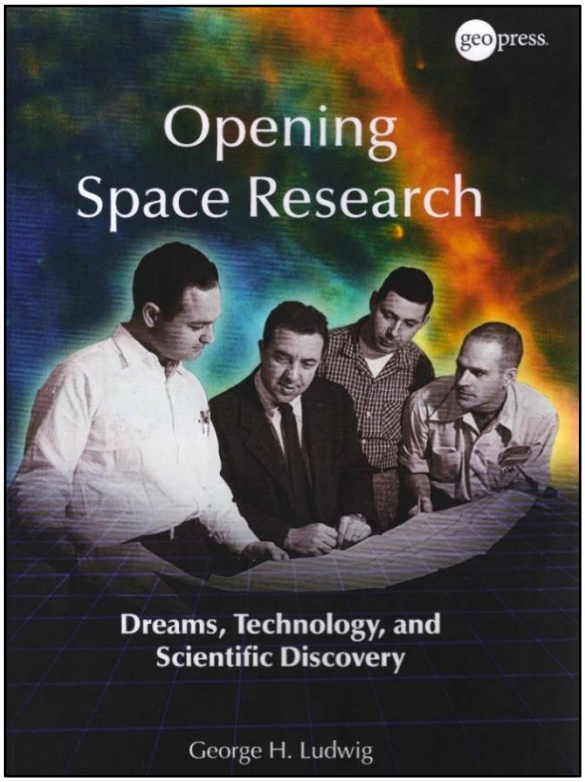
TRANSISTOR MUSEUM BOOK REVIEW
Opening Space Research by George H. Ludwig



Book Cover

The author, Dr. George H, Ludwig, is shown third from left. Caption: "Pondering the early puzzling data from Explorer I. From the left, Carl McIlwain, James Van Allen, George Ludwig and Ernie Ray. March 1958."

Opening Space Research
Dreams, Technology, and Scientific Discovery

Author: George H. Ludwig
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Reviewed by: Jack Ward. December 2014.

TRANSISTOR MILESTONE

WHAT & WHEN

First successful U.S. earth satellite, the Explorer I, launched on January 31, 1958.

THE FIRST TRANSISTORS IN SPACE

Dr. George H. Ludwig, a graduate student at the University of Iowa in the mid-1950s working under the leadership of Dr. James Van Allen, was responsible for designing the cosmic ray instrumentation packages of the first Explorer and Vanguard satellites. Dr. Ludwig provides a highly readable and technically complete account of his pioneering work with very early transistor types and the resultant successful performance of these designs in space.

The successful launch of the Explorer I satellite on January 31, 1958 was the first U.S satellite to achieve earth orbit and was a milestone in the history of space technology. This same timeframe also coincided with the rapidly evolving development of the first transistors capable of performing reliably enough to be considered for use in space environments. George Ludwig, then a graduate student at the University of Iowa in the Radiation Laboratory under the directorship of Dr. James Van Allen, was assigned the task of designing the cosmic ray instrumentation packages for the first Vanguard and Explorer satellites. In this recently published book, George Ludwig provides a "front row" seat to the important events, interesting personalities and emerging space program technologies as he describes the excitement, and ultimate success, of evaluating and using the newly developed transistor types into his design of the cosmic ray satellite electronics. Ludwig's instrumentation packages worked flawlessly in Explorer I and later satellite launches and provided the telemetered data that lead to the discovery of the Van Allen radiation belts. *Opening Space Research* provides a unique, comprehensive and unparalleled view into the earliest days of the U.S. space program and the history of early transistor technology.

