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## Storms in Space

*Storms in Space* is the story of the exciting and mysterious region between the Earth and the Sun, where violent storms rage unseen by human eyes. Disruption of spacecraft and satellites, television transmission failures, and power blackouts are just a few of the effects of this powerful force of nature, caused by the charged particles and electromagnetic force fields that dominate space.

This is a highly readable synopsis of man's current understanding of the space environment. The book discusses the strong similarities between terrestrial weather and space weather, and goes on to describe the causes and effects of space storms, and how they can be monitored by satellites and from observatories on Earth. The forecasting of storms in space is presented, along with prospects for improved models in the future.

Freeman's compelling story is written in a clear and engaging fashion, accessible to all levels of readership. The book will be valuable to space scientists, physicists, astronomers and anyone with an interest in understanding the phenomenon of space weather.

JOHN FREEMAN is Professor Emeritus and Research Professor of Physics and Astronomy at Rice University, Houston, Texas. His primary research interests include computer modeling of the Earth's magnetosphere for space weather specification and prediction, neural networks and other artificial intelligence applications to forecasting geophysical parameters.

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Foreword by George Siscoe



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## Foreword

John Freeman has done the impossible, written a book on space weather that's a fun read. It's hard enough to create a non-fiction book on regular weather that's a fun read, unless like Sebastian Junger's *The Perfect Storm* it's about people and violence. The genius of John's book is its inventiveness. In it we read a short story that *is* about people and violence and that tells us what space storms are and what they do. We take a whirlwind tour through Earth's space weather machine, called the magnetosphere, riding a proton then an electron. We listen to an interview with Joe Allen, the world's premier archivist of space-weather damage who knows where the bodies are buried. The important facts are here, told by an insider with a talent for telling the significant and discarding the rest.

John's own contribution to space weather will go in history books when the subject grows old enough to have a history. Working with colleagues at Rice University, he developed the first numerical space-weather model to go into operation at a national space weather center. A corresponding event happened in the history of meteorology in 1955, when numerical weather forecasting was inaugurated at the US Weather Bureau (as it was called then). That event led over time to the present highly successful forecasting capability of the National Weather Service (jokes to the contrary notwithstanding). John and his co-workers have put space weather on the same path that, because numerical codes constantly improve through incorporating better physics and better data, leads inevitably to steady improvement.

This book is a masterly blend of the people side and the technical side of space weather. I wish I had written it.

George Siscoe

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### **Dedication**

This book is dedicated to Alexander J. Dessler whose boundless enthusiasm, friendship and insight have inspired a generation of scientists, and also to my loving wife who has been my inspiration for 45 years.



## Preface

The purpose of this book is to provide a brief glimpse of an astounding and beautiful aspect of nature known only to a relative handful of space scientists and yet which is capable of disrupting human technical systems ranging from communication satellites to electric power grids—storms in space.

The problem faced by a specialist writing for a general audience encompasses several challenges: first, he or she must draw connections to everyday experience that lead the reader into the realm of the new phenomenon along familiar and enticing paths; second, the writer must avoid technical jargon and translate the descriptions into understandable word images; and last, the unveiling of new concepts must be layered and progressive as the reader's comprehension matures.

The problem of describing storms in space is doubly challenging because the majority of the phenomenon is invisible to the human eye. This is why little progress could be made studying the phenomenon until the space age when in-situ satellite investigations became possible. It is also why we space physicists are continually jealous of astronomers who can show marvelous images of the objects of their studies.

I have undertaken these challenges, partly because of a desire to explain to my friends what my work is all about, but in a larger sense because I want to share with students and the public some of the awesome beauty of the unseen world of space. A further objective is to foster a general appreciation of the hazards that storms in space represent in order that they may gain some respect as a significant force in nature.

One approach to the first challenge is to draw parallels between storms in space and storms on the Earth. As we shall see, these parallels

X STORMS IN SPACE

are numerous and instructive. At the same time, the differences lead us to a description of elements of nature that may be new to us. The physical elements that make great storms on the Earth are well known to us. The wind and rain, clouds, thunder and lightning, snow, ice and hail all leave no doubt about the presence or imminence of a storm. Even though we can't see the wind we feel its effect on our skin and our clothing, and we see trees sway.

In stark contrast, the elements of a storm in space are unfelt by the human senses. These elements are subatomic charged particles and force fields detectable only by charged particles as they move freely in the vacuum of space. They form a very low-density, almost ethereal, and essentially invisible medium that pervades the vast space near the Earth and beyond. It is somewhat of an enigma that out of this seemingly insignificant medium can grow great storms in space that are capable of wreaking havoc on human systems.

This book is dedicated to revealing the nature of these storms and some of their awesome and dangerous effects.

John W. Freeman