

# AN EDUCATIONAL MULTIMEDIA PRESENTATION ON THE INTRODUCTION TO SPACECRAFT CHARGING

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## **Background**

Over the last few decades, significant knowledge has been gained in how to protect spacecraft from charging; however, the continuing technical advancement in the design and build of satellites requires on-going effort in the study of spacecraft charging.

A situation that we have encountered is that not all satellite designers and builders are familiar with the problem of spacecraft charging. The design of a satellite involves many talented people with diverse backgrounds, ranging from manufacturing and assembly to engineering and program management. The complex design and build of a satellite system requires people with highly specialized skills such that cross-specialization is often not achievable. As a result, designers and builders of satellites are not usually familiar with the problems outside their specialization. This is also true for spacecraft charging. Not everyone is familiar with the definition of spacecraft charging and the damage that spacecraft charging can cause. Understanding the problem is an important first step in getting everyone involved in addressing the appropriate spacecraft charging issues during the satellite design and build phases.

To address this important first step, an educational multimedia presentation has been created to inform the general engineering community about the basics of spacecraft charging. The content of this educational presentation is based on relevant published technical papers. The presentation was developed using Macromedia Flash. This software produces a more dynamic learning environment than a typical 'slide show', resulting in a more effective learning experience. The end result is that the viewer will have learned about the basics of spacecraft charging.

This presentation is available to the public through our website, [www.dplscience.com](http://www.dplscience.com), free of charge. Viewers are encouraged to pass this presentation to colleagues within their own work environment.

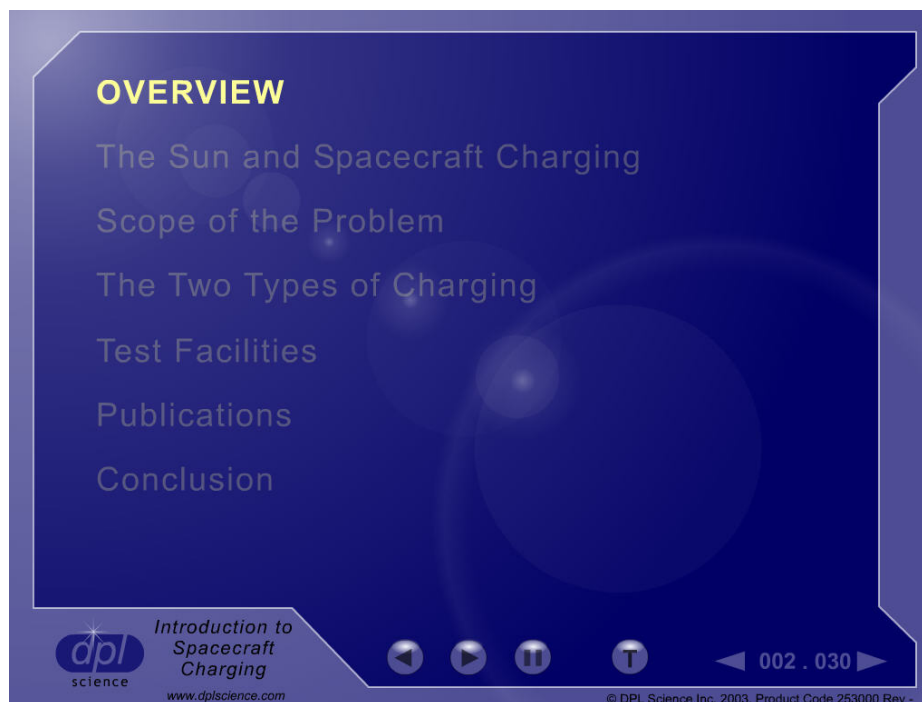
This paper describes the content of the multimedia presentation.

## Description of the Presentation

Macromedia Flash was selected as the software tool for this presentation due to its powerful animation capability and its ability to support different media (CD, DVD, Video and Internet). The software allowed us to create the presentation as a stand-alone unit by combining text, pictures, video and audio tracks. We were able to successfully illustrate key points by maximizing the visual content and synchronizing the visual images with the audio track, resulting in an effective learning experience.

The information presented was gathered from various technical sources. A listing of these sources is provided at the end of this paper and includes the Canadian Space Agency, the European Space Agency, and NASA. Technical reviewers included Mr. Richard Adamo (SRI International), Dr. Keith Balmain (University of Toronto), and Mr. Jody Minor (NASA SEE Program). We are grateful for their comments.

The presentation is divided into six major sections. Figure 1 is a snapshot taken from the presentation, identifying the six sections.



