This second edition is dedicated to the many unsung seekers of fact (my wife, father, and many friends included) amidst the chaos that humanity brings upon itself. May we all endeavor to keep our sense of wonder and curiosity in the face of bureaucracy.

Also, to Luke and Sandi for a much-appreciated boost into a career I love, and to my wife, whose unswerving support in this wild profession has been a source of unbelievable strength.

Michael Haag

For Sandi, Matt, and Mike for whom nearly every picnic or outing in our beautiful Arizona desert ended in gunfire.

And to the memory of Gene Wolberg.

Lucien Haag
# Contents

**Introduction**  xi

**Introduction to First Edition**  
by Lucien C. (Luke) Haag  xv

1. Case Approach, Philosophy, and Objectives  1  

- Why This Book?  1  
- Reconstruction: The Ultimate Goal of Criminalistics  2  
- Basic Skills and Approach to Casework  2  
- General Philosophy  5  
- The Scientific Method  6  
- Specific Considerations  7  
- Summary and Concluding Comments  10

2. Working Shooting Scenes  13  

- Introduction  13  
- The Team  14  
- At the Scene  15  
- Investigation Teams and Laboratory Work  27  
- New Techniques in Shooting Scene Investigations  27  
- Summary and Concluding Comments  31

3. The Reconstructive Aspects of Class Characteristics and a Limited Universe  35  

- Bullet Design and Construction  35  
- Class Characteristics and Fired Cartridge Casings  38  
- Class Characteristics and Fired Bullets  41  
- Revolvers and the Limited Universe  47  
- The Worth of Weight  48  
- Summary and Concluding Comments  53

4. Is It a Bullet Hole?  55  

- The Question of Holes  55  
- Bullet Holes in Typical Materials  62  
- Summary and Concluding Comments  65

5. Some Useful Reagents and Their Application  67  

- Introduction  67  
- Testing for Copper, Lead, and Nickel  67  
- The Dithiooxamid Test for Copper Residues  70  
- The Sodium Rhodizonate Test for Lead Residues  75  
- Direct-Application Methods for Testing  77  
- “Lifting,” or Transfer, Methods for Testing  79  
- The Dimethylglyoxime Test for Nickel Residues  81  
- Summary and Concluding Comments  84

6. Distance and Orientation Derived from Gunshot Residue Patterns  87  

- Introduction  87  
- Target Materials  93  
- Interpretation and Reporting of Results  93  
- GSR and Revolvers  95  
- The Modified Griess Test for Nitrite Residues  97  
- Primer Residues  100  
- Summary and Concluding Comments  102

7. Projectile Penetration and Perforation  105  

- Introduction  105  
- Sheetrock/Wallboard  106  
- Wood  110  
- Sheet Metal  112  
- Rubber and Elastics  118  
- Plastics  123  
- Summary and Concluding Comments  123

8. Projectiles and Glass  125  

- Introduction  125  
- Evidence of Glass Impact on Bullets  125  
- Types of Glass  129  
- Summary and Concluding Comments  141
CONTENTS

9. Projectile Ricochet and Deflection 143
   Introduction 143
   Definitions 144
   Examining Ricocheted Bullets 146
   Projectile Impacts 151
   The Post-Impact Flight of Ricocheted and Deflected Bullets 164
   Wounds from Ricocheted and Deflected Bullets 165
   Perforating Projectiles and Perforated Objects 168
   Summary and Concluding Comments 172

10. The Principles of “Trajectory” Reconstruction 175
    Introduction 175
    Bullet Hole Location and Angular Components of a Projectile’s Path 175
    Measurement Procedures 177
    Nonperforating Bullet Paths 183
    Lasers’ Use, Advantages, and Limitations 185
    Thoughts About Reconstructed Angles 186
    Trajectory Reconstruction Techniques, Tools, and Supplies 187
    Summary and Concluding Comments 188

11. Determining Bullet Track (“Trajectory”) in Gunshot Victims 191
    Introduction 191
    Entry and Reentry Wounds 193
    Gunshot Wound Projectile Path Determination 195
    Blood Spatter and Gunshot Wounds 197
    Survivors of Gunshot Wounds 199
    Projectile Deformation in Bodies 201
    Summary and Concluding Comments 204

