies Systems Division). It is the natural counterpart of the SEE Handbook and a complete overhaul of NASCAP/GEO. NASCAP 2K/GEO uses the boundary element method (BEM) to solve the spacecraft surface charging algorithms by using Green's function. Using Green's function allows the ability to construct equations with electric fields on all elements. Also, Green's function is able to relate potentials and field due to sheet of charge.

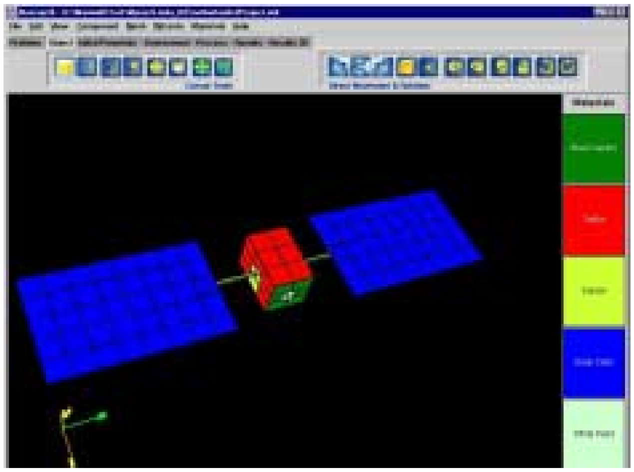

Figure 4. View of hypothetical satellite in NASCA 2K/GEO highlighting the solar cell view.

The modeling capabilities of NASCAP 2K/GEO are easy for the user to comprehend, while providing enhanced geometrical (such as the allowance of curved surfaces) and field solution sophistication. Figures 4 and 5 show the same model as in Figures 1 and 2, built in NASCAP 2K/GEO. NASCAP 2K/GEO utilizes a screen driven JAVA interface. There is no size limitation to the spacecraft (recall the 16 x 16 x 32 grid size for NASCAP/GEO). There is a three-dimensional interactive design, which allows the user instant feedback with the spacecraft model. The code had a charging time of 6000 seconds with 100 timesteps. It took approximately fifteen minutes on a 486/32 MB RAM personal computer.

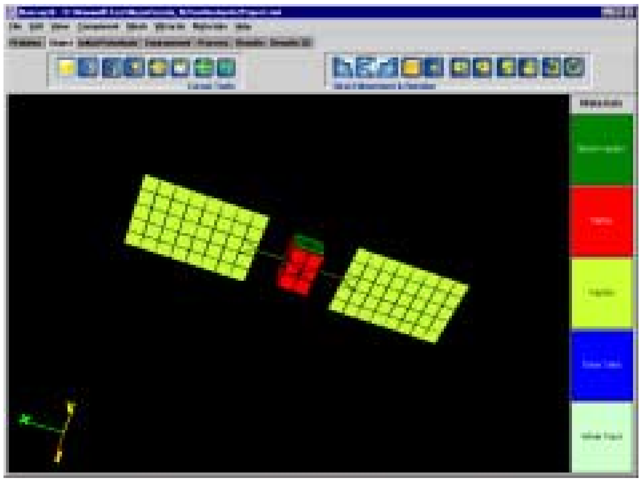

Figure 5. View of hypothetical satellite in NASCAP 2K/GEO highlighting the eclipse side view.

5.0 Comparison of NASCAP, SEE Handbook, NASCAP 2K Results

For the NASCAP/GEO run, the sunlit side (sun incident normal to the solar arrays), the solar cells charged anywhere from –10.5 kV on the edges to –8.5 to –9.5 kV directly in the center going outward, respectively. Figure 6 shows the potentials for the sunlit side. Directly on the opposite side of the solar arrays, the Kapton® in darkness charged from –16 kV on the edges to –18.5 kV in the center. This is illustrated in Figure 7. The strip of SIO2 (OSR in the other charging analyses) charged 2 kV less negative than the adjacent Teflon® (-13 kV and –15 kV, respectively). The black Kapton® faces of the spacecraft body were –6.5 kV and they were partly exposed to sunlight. The Teflon® in sunlight was approximately –8.5 kV, while on the eclipse side, it charged to –15 kV. This shows the strong influence of the photoelectron effect in geosynchronous orbits. Ground was –6.3 kV. The largest differential charging levels were between ground and the Kapton® side of the solar arrays, those being 12 kV.

