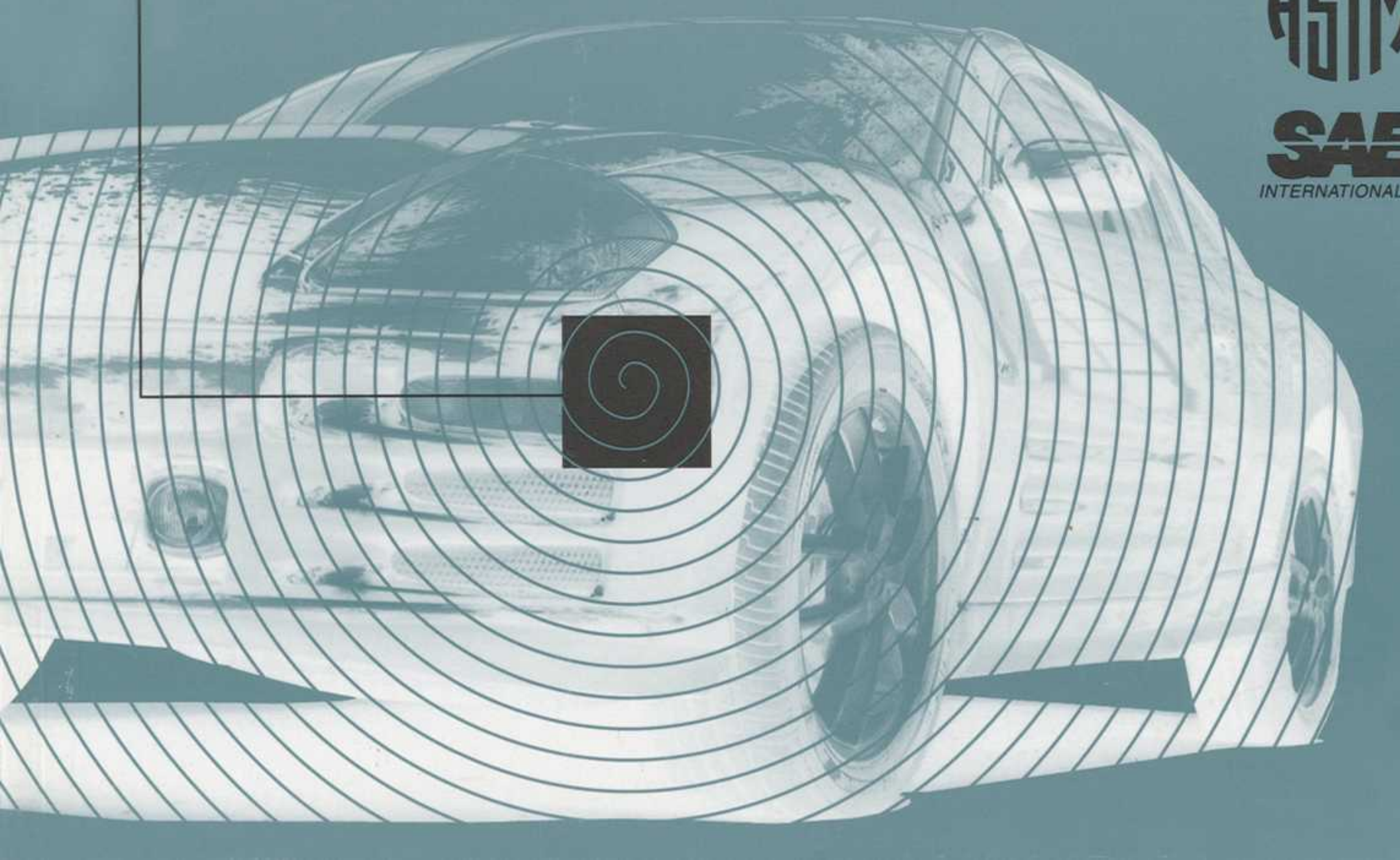
Investigation and Interpretation of Black Box Data in Automobiles

A Guide to the Concepts and Formats of Computer Data in Vehicle Safety and Control Systems

William Rosenbluth



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Dedication

THIS BOOK IS DEDICATED to my wife, Jean Joy Rosenbluth. Her strong belief in me, and her continuous encouragement, patience, and ever present support in the face of manifold adversities and diversions, made possible the development of the data skills and the laboratory where I accomplished much of the work and learning chronicled herein. That foundation ultimately made this book possible.