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Curator's Introduction

In the late 1990s, when the Transistor Museum first began to develop oral histories of major contributors to the early development of transistor technology, it seemed very appropriate to contact Dr. James Van Allen to best document the use of transistor electronics in the first U.S. earth satellites because of his prominent role in both the Vanguard and Explorer programs. A brief phone discussion with Dr. Van Allen led to an enthusiastic recommendation to contact George Ludwig as the expert on the topic of early satellite transistor electronics. This exchange led to a multi-year highly productive and thoroughly enjoyable series of emails and phone interviews with Dr. George Ludwig, who, as I would soon discover, was indeed qualified to comment on early transistor technology from a very unique perspective – he had been a graduate student in the mid-1950s working under Van Allen's direction at the Cosmic Ray Lab at the State University of Iowa and had been the designer of the first transistorized radiation detection instrumentation to reach orbit. Dr. Ludwig proved to be a supportive, engaging and very thorough interviewee for the Transistor Museum oral history, and provided many documents and personal accounts of his pioneering work in this field. This material was developed and posted online in 2007 as "A Transistor Museum Interview with Dr. George Ludwig: The First Transistors in Space - Personal Reflections by the Designer of the Cosmic Ray Instrumentation Package for the Explorer I Satellite". This oral history has proven to be one of the most popular and highly visited sections of the Transistor Museum and contains photos and technical descriptions provided by Ludwig of the first transistors in space. Use the link above to view the oral history, which also includes audio clips of the museum interviews with Dr. Ludwig. *Opening Space Research* is a much more comprehensive account of the early U.S. space program, and is the subject of this review.

Shown at top is a 1958 photo of George Ludwig in Pasadena with the Explorer I backup satellite. (Photo courtesy of George Ludwig). The second photo is also from 1958 and shows Ludwig holding his newly designed data recorder which performed flawlessly in Explorer III and which contributed to the discovery of the Van Allen radiation belts. The Explorer III instrumentation package is at left in the photo. (AP Wire Photo).

Organization of *Opening Space Research*

Covering a period from the early 1950s through the 1960s, *Opening Space Research* is organized chronologically and is based on George Ludwig's personal observations and reflections on the important events, people and technology during the exciting times of the first earth satellites. A unique and fundamental aspect of this book is the extensive use by the author of the information contained in his laboratory notebooks, which he maintained on a daily basis throughout most of this timeframe, and from which otherwise unobtainable decade's old facts and recollections would not be available. Shown at right are the sixteen chapter titles and related supporting material from the book. For those visitors to the Transistor Museum whose primary interest lies in the technical and historical details of the electronics used in the first satellites, chapters 3, 4, 5, 10, 11 and 12 are most relevant. However, because this book has been crafted so thoughtfully to document many other aspects of the early U.S. and Soviet space programs, I'd suggest that a complete read of the book would be important to best understand the state of midcentury space technology. This review will highlight the broad range of interesting topics discussed in the book.

From the Foreword

This book is a participant's well-told and perspective account of the early days of scientific research in space, with emphasis on the role of the University of Iowa. The unique core of the book, Chapters 5-11, is the inside story of the development of the radiation instruments that were flown successfully on the first American Satellite Explorer I and its prompt successor, Explorer III, both in early 1958. The author, George H. Ludwig, then a graduate student in physics at the University of Iowa, was the central person in developing those instruments and the decoding and tabulation of their in-flight data. His detailed narrative of this work has a special authenticity because of its dependence on his meticulous records.

Foreword, Prologue, and Introduction:

Chapter 1: Setting the Stage at the University of Iowa

Chapter 2: The Early Years

Chapter 3: The International Geophysical Year

Chapter 4: The IGY Program at Iowa

Chapter 5: The Vanguard Cosmic Ray Instrument

Chapter 6: Sputnik!

Chapter 7: The U.S. Satellite Competition

Chapter 8: Go! Jupiter C, Juno and Deal I

Chapter 9: The Birth of Explorer I

Chapter 10: Deal II and Explorers II and III

Chapter 11: Operations and Data Handling

Chapter 12: Discovery of the Trapped Radiation

Chapter 13: Argus and Explorers IV and V

Chapter 14: Extending the Toehold in Space

Chapter 15: Pioneering in Campus Space Research

Chapter 16: Some Personal Reflections

Epilogue, Acronyms and Abbreviations, Selected Bibliography, Name Index, Subject Index