12. Trace Evidence Considerations Associated with Firearms 207
    Introduction 207
    Locard’s Principle Revisited: Trace Evidence Transfer and Deposit Examples 208
    Trace Evidence Sequence of Events: Three Case Examples 212
    Summary and Concluding Comments 216

13. True Ballistics: Long-Range Shootings and Falling Bullets 219
    Introduction 219
    Basics of Exterior Ballistics and Their Forensic Application 220
    Case Situations: An Overview 225
    Maximum-Range Trajectories 229
    Potential Procedure for Long-Distance Shooting Reconstruction 238
    Summary and Concluding Comments 243

14. Cartridge Case Ejection and Ejection Patterns 245
    Introduction 245
    Scene Work—Terrain/Substrate Considerations 246
    Review of Marks on Fired Cartridge Casings 248
    Laboratory Examination of Ejected Cartridge Cases 252
    Manually Operated Firearms 262
    Summary and Concluding Comments 262

15. The Shooting of Motor Vehicles 265
    Introduction 265
    Vehicles at a Scene 266
    Projectile Strikes 270
    Summary and Concluding Comments 275

16. Shotgun Shootings and Evidence 277
    Introduction 277
    Shotgun Design and Nomenclature 279
    Choke and Patterning 282
    Shot Charges and Dram Equivalents 283
    Wads and Shotcups 284
    Powder, Gunshot Residues, and Buffer Material 287
    The Exterior Ballistics of Shotgun Pellets 288
    Summary and Concluding Comments 292

17. Sound Levels of Gunshots, Supersonic Bullets, and Other Impulse Sounds 295
    Introduction 295
    The Nature of Gunshots and Their Measurements 295
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>ix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Experience and Weighted Scales in Sound Level Meters</td>
<td>296</td>
</tr>
<tr>
<td>Multiple Firearms of the Same Make and Model</td>
<td>307</td>
</tr>
<tr>
<td>Velocity and Muzzle Pressure Versus Peak dB</td>
<td>312</td>
</tr>
<tr>
<td>Supersonic Bullets</td>
<td>322</td>
</tr>
<tr>
<td>A Frame of Reference for Judges and Jurors</td>
<td>325</td>
</tr>
<tr>
<td>Summary and Concluding Comments</td>
<td>328</td>
</tr>
<tr>
<td>18. Ultimate Objectives, Reports, and Court Presentations</td>
<td>331</td>
</tr>
<tr>
<td>Introduction</td>
<td>331</td>
</tr>
<tr>
<td>Explaining What Reconstructionists Do</td>
<td>331</td>
</tr>
<tr>
<td>Legal Challenges and Reconstructionists’ Role in Litigation</td>
<td>332</td>
</tr>
<tr>
<td>Reports and Report Writing</td>
<td>336</td>
</tr>
<tr>
<td>A Test for the Reader</td>
<td>337</td>
</tr>
<tr>
<td>Suggested General Outline for Reports</td>
<td>344</td>
</tr>
<tr>
<td>Concluding Comments about the Book</td>
<td>350</td>
</tr>
<tr>
<td>Appendix</td>
<td>353</td>
</tr>
<tr>
<td>Glossary</td>
<td>387</td>
</tr>
<tr>
<td>Index</td>
<td>409</td>
</tr>
</tbody>
</table>
Introduction

As I write this second edition of *Shooting Incident Reconstruction*, I reflect on my experiences with firearms and my professional experiences with investigations of shooting incidents. I was extremely fortunate to have grown up with two fantastic parents who encouraged inquisitiveness, thoughtfulness, and a sense of excitement for the unknown. Such characteristics are common in the individuals who have inspired me personally and professionally.

Of the volumes of information I have collected from my dad, there is one quote that I commonly find comforting when dealing with lawyers, investigators, and peers. It sums up a very pure thought and intention that should be a foundational belief of anyone in this profession: “We aren’t in the happiness business.” No matter what we find, someone will be unhappy. Unlike the many “CSI” programs that populate television these days, it is a fact of real life in forensics. One side or the other will want to find something to criticize in our work, and that is the nature of an adversarial legal system.