Foreword

THIS PUBLICATION, *Investigation and Interpretation of Black Box Data in Automobiles: A Guide to the Concepts and Formats of Computer Data in Vehicle Safety and Control Systems*, was sponsored by Committee E30 on Forensic Sciences and the Society of Automotive Engineers, Inc. This is Monograph 4 in ASTM's monograph series.

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Gerald Rosenbluth, Automotive Consulting Services, Inc., Tempe, AZ, for the use of his extensive library of specifications and service data, and for his professional inspection facility used to conduct many of the tests documented herein.

Steven Rosenbluth, The Jim Henson Company, Inc., Hollywood, CA, for his pioneering development of electronic data interfaces, interrogation software, and original data interpretation formats, all of which have allowed us to perform multiple comparative EEPROM crash-data analyses, for both simulated and real crash events.

Contents

Preface

CERTAINLY NO ONE WISHES FOR AN AIRCRAFT DISASTER, but when one occurs, everyone wants to know why. In the analysis of aircraft disasters, among the primary investigative tools used by the FAA and NTSB are the continuing data recorders on the aircraft itself. Those data recorders, the cockpit voice recorder (CVR) and the digital flight data recorder (DFDR) shown in Fig. P1, are colloquially known as *black boxes* and are often the focus of intensive searches at the crash site because of the valuable information they may contain about conditions before and during the last moments of aircraft operation. The CVRs and DFDRs save their data in media that survive most crashes, and their information and operational parameters[1] can help identify human error, equipment malfunction, or unexpected weather anomalies. But, not all situations can be predicted. For example, in the Oct. 25, 1999 Learjet crash that killed golfer Payne Stewart and five others, investigators did not find any CVR voice information because it operated as a 30 minute tape loop. Unfortunately, the likely decompression incident happened in the first 30 minutes of flight, hours before the crash-caused loss of power stopped the tape loop. By that time, all persons were unconscious, the valuable cockpit conversation(s) were overwritten, and the only data on the CVR were cabin pressure and stall warnings as the plane ran out of fuel (Moss 1999; Lunsford 1999; Hembree 1999; NTSB Advisory 1999; NTSB Investigation undated).

Technology advances within the past ten years have allowed increasingly sophisticated nonvolatile electronic data storage capabilities on automobiles and trucks. Among the first were electronic odometers, which saved the vehicle cumulative mileage, even if the battery was disconnected. Application of nonvolatile electronic data storage was then incorporated to assist with the diagnosis and repair of intermittent electronic faults that would otherwise be difficult or impossible to diagnose. Systems having the capability to incorporate nonvolatile electronic data storage include engine fuel management (EFI), antilock braking (ABS), automatic traction control (ATC), cruise control (CC), air bags (SRS), and seat belt tensioners (ETR). Figure P2 shows a simple example of ECU controllers for the ABS and SRS.

One byproduct of the incorporation of nonvolatile electronic data storage for diagnosis and repair is the utility of this electronically saved data to assist land vehicle investigators in determining vehicle conditions before and during an accident in a way unavailable by previous post accident mechanical analysis techniques. However, because the original intent of this electronically saved data capability was to assist repair, and not necessarily to assist accident investigation, these data are often distributed among several different units, which save data in their own formats and for their own diagnostic purposes (EFI, ABS, ATC, CC, SRS, ETR, etc.).

In each system that incorporates computer control, the assembly containing the integrated circuit microprocessor unit (MPU) is called the electronic control unit (ECU). Within the ECU, the desired nonvolatile information is saved in EEPROM.[2] This information usually includes diagnostic trouble codes (DTCs),[3] and optional par-

[1] DFDRs on commercial airlines save over 50 mandatory and 30 optional parameters. A reference showing a complete list of DFDR parameters, including a comparison to known automotive parameters, is shown in Appendix E: "A Comparison of Recorded Data Parameters, Aircraft versus Automotive Black Boxes."

[2] EEPROM—Electrically Erasable Programmable Read Only Memory. EEPROM is fabricated using a special semiconductor construction that allows it to retain previously stored data even when the battery is disconnected. A similarly functioning technology, Flash Memory, is also used for this purpose.

