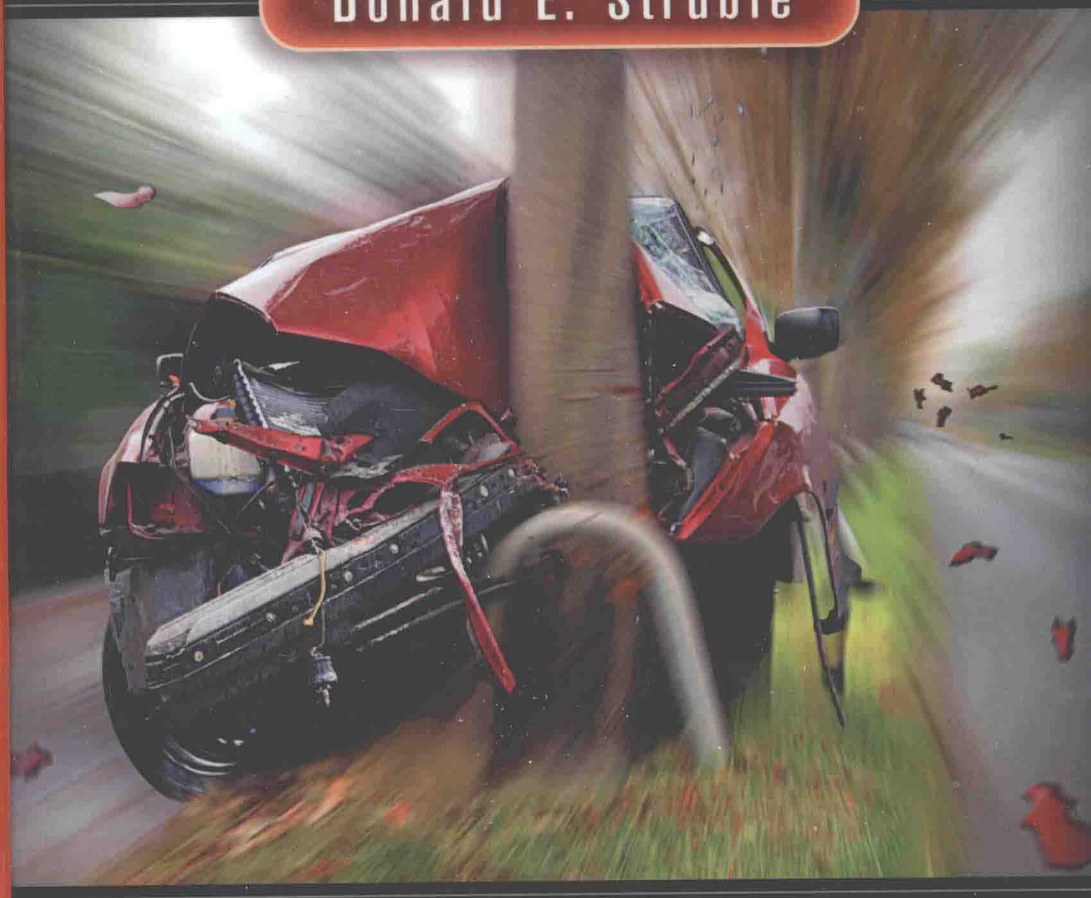
Ground Vehicle Engineering Series

AUTOMOTIVE ACCIDENT RECONSTRUCTION

Practices and Principles

Donald E. Struble



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Preface

Before entering the field of motor automotive safety, I specialized in aircraft and missile structures all the way through graduate school and into a university teaching career. However, the fascinating field of automotive crashworthiness beckoned, and before long I was focused on car crashes, energy-absorbing structures, and occupant protection. Eventually, I went into accident reconstruction.

Becoming a reconstructionist meant that there was much to learn; like so many other newbies, I needed mentoring. Don Friedman, Bob Cromack, and Chuck Warner were instrumental in that regard. Nevertheless, there was no single textbook, no single source for the requisite theory, and no road map showing how to acquire the data and information I needed. So, I did what so many others have probably done—worked out the theory and the practical techniques myself, aided by technical papers written by those who had gone before, and spurred on by invigorating discussions with my colleagues at Minicars, Inc. and Collision Safety Engineering. The theory gradually wounded up in the form of pen and paper calculations, computer programs, and written documents that were distributed to the younger engineers and referred to constantly as time went on. Some of this material found its way into technical papers. At the same time, experience gradually revealed investigation and measurement techniques—some of which worked better than others—and how the necessary data and information could be obtained.

To the younger engineers who both received and helped develop this knowledge base, much credit is due—particularly Kevin Welsh and John Struble—who went through the written materials and participated in many discussions, asking probing questions, challenging assumptions, and working out procedures. This book is an attempt to gather, in one place, the material that other young engineers will need to master in order to investigate and reconstruct crashes. My aim has been to make it an authoritative source they can consult throughout their careers, enabling them to base their work on the stoutest possible foundation.

The material consists of practical matters, like where to find the technical information one needs, how to acquire and analyze publicly available data, and how to interpret evidence, for example, as well as more theoretical subjects such as how to apply the principles of mechanics so as to analyze crashes. Of course, the book does not cover everything; journal articles and even other books will always be important, particularly as the field evolves. The discerning reader will notice, for example, that crashes involving heavy trucks and other articulated vehicles are not covered. Simulation models are

discussed only in an introductory manner. But one has to stop somewhere, lest the tome becomes unwieldy. Most of the investigative techniques and all of the fundamental principles and resulting equations will still apply. If this book does its job, it will serve as a valuable resource for reconstructionists as they build their own careers.