In the end, this is a good thing. It ensures that we are always on our toes as we attempt to improve the quality of our work. It also means that we should be open to new ideas and concepts because the way we investigate events is always changing (hopefully for the better). In an era in which ASCLD-ISO literature governing the accreditation of crime laboratories in the United States attempts to have the scientist act in a fashion that is oriented toward “customer” service, the correct forensic scientist will step back and repeat the mantra, “I am not in the happiness business.”

Take comfort in that, and know that while we should always keep an open mind to criticisms and new ideas, we are not driven to any conclusion to please a lawyer, police investigator, plaintiff, defendant, judge, or supervisor. Most carefully, we should guard against any belief that what we conclude is relevant to any sort of sense of justice. At the end of the day, we must all report only what we believe the evidence is telling us. This may mean a simple “I don’t know” or “Inconclusive”; that is, the result is the best we can glean from the available information. The scientists who do their job correctly are at peace with this, knowing that we are interpreters, and a voice, for otherwise mute physical evidence. We are not avenging angels, servants of a higher power, or puppets to simply repeat or publish what an attorney or police official would like to hear.

From my earliest years, I remember seeing both the positive and the negative effects of people’s use of firearms. Many of my weekends from grade school on were spent in the beautiful Arizona deserts and forests conducting experimental research or case investigations relating to firearms. These endeavors were often spawned from some horrific event created by one human being’s actions toward another, but the more important aspect of these times were the life lessons I learned from my parents with regard to personal use of firearms and respect for them.

While I was becoming familiar with the reconstructive aspects of firearms and of ammunition, as well as terminal and external ballistics, I was almost subconsciously learning about the great responsibilities that should
be associated with the ownership of firearms. These lessons of conscientiousness and responsibility should be, and are, common sense to most law-abiding owners of firearms. But there is a strange dichotomy in my life in that my work and passion—shooting incident reconstruction—is fueled by the antithesis of these tenets.

The first edition of this book was written by my father as a result of a life-long interest in and enjoyment of firearms: their power, their mystique, their ability to defend a life, to save a life, and to take a life. We are both passionate about the Second Amendment—in fact, all of the amendments to the U.S. Constitution—and are always very troubled by those who would pervert it, abolish it, or deny law-abiding citizens the ability to keep and bear arms in the defense of themselves and others.

For Luke also, an interest in firearms started when he was a boy. He grew up outside of Springfield, Illinois, where he received his first BB gun, a Red Ryder 500-shot lever-action blue-steel beauty that still today resides somewhere among the many firearms he has come to own.

During his high-school years in Lynwood, California, Luke became an avid hand loader for several centerfire rifles and handguns, joined the high school rifle team, and often spent his weekends in the Mohave Desert camping and enjoying informal target shooting. It was during these outings that he came to be more and more interested in the technical and scientific aspects of firearms. He began to ponder questions such as “How far do bullets travel?” “How far do ricocheted bullets travel?” “What do such bullets look like after they have ricocheted off a variety of surfaces?” “What do a bullet and a gunshot sound like when heard from a substantial distance downrange?” “How deeply do bullets penetrate into a variety of materials?”

Following the receipt of his Bachelor of Science degree from the University of California at Berkeley, Luke took several courses in criminalistics at California State College at Long Beach, where he first became aware that firearms identification was a part of this profession. A career in criminalistics and a position in a crime laboratory would be a way to apply his training in chemistry, math, and physics to tests and experiments with firearms.

This ideal arrangement was realized when he obtained a position as a criminalist for the City of Phoenix in June of 1965. His arrival there made the Phoenix Police Crime Laboratory a two-man organization. It was a classic case of being in the right place at the right time.

During the next decade, he worked in all sections of this growing crime laboratory, including the new firearms section. Sometime during the 1970s he became the supervising criminalist of the Phoenix lab. All the while, the firearms-friendly State of Arizona provided many locations and opportunities to carry out applied research, and he began writing and publishing papers in the forensic literature.

In 1982 Luke left the Phoenix laboratory to start his own consulting company specializing in the investigation of shooting incidents. He then continued to experiment, to publish, and to give training seminars related to firearms evidence and shooting scene reconstruction. These seminars and workshops ultimately became the book Shooting Incident Reconstruction, first published in 2005.