[3] Often called *error codes*.

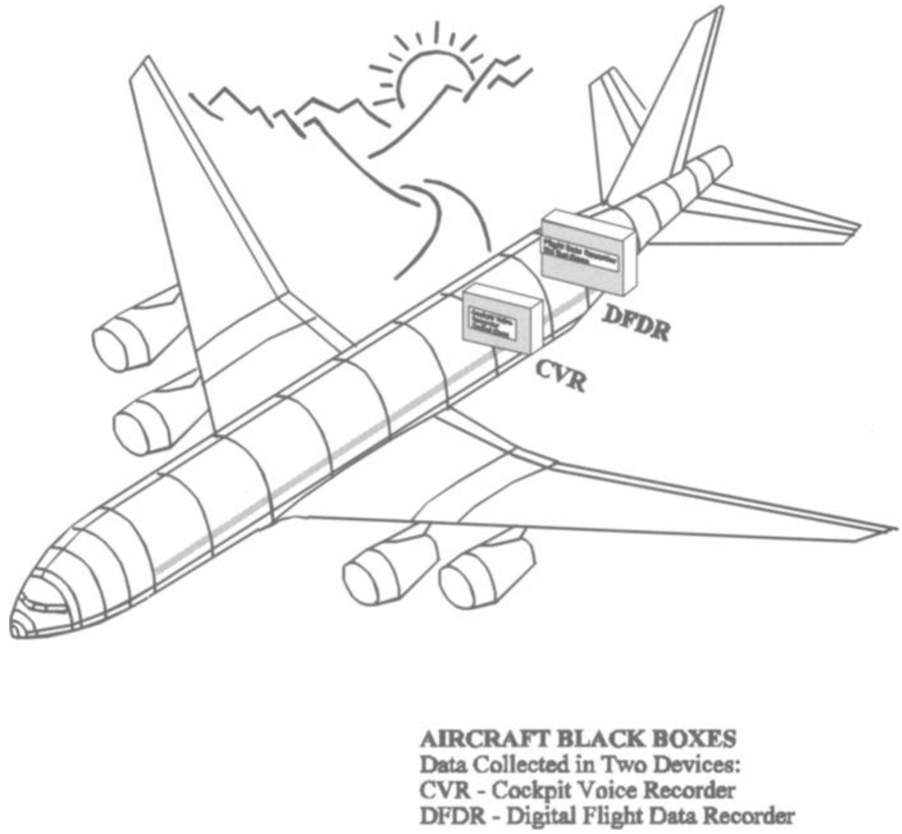

FIG. P.1—Aircraft data recorders.

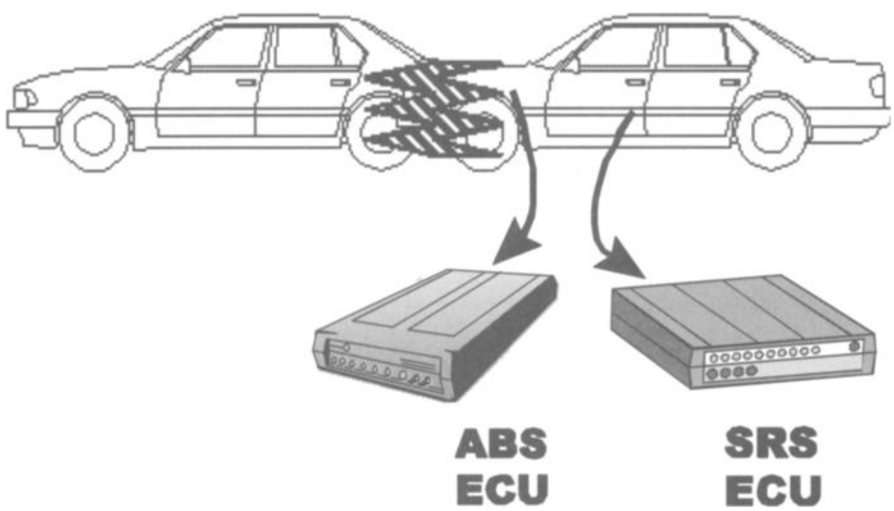

FIG. P.2—ABS and SRS ECUs.

ametric data. Because EEPROM is nonvolatile, it retains its data even when the battery is disconnected. EEPROM data are downloaded from a vehicle ECU using a scanner[4] or via a microprocessor interface, in much the same way as a credit card terminal is used to query a central data bank to authorize a credit purchase. This concept is shown in Fig. P3. There are two levels of stored data: repair-level DTCs and engineering-level

[4] Scanner—Small hand-held microprocessor capable of sending serial data commands to a vehicle ECU and then receiving and selectively recording/interpreting ECU serial response data.