**Figure 1. The six major sections of the presentation.**

### **Section 1: The sun and spacecraft charging**

The presentation begins with a description of the sun and its role in spacecraft charging. We introduce the concepts of sunspot cycle, flares and eruptions, coronal mass ejection, solar wind and high-energy particles. Figure 2 is a snapshot taken from this section, comparing the size of the earth to that of a typical solar flare. The objective of this section is to explain to the viewer that the sun is the main contributing factor to the existence of high-energy particles and that the

presence of these high-energy particles is one of two primary reasons why spacecraft charging occurs.



**Figure 2. A snapshot from Section 1 of the presentation, showing the size of a typical solar flare compared to the earth. (Photo credit NASA)**

## **Section 2: Scope of the Problem**

The second section focuses on the scope of the spacecraft charging problem. By ‘scope of the problem’, we aim to define the causes of spacecraft charging and hence explain why charging occurs. Spacecraft charging can exist because of the following situations:

- high-energy particles found in the natural space environment plus the existence of ungrounded metal, or
- high-energy particles found in the natural space environment plus the use of dielectric material.

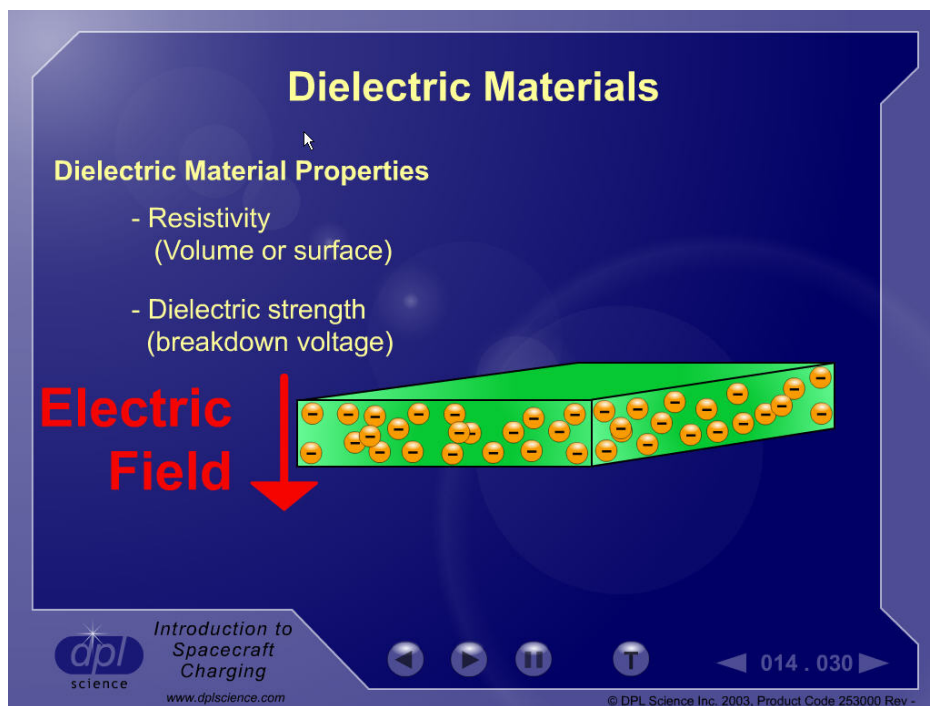
The three components (high-energy particles, ungrounded metal and dielectric material) are then discussed.

The discussion on high-energy particles was presented in Section 1 so that only a brief summary is made here.

The discussion on ungrounded metal essentially advises the viewer that floating metal should be avoided. We emphasize that discharges from a floating metal can be more powerful than a

discharge from a dielectric because more electrons are involved in the discharging process, due to the high mobility of electrons in a conductor.

The discussion on dielectric material is the heart of this section. We explain that dielectric materials are abundantly used in spacecraft design and that their use cannot be avoided. The viewer learns that the unavoidable use of dielectric materials in spacecraft design is the other primary reason why spacecraft charging exists. Since it is necessary to use these materials, we need to understand their properties and behaviour. We introduce the concepts of resistivity and dielectric strength. Figure 3 is a snapshot taken from this section, illustrating the concepts of resistivity and dielectric strength. We explain that the continuing technical advancement in the design and build of satellites means that we cannot take previously used materials for granted. This includes commonly used materials such as Second Surface Mirrors, Sunshields and Thermal Blankets. We emphasize that the constant evolution in spacecraft design and technology implies that spacecraft designers must always be mindful about what dielectric materials are being used and where.



**Figure 3. A snapshot from Section 2 of the presentation, illustrating the concepts of resistivity and dielectric strength.**

Discharge effects are described briefly and include physical damage to the material and electromagnetic effects.