The dedication in the first edition has a somewhat tongue-in-cheek apology to my mother, my older brother Matt, and me for “subjecting” us to experiments that were nearly always a part of any outing in the desert or mountains of our state. My memories of my youth often involved some sort of experimenting. Soon I was helping my
father with his experiments, and my brother and I were presented with guns of our own from our trusting parents, along with instructions in the safe and responsible handling of same, as a classic right of passage into adulthood for an American boy.

In more ways than I can count, my dad’s interest in “all things firearms” wore off on me. Those many weekends in grade school spent getting up before sunrise to trek out into the fantastic Arizona desert were sometimes grueling but always rewarding. And I mean that not just in the sense of learning about my future profession but, more important, in the sense of learning about work ethic, about responsibility (in more than just the use of firearms), and about my dad. Most in “the business” know him professionally, but I consider myself beyond privileged to also know his peculiar sense of humor and about the many things that he holds as imperatively sacrosanct.

ACKNOWLEDGMENTS

I feel that I have had an almost unfair advantage in this field because of my contact with my dad. I am always touched by the fact that I can travel halfway (or all the way) around the world and find investigator after investigator who he has helped in one way or another. He is always there to lend an ear and give a helpful suggestion. Especially considering all of his accomplishments, and the positive effect he has had on the science of shooting incident reconstruction, he is the most humble man I know.

I would like to express my deep appreciation to the many law enforcement officers and crime scene investigators I have met and worked with who have the fortitude and integrity to conduct themselves professionally in the face of some of the worst acts human beings can commit on one another. While I have met my share of individuals in this profession I would not particularly care to associate with, the overwhelming majority have been some of the best people I will ever meet. Luck, fate, fortune, or destiny brought me to one of the finest police organizations in the country. I am grateful to have worked with the investigators, scientists, detectives, and supervisors of the Albuquerque Police Department.

As much as the first edition of this book was my dad’s work, and this one is mine, none of it would have been possible without the strong backing of my wonderful wife Kimberly DaVía Haag, who is also a well-known and respected firearm and toolmark examiner. If I were to die tomorrow, I would feel proud and thankful to have had even a week in her company. For every bit of turbulence during the flight, she has been the tailwind making the journey better.

It is my sincere hope that readers of this text will share in my enthusiasm and passion for this work.

Michael G. Haag
At the time this introduction was written, the author had been employed as a criminalist and forensic firearm examiner for more than 39 years, 17 of these with the Phoenix Arizona Police Department as a criminalist and later as technical director of that laboratory, followed by another 22 as a private consultant working for prosecutors; private attorneys; educational institutions; insurance companies; law firms; firearms manufacturers; and, on occasion, private individuals. I had always found the work interesting and challenging and still do.

The concept of how science might aid the court and jury in determining what did and did not happen in the matter at trial is still an exciting one for me. Although many of us in the field of forensic science frequently disparage lawyers and the legal process, it is the anomalous trial outcome that gains our attention and generates our scorn. Most of the time juries are able to grasp the evidence we present, and that should be all that matters. What they do with that information may be, at times, disappointing to us personally but their decision is not ours to make and it may often be made on some other basis than observations and opinions derived from the physical evidence.

Working within the legal system is also fascinating. I suspect nearly all of us enjoy a good courtroom drama. A trial can be high exciting, involving verbal and mental chess on the part of lawyers and witnesses. Lives, careers, futures, personal freedom, and, in civil cases, large amounts of money are often at stake. The side that calls us as expert witnesses will usually praise our work, but may also pressure us to extend ourselves beyond where we should go in the furtherance of their cause. Our employer’s cause must not become our cause. Our only advocacy must be for our analysis of the evidence carried out by scientifically sound means.

As well, the reader should remember that it is often our cross-examiner’s mission to make us look like biased witnesses, fools, lackeys, mountebanks, or incompetents. The witness stand is a decidedly uncomfortable environment for most scientists, and one best observed in the movies or on television rather than from the actual site. It is, and should be, a stressful place, but it is one that I have become used to and have even come to enjoy for the reasons stated earlier.

At the risk of seeming a bit immodest, it occurred to me that some readers might be interested in how I became gainfully employed (indeed, well paid) shooting guns and shooting things for a living.