Acknowledgments

This book would not have been undertaken except for the prompting by my wife Lonny and my son John, and could not have come to fruition without the continuous and enthusiastic support by my entire family. My deepest thanks go to all of them, particularly to John, who read and reviewed various chapters and—as usual—provided valuable comments and insights, and pointed out errors. Those that remain are due to me and no one else.

Author

Donald E. Struble holds BS, MS, and PhD from California Polytechnic State University (San Luis Obispo), Stanford University, and Georgia Institute of Technology, respectively, all in engineering with an emphasis on structural mechanics. Dr. Struble was assistant professor of aeronautical engineering at Cal Poly, manager of the Research Safety Vehicle program and senior vice president of Engineering and Research at Minicars, Inc., and president of Dynamic Science in Phoenix, Arizona. He has worked in automotive safety since 1972, including occupant crash protection and crashworthiness at the highest crash severities (50 mph barrier crashes, for example), and has been reconstructing accidents since 1983.

Dr. Struble has published numerous papers in these areas. A 2001 paper, "SAE 2001-01-0122" (SAE International, Warrendale, PA), received the Arch T. Colwell Merit Award, for papers based on "their value as contributions to existing knowledge of mobility engineering, and primarily with respect to their value as an original contribution to the subject matter." He has had three papers selected for inclusion in *SAE Transactions*, "judged by a distinguished panel of engineering experts to be among the most outstanding SAE technical papers." Three other papers were selected for inclusion in SAE technical compendia on air bags and accident reconstruction. Dr. Struble was editor of *Advances in Side Airbag Systems*, published by SAE International, 2005.

Dr. Struble has delivered invited presentations at two ESV (Experimental Safety Vehicle) conferences, and is co-holder of a patent on a side impact airbag. Dr. Struble has been an SAE TopTec instructor on the following topics: air bags, high-speed rear impacts, and accident reconstruction. He is a member of SAE, AAAM, and Sigma Xi, the Scientific Research Society. Formerly senior engineer at Collision Safety Engineering in Phoenix, Arizona, and president of Struble–Welsh Engineering in San Luis Obispo, California; he is now retired.

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thoughts, advanced it to the state of science"[2] (p. 73). So, in this book, we will be concerned more about the quantitative than the qualitative measure.

Units, Dimensions, Accuracy, Precision, and Significant Figures

To put numbers on things, we must speak a common language. It is the case that the Système International d-Unitès (International System of Units), or metric system, abbreviated SI, has been adopted and used throughout the world. It is also the case that a notable exception is the American public, which populates the majority of jury boxes, judges' benches, and law practices around the world. These are the people with whom the reconstructionist must communicate in the US legal system. Indeed, the Technical English System of Units is the language spoken by most reconstructionists.

The base units used in this book are force (pounds, abbreviated lb), length (feet, abbreviated ft), and time (seconds, abbreviated sec). Metric equivalents will be provided on occasion. An example would be barrier forces in Newtons, even though this author has yet to encounter a bathroom scale that reads in such units. In vehicle crashes, times are often discussed in milliseconds (thousandths of a second, abbreviated msec). Derived units are obtained from the base units. For example, area is a measurement derived from length and is reported in square feet (abbreviated ft^2). Velocity is derived from length and time and is measured in feet per second (abbreviated ft/sec), as is acceleration, measured in feet per second per second (abbreviated ft/sec^2).

A Word About Mass

It is a measure of the amount of substance—that which resists acceleration. It is a derived unit; namely, the amount of mass which would require the application of one pound of force to achieve an acceleration of one foot per second per second. This amount of mass, called a slug, would weigh about 32.2 lb on the surface of the earth. (But on the moon, one slug would weigh about 1/6 as much, because the moon's gravity is about 1/6 Earth's.) By Newton's Second Law, we see that $m = F/a$, and so one slug equals one $lb{\cdot}sec^2/ft$. Since lay persons usually have no concept of a slug mass, it has been this author's practice to speak only of weight (units of force), and reserve the slug for computation only. The concept of pound mass does not relate to base units, is easily confused with pound force, and is not used herein.

Another Word About Inches

Generally, length quantities for vehicles are reported in inches (abbreviated in.). This includes the all-important (to reconstructionists) measurement

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General Principles

An Exact Science?

Science is the endeavor of examining the world around us, developing hypotheses that may explain its behavior, testing those hypotheses, and thereby obtaining a deeper understanding of how that world works. Notice that the word "exact" was not used in this description of science. Science seeks exactness, but there are always limits. In fact, Werner Heisenberg pointed out that, in the limit, the very act of observing one property degrades our knowledge of another.[1] The best science can do is approach exactness as closely as possible, within the limits of time, money, and practicality.

Engineering is different from science in that it seeks to apply the knowledge of science in the design, development, testing, and manufacture of new things. Certainly motor vehicles, roads, and roadside appurtenances are engineered things that must be understood by the reconstructionist. Motor vehicle crashes are events out of the ordinary that occur outside of the laboratory (and outside the presence of the reconstructionist), without many (or even all) of the measurement and observation tools available to the scientist. Very often important information is entirely missing.

So reconstruction is neither exact; nor is it a science. It is partly engineering, in that it deals with engineered things. It is also an art, significantly shaped by experience and intuition. It is not the purpose of this book to emphasize this latter aspect, since that is covered more thoroughly elsewhere, although certain practices and observations from the author's experience will be introduced where they may be helpful. Rather, it is hoped that fundamentals essential to reconstruction will be set forth, and illustrative examples included, so that the reconstructionist can put numbers on things and ensure that his opinions are consistent with the physical evidence and the laws of physics, and are therefore as close to the truth as he or she can make them. After all, it was Sir William Thompson, Lord Kelvin, who said, "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge of it is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your