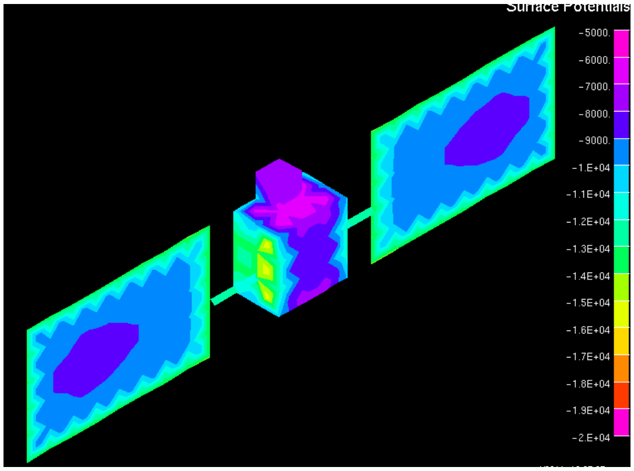

Figure 6. NASCAP/GEO charging results. Shown are the potentials on the sunlit side of the solar arrays and spacecraft body. The largest potential is –10.5 kV.

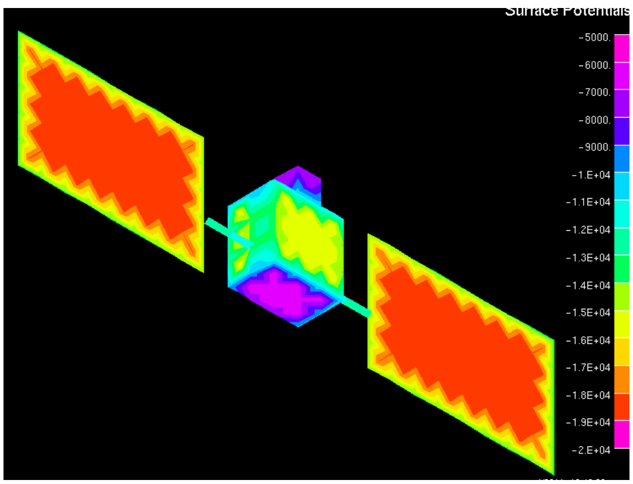

Figure 7. NASCAP/GEO charging results. Shown are the potentials on the eclipse side of the solar arrays and spacecraft body. The largest potential is –18.5 kV.

The SEE Handbook charging run was 5000 seconds. It took less than two minutes for the code to run. Spacecraft ground charged to –4.5 kV. The sunlit side show the solar cells charging from –2 kV at the far ends to –3 kV closest to the spacecraft. The spacecraft on the sunlit side charged to –4.5 kV, while in eclipse it charged to –7 kV. The Kapton® side of the solar arrays also charged to –7 kV. Figures 8 and 9 show the potential charging results from this run.

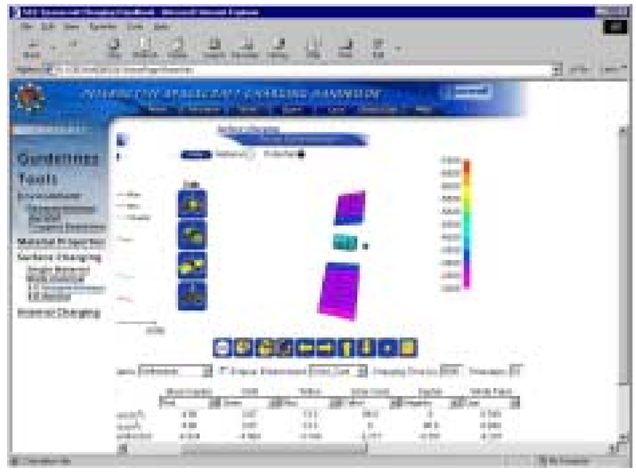

Figure 8. SEE Interactive Charging Handbook charging results. Shown are the potentials on the sunlit side of the solar arrays and spacecraft body. The largest potential is –3 kV.

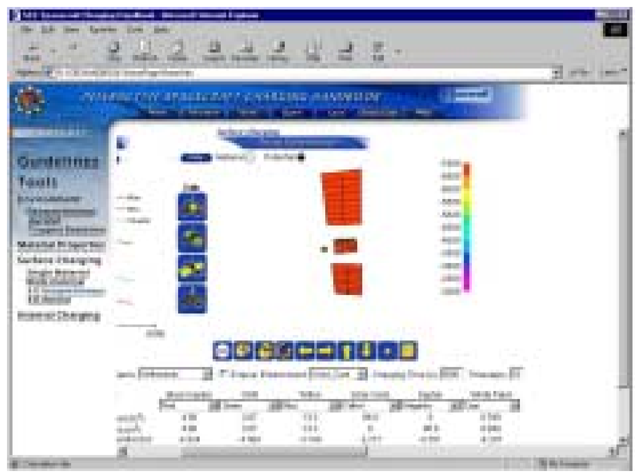

Figure 9. SEE Interactive Charging Handbook charging results. Shown are the potentials on the eclipse side of the solar arrays and spacecraft body. The largest potential is –7 kV.