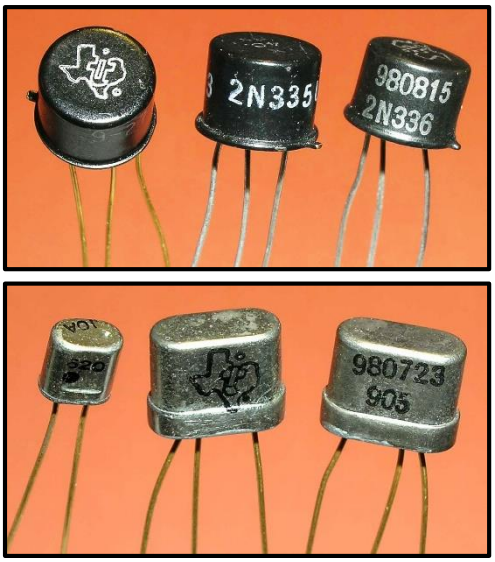
Chapters 1 and 2:

- The early high altitude research cosmic ray research program at Iowa is described, beginning with the arrival of James Van Allen in Iowa City in 1951.
- There are short biographies of key personnel in this program, including James Van Allen, Les Meredith, Frank McDonald, Kinsey A. Anderson and Carl McIlwain.
- The first research was performed with balloons, and later with balloons used as launch platforms for rockets – the Rockoon was invented.
- There are comments and a description of the post WWII U.S. rocket program based on German V2 technology and personnel. By the end of 1953, approximately 63 V-2 rockets had been launched by the U.S.
- The electronic instrumentation developed for cosmic ray research used miniature vacuum tube circuits, related to the types developed during WWII for proximity fuses.
- A brief personal background on George Ludwig is provided, including a discussion of his tour of duty as a flight officer with the USAF, ending in 1952.
- Ludwig's father hosted a local morning radio program and introduced George to Dr. James Van Allen, who had been a previous guest on the program. This introduction led to a first job in space electronics as a student at Van Allen's cosmic research lab at the University of Iowa.
- There are numerous photos and illustrations of the cosmic research program at Iowa, including rockets, balloons, and rockoons.

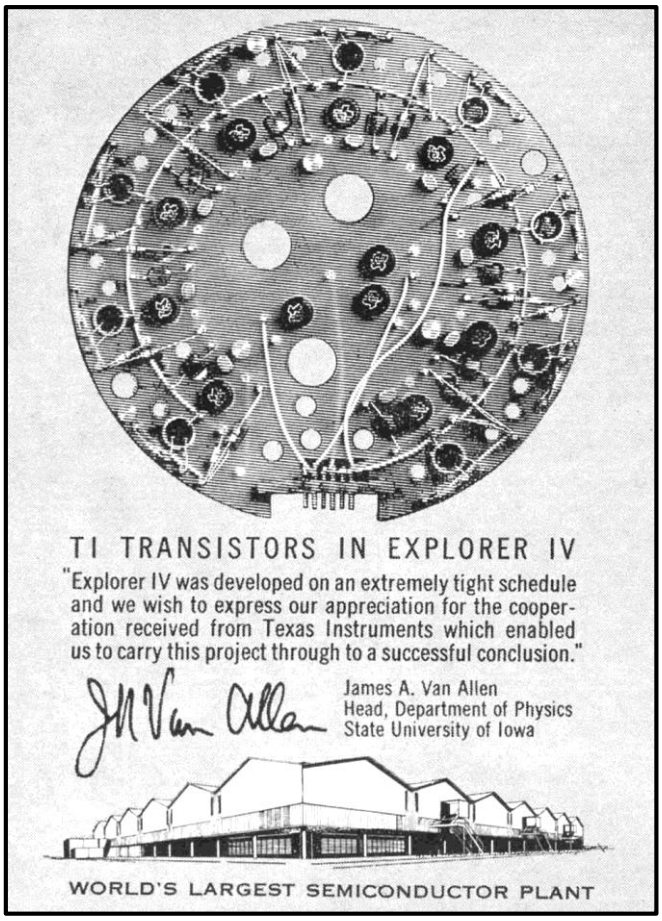
Chapters 3, 4 and 5:

- The International Geophysical Year (IGY – 1957/1958) is discussed by Ludwig as an epical scientific event. This program was the basis for studying international geophysical effects, including meteorological, magnetic and auroral.
- The Naval Research Lab (NRL) received the IGY assignment for developing a U.S. earth satellite (Vanguard). There is a discussion of this program and the many failed launch attempts.
- Van Allen was an active leader in IGY, and when his formal proposal for a GM counter/cosmic ray package was accepted, Ludwig was assigned the design responsibility for the first cosmic ray instrumentation package for Vanguard, which was later shifted to the U.S. satellite program for Explorer.
- The Iowa IGY program evolved from earlier rockoon sub-orbital expeditions in Canada, Antarctica and the equator.
- There is an excellent discussion of the state of transistor technology in the mid-1950s (less than ten years after the invention of the transistor at Bell Labs in Dec 1947).

- Ludwig was responsible for the cosmic ray instrumentation package for Explorer and provides a first-hand account of how he was able to develop reliable transistor circuits for the first U.S. satellites. He designed the cosmic ray instrumentation packages for the first eight successful U.S. satellite launches, and there were no documented failures.
- There is a further discussion of the lack of available industry information on transistor design, and how Ludwig used popular articles in Electronics magazine as the basis for understanding transistor technology. Specific issues/dates of Electronics magazine are cited in the chapter endnotes.
- In addition to the transistor work, Ludwig provides technical information and photos of the data recorder he designed and built to be included on Vanguard and later on Explorer III as a primary element of the cosmic ray instrumentation.
- A short biography of Laurence J. Cahill Jr. is included.
- There are photos of transistor electronics and a discussion of early types such as Philco germanium surface barrier and Texas Instruments 2N33X silicon devices. Also included are diagrams of the instrumentation system and layouts of the Vanguard satellite.



George Ludwig selected early silicon transistor types for use in the Explorer satellite cosmic ray package. The Texas Instruments 2N33X series, shown above at top, was used in the GM scalar circuits for Explorer I and IV. The TI 900 series transistors shown above was used for the scalar circuits in Explorer III. Shown at right is an ad from the Feb 13, 1959 issue of Electronics magazine showing the 2N33X transistors mounted on the GM scalar circuit board designed and built by Ludwig.



Chapters 6, 7, 8 and 9:

- The successful launch of Sputnik on October 4 1957 is discussed in detail, including the large impact on the U.S. political environment and military planning – the Soviets achieved a major first with this satellite.
- The competing U.S. satellite strategies between the Navy with the Vanguard program and the Army with the Explorer program are analyzed and documented with an insider's view.
- Additional comments regarding Wernher von Braun and the Army program are included. There is speculation that if the Army satellite program had been prioritized by the U.S. government, instead of the Navy's Vanguard program, then Explorer would have been launched before Sputnik.
- There is more discussion on the failed Vanguard launches and the urgent shift to the Army's Jupiter rocket launch vehicle and the Explore satellite. The successful Sputnik 1 and Sputnik 2 launches placed tremendous pressure on the U.S. satellite program and resulted in the rapid shift of priority and resources from Vanguard to Explorer
- Ludwig's detailed work on the Explorer I, II and III instrumentation packages is covered, including his continued design work on the data recorder successfully launched with Explorer III.
- During this time, Ludwig moved to Pasadena and became an employee of JPL, where his transistor work on the Explorer electronics was completed.
- Figure 9.2 illustrates recorded radio telemetry signals from the Explorer I GM/cosmic ray instrumentation package developed by Ludwig.
- Ludwig provides a very readable and detailed description of the Explorer I satellite technical specifications and adds personal comments and recollections about the successful launch events of the satellite with his instruments aboard.
- Short biographies of William H. Pickering, Henry L. Richter Jr. and Ernst Stuhlinger are included.