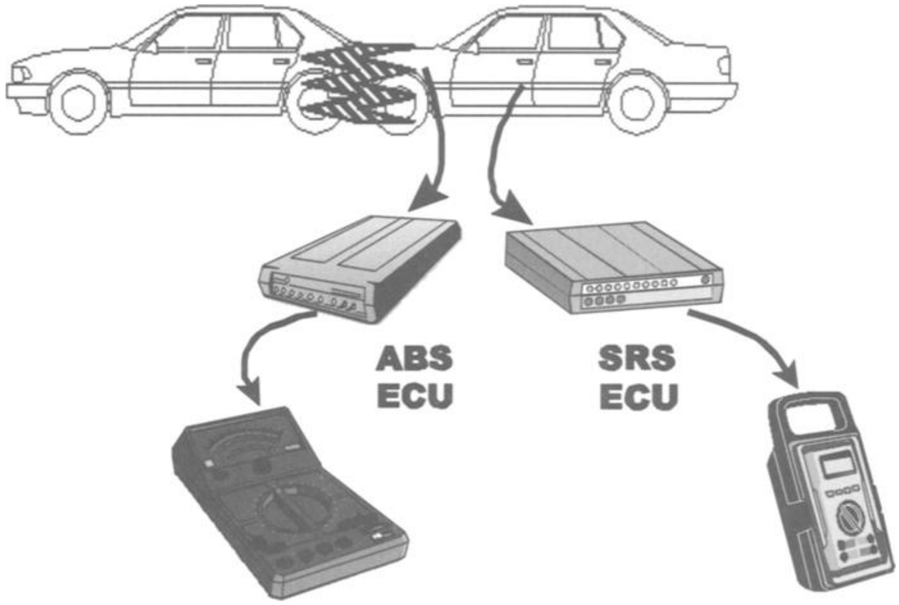

FIG. P.3—ABS and SRS ECUs with dedicated scanners.

parametric crash data. Generally, repair-level scanners cannot access engineering-level data, whereas engineering-level scanners can access all data.

As we have discussed above, certain crash-related data may be stored in the EEPROMs of several vehicle ECUs, requiring the use of several scanners, one dedicated to each type of system ECU, to acquire a complete set of crash data. This is shown schematically in Fig. P3. Newer vehicle models[5] utilize advanced scanners that often incorporate multi-system interrogation functions in a single unit.

Thus, the concept of vehicle black box data is actually an umbrella term, which implies using data components that are obtained by interrogating several different system units that can be assembled to provide a set of electronically saved data useful to the accident investigator.

In addition to scanners, a laboratory computer interface can be used to accomplish the EEPROM download process for both repair and engineering-level data. Sometimes, this method provides more detail than field scanners can provide. An illustration of a laboratory download of air bag ECU EEPROM data is shown in Fig. P4.

Engineering-level data can incorporate additional parameters such as time, ignition cycles, velocity change, pre-event velocity, acceleration profile, seat belt status, and other crash event data.

When a set of data is saved only after a certain condition or event, that data is often called a *freeze frame*, and the triggering condition is called the *event trigger*. An air bag ECU data event trigger is a crash deployment command, and the saved freeze frame data can identify crash timing, crash velocity changes, seat belt usage, etc. An ABS ECU event trigger can be any DTC, for example, a front wheel sensor malfunction DTC as caused by a crash. The saved freeze frame data can identify wheel speeds, brake apply status, ignition cycles, etc., at the time the DTC was set.

If a crash event has triggered both of the above freeze frame examples, one can see how the combined set of saved data can present an extended overview of vehicle conditions at a critical moment, such as the instant of the crash.