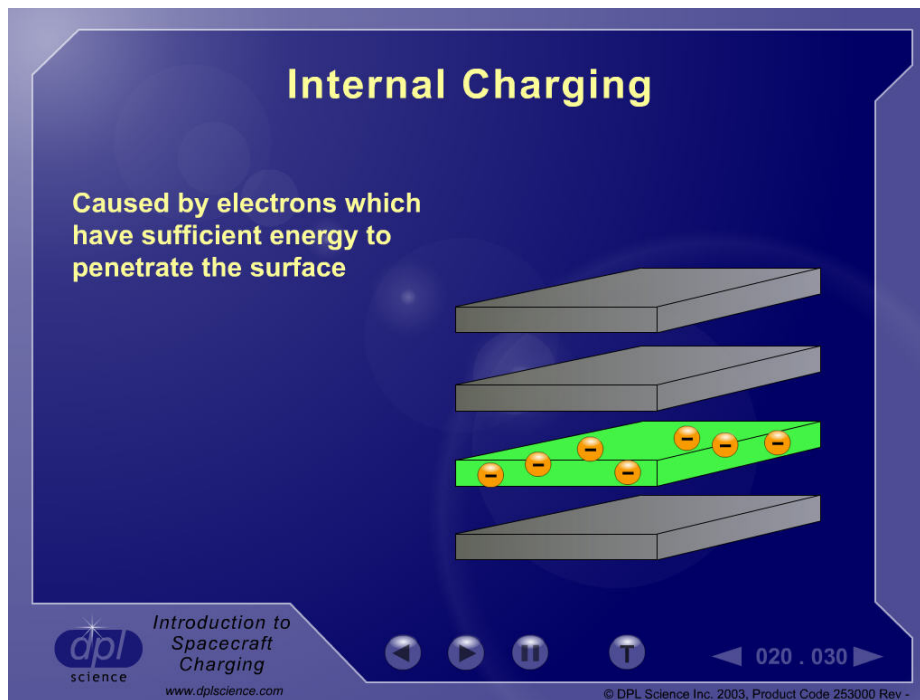
The section ends with a positive note: reference is made to the role of the Spacecraft Charging Specialist and how this technical authority can help in the mitigation and prevention of spacecraft charging and its effects.

### Section 3: The Two Types of Charging

The third section describes the two types of charging: surface charging and internal charging. The objective is to differentiate the two and to explore ways in which the charging can be minimized.

We begin with the definition of surface charging and proceed to the design techniques to prevent surface charging. A simplified summary of some of the design guidelines found in NASA Technical Paper 2361 (Ref [11]) is presented to the viewer.

Next, we present the definition of internal charging and the design techniques to prevent internal charging. Figure 4 is a snapshot taken from this section, illustrating the meaning of internal charging. A simplified summary of the design guidelines found in NASA Handbook 4002 (Ref [9]) is presented to the viewer.