Chapters 10, 11 and 12:

- Explorers II and III – discussion of Ludwig's design work including circuits on instrumentation packages, and especially the data recorder.
- There is a long discussion regarding the success of Ludwig's electronics packages, and his assignment to future planned satellites.
- There is a very detailed technical discussion regarding Explorer I and III specifications and scientific results.

- The lengthy analysis process of the telemetry data from the cosmic ray instruments on Explorer I and III is explained and the resulting discovery of the Van Allen belts is discussed.
- From a personal perspective, Ludwig describes the launch process and his excitement while participating in the successful launch of Explorer III satellite which carried into orbit his cosmic ray instrumentation package. Ludwig also recounts his trip back from JPL to Iowa in a rented U-Haul trailer, which also contained his spare/back-up Explorer I satellite.
- Short biography of Ernest C. Ray is included.

Chapter 13:

- One of the most interesting and unusual early satellite projects was code named "Argus" and is described in a detailed and very readable style by Ludwig. The Argus effect was postulated soon after the Van Allen belts were discovered and theorized that a high tonnage nuclear blast in orbit would flood the belts with high energy particles which would provide a shield against Soviet intercontinental rockets by destroying the onboard electronics. Many Project Argus technical and operational details are discussed.
- Ludwig designed and built the cosmic ray instrumentation packages for Explorer satellites IV and V, which included additional electronics (developed under strict government secrecy) required to detect the presence of high energy particles injected into the Van Allen radiation belts following nuclear explosions conducted in the upper atmosphere by the U.S. This effort was to confirm the accuracy of the Argus effect predictions.
- Two personal observations about the Explorer IV and V satellites are provided by Ludwig which highlight the informal nature of the early U.S. space program: (1) Pentagon brass visitors to the University of Iowa during 1958 were astonished to find that such a crucial aspect of military/space program was entrusted to two grad students and (2) Late in the launch process for Explorer V, Ludwig noticed some soldering issues with the instrumentation package electronics and took it on himself to personally re-solder the cable connections in question. In the greater formality of the satellite launches soon to follow, this type of repair would never have been allowed.

Chapter 14:

- By the end of the summer of 1958, less than a year after the first successful earth satellites, the U.S and the Soviets attempted many more launches, and the list of satellites is discussed here, including Vanguard II, SCORE, several Pioneer craft and multiple Soviet Luna probes. The race to the moon is described.
- Table 14.1 of the book is an incredible resource for those interested in early space history, as it is a comprehensive scorecard of the more than 50 satellite launches occurring between 1957 and the end of 1959, including all successful and failed attempts. A brief description of each launch is provided.

Chapters 15 and 16:

- The family life for the Ludwigs is discussed and it is noted that George's studies in physics and engineering at the University of Iowa, the work in the Physics Department's Cosmic Ray Laboratory and family life were inextricably intertwined and all-consuming throughout the seven and a half years spent in Iowa. Despite the intense pace of the satellite work, the young Ludwig family did enjoy family vacations, including well-remembered tenting vacations in remote northern Minnesota.
- When Ludwig received his Ph.D. diploma from Iowa in 1960, the Ludwig family consisted of George, wife Rosalie and four young children – Barbara, Sharon, George and Kathy. The family moved to Silver Spring Maryland in 1960 when Ludwig accepted a position there with the newly formed Goddard Space Flight Center. Ludwig has spent his later career in senior positions related to satellite research at NOAA and NASA, and a detailed bio can be found on page 22 of the book.
- There is an enthusiastic discussion of the importance of James Van Allen as a mentor to Ludwig during the years at Iowa when he was first involved in early space electronics. Van Allen is described as a truly remarkable teacher who was admired for his willingness to give his students substantial freedom and responsibility on such important projects as the first U.S. satellites and give them freedom in carrying the projects forward.

Curator's Summary

In reading *Opening Space Research* I came to whole heartedly agree with George Ludwig's prescient comments in the Foreward – this book is indeed "a well-told and perspective account of the early days of scientific research in space". While the scope of this Transistor Museum review was initially cast to cover the specifics of Ludwig's design and implementation of the cosmic ray instrumentation and the resulting story of the first transistors in space, the strengths of this book in several other areas became apparent and so will also be noted in this summary.