The balance of this book identifies where and how to find various data parameters, as saved in various freeze frames, which have multiple formats, and shows how to interpret and combine them so their sum can present a vehicle condition overview that can provide significant additional information when compared to traditional post accident mechanical analysis techniques. As we continue this investigation, we will

[5] Models starting with the 1996 model year are mandated to have OBD-II compliant scanners, many of which incorporate multi-communication protocols and multi-system functions in a single integrated scanner unit.

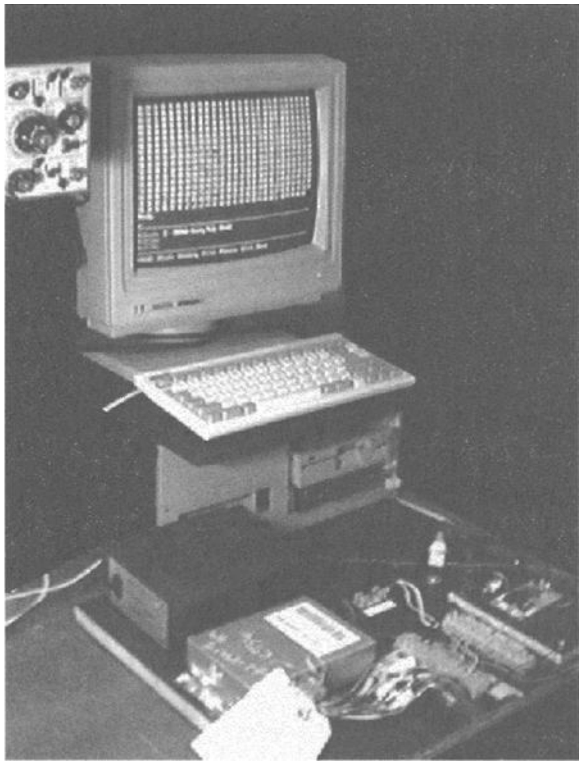

FIG. P.4—Laboratory download of an SRS ECU.

also cover some mathematical structures, basic Newtonian physics, and basic electronic circuits. These concepts are then integrated into several case studies.

Also included are several appendices with information useful to investigators in this field:

Appendix	Title
A	Glossary of Terms and Conversion Factors Used in Vehicle Data Systems
B	Scan Tools, Scanners, Bus Interfaces, and Manufacturer Contacts
C	Government Standards and Regulations (CARB, DOT/NHTSA, EPA)
D	Industry Standards and Specifications (SAE, ASTM, ISO, etc.)
E	Comparison of Recorded Data Parameters, Aircraft versus Automotive Black Boxes

In conclusion, the reader should be aware that, just as with aircraft CVR and DFDR data, the inexorable progress of time and technology will serve to make the set of available crash event data increasingly more complete and more useful. These advances will almost certainly incorporate increasingly more complex data formats and sources, so the methods and formats discussed herein will probably be considered only a primer for future investigators probing electronically saved data.

ABOUT THE AUTHOR

WILLIAM ROSENBLUTH is a Fellow of the American Academy of Forensic Sciences (AAFS), a member of the Society of Automotive Engineers (SAE), the American Society for Testing and Materials (ASTM), the Institute of Electrical and Electronic Engineers (IEEE), and the IEEE Computer Society.

At IEEE and AAFS, he has presented over 40 papers dealing with automotive engineering investigations, co-instructed a continuing education short course, and organized engineering technical sessions. His engineering achievements were recognized by the AAFS at its February 1999 meeting, where he was presented with the Andrew H. Payne, Jr. Special Achievement Award for Pioneering New Procedures, Outstanding Professional Performance and Outstanding Forensic Engineering Leadership.

He was employed by the IBM corporation for 21 years, and for the past 15 years he has been principal engineer for Automotive Systems Analysis, Inc. (ASA), in Reston, Virginia.

He holds three US Patents, including one for a device to measure air bag static deployment throw and velocity using digital data acquisition.

His publications include a paper summarizing his work on low-speed rear-end impacts and occupant stress parameters published in the *Journal of Forensic Sciences*, a book chapter covering vehicle air bag systems and internal information and codes published by LEXIS Law Publishing and two articles on high speed sensors and data acquisition for *Sensors Magazine*.

He lives with his wife Jean in Reston, Virginia.

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