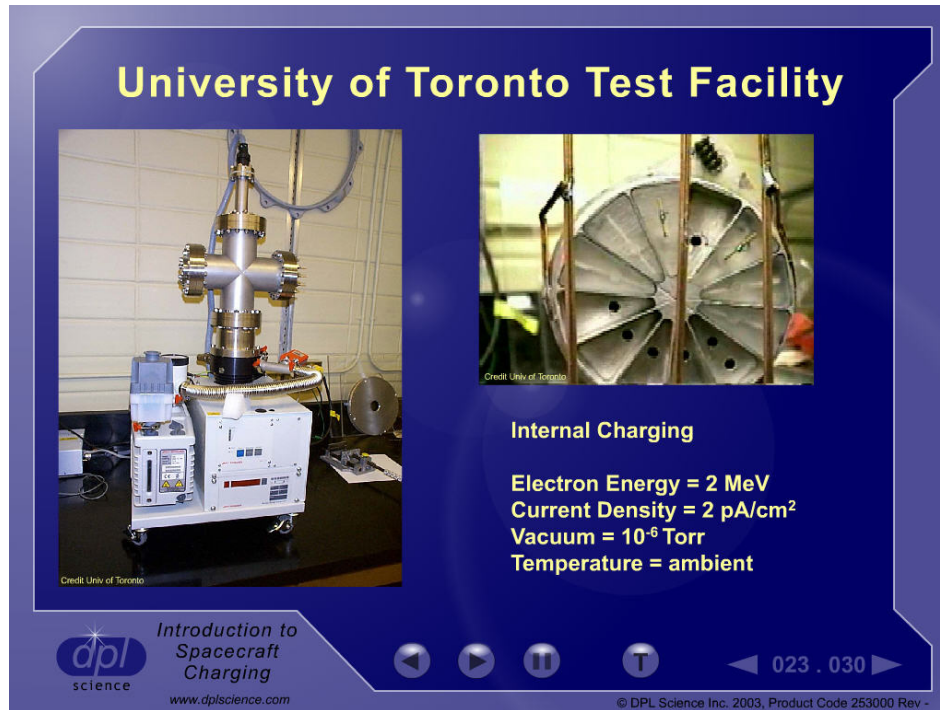


**Figure 4. A snapshot from Section 3 of the presentation, illustrating the meaning of internal charging.**

Since the selection of dielectric material will not always conform to the guidelines, we also look at the use of tests and analyses as methods of validating the choice of a dielectric material. Spacecraft charging tests and analyses are rarely straightforward and we identify some of the difficulties that are frequently encountered: lack of proper information on dielectric material properties (resistivity values over temperature, dielectric strength values), inaccuracies in the characterization of the space environment, limitations of a test set-up, uncertainty in the sensitivity of the victim circuit, etc.

## Section 4: Test Facilities

The fourth section includes photographs of two spacecraft charging test facilities: SRI International in Palo Alto, California and the University of Toronto in Canada. The authors had the opportunity to work with Mr. Adamo and Dr. Balmain in past projects and were pleased to be able to include descriptions of their facilities in this presentation. Figure 5 is a snapshot taken from this section, showing Dr. Balmain's internal charging test set-up at the University of Toronto. This section gives the viewer a look at the practical aspects of spacecraft charging work, complementing the previous theoretical sections.



**Figure 5. A snapshot from Section 4 of the presentation, with a look at Dr. Balmain's internal charging test set-up.**

## Section 5: Publications

The fifth section directs the viewer to some excellent publications available for further study. Figure 6 is a snapshot taken from this section, showing some of the suggested publications. We wished to emphasize to the viewer that this presentation is only a general introduction to the topic of spacecraft charging and that there are many articles and documents available for further reading.





**Figure 6. A snapshot from Section 5 of the presentation, with a look at some of the suggested publications.**

## **Section 6: Conclusions**

The conclusion re-iterates the need for some of the on-going work in the field of spacecraft charging, namely: studies on the changing space environment and the characterization of dielectric material properties. Figure 7 is a snapshot taken from this section, reviewing the need to have more information on dielectric material properties. We wished to make this emphasis since the definition of the space environment and the identification of dielectric material properties have immediate impact on the ability to accurately assess spacecraft charging effects for any satellite program.




**Figure 7. A snapshot from Section 6 of the presentation, emphasizing once again the need to have more information on dielectric material properties.**

When played from start to end, the entire presentation will last approximately fifty (50) minutes. The viewer can pause the presentation at any time then resume playing when desired. Re-plays are also possible by using the 'play back' button. The viewer can also directly access a specific part of the presentation by using the Table of Contents feature. Figure 8 is a snapshot of the Table of Contents taken from the presentation.



<b>1. Overview</b> (1:04)	
<b>2. The Sun and Spacecraft Charging</b>	
Space Environment (1:11)	
Solar Flare Size (0:37)	
Coronal Mass Ejection (0:48)	
Solar Wind (0:37)	
Back Entry of Electrons (0:46)	
<b>2. Scope of the Problem</b>	
Spacecraft Anomalies (2:22)	
Why Spacecraft Charging Exists (0:34)	
Natural Space Plasma (2:14)	
Floating Conductor (0:42)	
Dielectric Materials (3:06)	
The Problem (3:00)	
Effect of Discharge (1:25)	
Role of Spacecraft Charging Specialist (3:01)	
	<b>3. Two Types of Charging</b>
	Surface Charging (6:47)
	Internal Charging (5:09)
	<b>4. Test Facilities</b>
	SRI International (2:47)
	Univ of Toronto (3:54)
	<b>5. Publications</b> (2:21)
	<b>6. Conclusion</b> (2:52)
	<b>7. Bibliography</b>
	<b>8. Acknowledgements</b>

**Note:** Duration is indicated in (minutes : seconds).  
Total duration is approximately 50 minutes.

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**Figure 8: The 'Table of Contents' in the presentation.**

### Conclusion

An educational multimedia presentation has been created to inform the general engineering community about the basics of spacecraft charging. The presentation is a general introduction to the topic and is intended for spacecraft designers, builders and project managers of all disciplines within the satellite industry. Topics covered in the presentation include the Sun and its role in spacecraft charging, the use of dielectric materials in spacecraft design, surface charging, internal charging, basic design guidelines to minimize charging, and spacecraft charging test facilities.

The presentation may be downloaded from our website [www.dplscience.com](http://www.dplscience.com), free of charge. We would appreciate feedback from the engineering community as to the effectiveness of this presentation as an educational tool.

### Acknowledgements

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Mr. Richard Adamo  
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Mr. Larry Harding  
Mr. Jody Minor

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