For the NASCAP 2K/GEO run, the solar cells charged between –11 kV to –15 kV in the middle, to -17 kV closest to the spacecraft. While the Kapton® side of the solar array charged –22.5 kV. The spacecraft body charged from –16.5 kV in sunlight to –20.5 kV in darkness. These results are in the same region as the NASCAP/GEO results, albeit more negative. Figures 10 and 11 show the potential results for this run for the front and back sides, respectively.

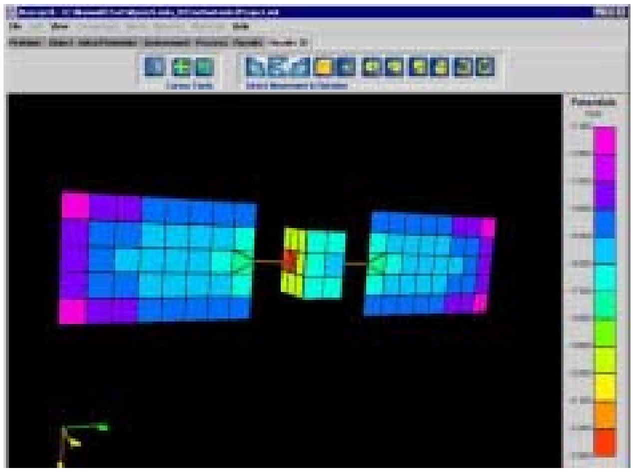

Figure 10. NASCAP 2K/GEO charging results. Shown are the potentials on the sunlit side of the solar arrays and spacecraft body. The largest potential is –17 kV.

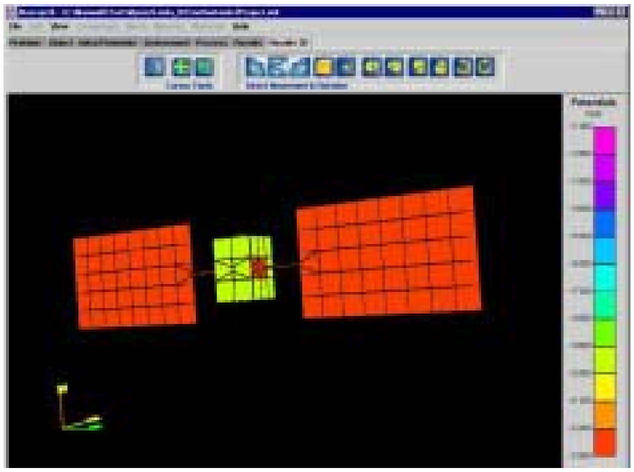

Figure 11. NASCAP 2K/GEO charging results. Shown are the potentials on the eclipse side of the solar arrays and spacecraft body. The largest potential is –20.5 kV.

6.0 Conclusion

For the same model, the three charging codes all show charging in the kilo volt range. The SEE Handbook shows the most modest charging levels of –2 kV in sunlight to –7 kV in eclipse, thereby creating a differential level of approximately 5 kV from front to back. NASCAP/GEO showed charging of –9 kV on the solar arrays to –18 kV on the eclipse side. Ground was –6.3 kV, which yields a 12 kV differential charge. The Beta version of NASCAP 2K/GEO had the largest absolute charging of –11kV in sunlight and –22 kV in eclipse, yielding a differential charging level from front to back of 11 kV. The larger absolute levels for this model concurs with the idea that NASCAP/GEO did not charge to as high of levels as would actually be seen by the spacecraft [Katz, private communication, 1999].

The results from both the SEE Handbook and NASCAP-2K/GEO were similar to those of NASCAP for this particular spacecraft. Although further validation is warranted, it appears that the SEE Handbook provides credible initial estimate answers for spacecraft designers. Results are within a factor of 2 of NASCAP and its ease of operation as well as available guidelines and multi-platform compatibility make this an excellent program for a cursory analysis to see if a possible charging problem may exist.

Users looking for more detailed analyses can utilize the NASCAP 2K/GEO program. Again, the NASCAP 2K/GEO results were similar to NASCAP/GEO. By far, the ease of modeling the spacecraft in NASCAP 2K/GEO is a marked improvement from that of NASCAP/GEO. Also, the interactive three dimensional graphics capabilities of NASCAP 2K cut down the modeling iterations dramatically. NASCAP 2K/GEO is an exciting prospect for spacecraft charging modeling for the years to come.

Acknowledgements

This work was supported in part (LFN and JIM) by NASA Contract NAS8-00187 to Sverdrup Technology, Inc.

Contacts

If you would like a copy of or more information for either the SEE Interactive Charging Handbook or NASCAP-2K.1, please contact Mr. Jody Minor of the SEE Program Office at 256-544-4041/jody.minor@msfc.nasa.gov.

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