Comprehensive view of the early space program: The decade from the 1950s through the early 1960s was a time of tremendous accomplishment in space technology and exploration. For those of us who remember this period, there are names, places and space terminology that sound familiar, and this list of "old friends" is long – von Braun, Van Allen, Eisenhower, Cape Canaveral, JPL, Huntsville, NASA, IGY, Sputnik, Vanguard, Explorer, cosmic rays, radiation belts, the dog Laika, the race to the moon…and the list goes on. George Ludwig's extensive and meticulous notes and his substantial participation in the early U.S. satellite program have given him such a wealth of information and insight into the early space program that the reader will become very interested in discovering the actual meanings and significance of the entries in the list above, and many other related topics as well. Ludwig's logical writing style results in clarity and completeness. *Opening Space Research* is not a "sit down and read it through" book. It is, however, enjoyable and well written and I found myself eager to return to it, if I had put it down for a while, to learn the details of the next breakthrough achievement in space technology. Greatly adding to the completeness of this coverage of the early space program, Ludwig intersperses the descriptions of events and technology with short bios and personal recollections about many of people associated with the work.

The first transistors in space: During the 10 years that followed the 1947 invention of the transistor, the initial germanium point contact technology evolved rapidly as new device types were developed with the intent to manufacture transistors with the consistency, reliability, high frequency response and power handling capabilities necessary to meet the requirements of commercial and military applications. Also of note is the introduction of grown junction silicon transistors in late 1954 by Texas Instruments, a new technology which set the stage for the development of modern silicon planar transistors in the early 1960s. It was into this mid-1950s environment that George Ludwig, as a graduate student in Van Allen's cosmic ray lab at the State University of Iowa, was given the assignment to design and build the instrumentation required to perform reliably in the harsh environment of earth orbit as part of the emerging U.S. satellite program. Of particular interest to Transistor Museum visitors, Ludwig's design work and ultimate success with selecting the best transistor types available, and learning how with work with these devices is a story well told and very worth reading. This material is a "must have" for those interested in the early history of transistors, and, in my experience, the best information available on this topic.

Reference material: An important aspect of this book is the extensive documentation of reference material. This is a resource that the interested reader can use to aid in further research. Below is a list of relevant reference material.

- Chapter Endnotes
- Acronyms and Abbreviations
- Selected Bibliography
- Name and Subject Indices
- Additional references available online:

1) A Transistor Museum Interview with Dr. George Ludwig: The First Transistors in Space - Personal Reflections by the Designer of the Cosmic Ray Instrumentation Package for the Explorer I Satellite

2) Van Allen Day October 9 2004

3) The Instrumentation in Earth Satellite 1958 Gamma – George Ludwig Master of Science Thesis

4) Physics Today Book Review of *Opening Space Research* by Henry Richter

Appreciation for George Ludwig and his work: Without a doubt, *Opening Space Research* is a comprehensive and readable account of the early days of space research, and the details of George Ludwig's pioneering work with the early transistor technology required for the Explorer and Vanguard satellites is an important resource for transistor historians. However, beyond this wealth of substantial technical information, the appeal of the book owes much to Ludwig's telling of his own story. From the beginning pages, the reader is offered a view of the historic accomplishments of the space program from the perspective of a thoughtful and dedicated participant – Ludwig's thoughts and feelings, dutifully recorded at the time in his ever present lab notebooks, offer a vantage point that helps the reader see and understand the true importance of these events. This approach is very effective and I had the feeling after reading the book that I had just spent an enjoyable few days getting to know George Ludwig personally. You can't read *Opening Space Research* without feeling the excitement and enthusiasm of a young graduate student and family man who dedicated many years of his life to contribute all that was asked of him to ensure the success of the first U.S. satellites.

Note: As of the posting of this Transistor Museum book review, *Opening Space Research* by George H. Ludwig is available through several websites including Amazon, American Institute of Physics, and Google Books.