I grew up in the Midwest in the late 1940s and early 1950s. Guns—some of which were always loaded—were in almost every home and farmhouse I visited. My childhood friends all had access to firearms, and after school we could often be found in a field with a rifle or shotgun. This was with our parents’ permission but without them necessarily being present. It was an age of trust on their part and personal responsibility on our part.

At the age of 6 or 7 I received my first Red Ryder BB gun from my father, and this is when my marksmanship training began. Neither I nor my friends ever considered using a gun to commit a crime or to endanger someone or damage property. We certainly
never discussed shooting at one of our classmates, our school, or our teachers.

My fondest memories of my father are of getting up before daybreak, having breakfast at some roadside truck stop, and then getting into the frosty woods at dawn with the sound of crunching autumn leaves underfoot and with my rifle or my shotgun in hand. It didn’t much matter whether we got any squirrels or rabbits or whatever was the quarry of the day. We walked and talked, and I learned of nature.

My father taught me firearms safety and personal responsibility. I saw firsthand that firearms, even my diminutive .22 rifle, were capable of inflicting serious and fatal wounds. Guns were not toys or something to be handled carelessly. And my father trusted me with guns. That meant a lot. I wish he were here to read this now. His lessons were ones that I have carried with me all of my life and have since passed on to my sons.

The use of guns in films of that time was typically portrayed as on the side of good. The Lone Ranger, Red Ryder, Roy Rogers, Gene Autry, and all the other lesser-known heroes of the Saturday matinee seldom had to shoot anyone because they were so competent and proficient in the use of their Colt single-action revolver or their Winchester rifle. They usually either shot the gun out of the bad guy’s hand or simply got “the drop” on them through their superiority in firearms handling. These were classic morality plays of good over evil in which firearms were an integral part. But today the blood-soaked films from Hollywood show guns creating unimaginable death, destruction, and mayhem in the shortest time possible. They are typically possessed by the psychologically flawed and unfit. It is difficult to think of a film in the past 20 years that depicts a gun on the side of right and in the hands of an honest person of character. It seems that we have forgotten that our special knowledge and proficiency with firearms is why we are citizens and not subjects. It is why we rightfully honor men such as Alvin York and Audie Murphy—those who grew up with firearms and used them for hunting, sport, and recreation and later used them so effectively in the defense of freedom.

In their day and in my youth, firearms were more accessible and readily available with little or no restrictions (other than those imposed by our parents) than they are today. And there were no school shootings, gang shootings, drive-by shootings, or any of the other senseless acts of violence committed with firearms such as we see today. As Hugh Downs (a well-known television commentator) once pointed out in reference to the present-day misuse of firearms, “It’s a software problem, not a hardware problem.”

But what of my life-long interest in firearms and how it relates to this book and its subject matter? I did bring home my share of rabbits and squirrels from the fields and woods of central Illinois, but hunting was never a burning passion with me. I was more interested in how far and how accurately a bullet could be fired; what it looked like after it hit or penetrated something. Why did bullets make that fascinating whining sound when I straddled a railroad track and ricocheted bullets off the iron rail after an impact at a low incident angle? I shot up a box of cartridges just to hear the sound that the departing bullets made. I even heard some of these bullets impact the ground some distance downrange and subsequently searched many times, in vain, in an effort to find one just to see if its “new” shape corresponded to the gray elliptical smear of lead at the impact site on the rail. (These characteristic impact marks are discussed and can be seen in Chapter 6.)

While shooting at sticks floating down a slow-moving stream from an old covered
bridge, I noticed that the sound of the bullet’s impact with the water changed at a recurring point downrange, and it became apparent that, whereas at closer distances the bullets were entering the water, at greater distances they were ricocheting. The phenomenon I was dealing with is critical angle—I just didn’t know the name for it in 1952. In subsequent years, I also fired many bullets vertically upward on calm days in the deserts of California and Arizona with the misplaced hope of hearing one return to the ground. (I had previously measured the roundtrip time for BBs from my Red Ryder and a Crosman pellet gun in my back yard in Illinois.)

During my high school years in Southern California, I shot competitively on a church-sponsored rifle team. Yes, dear reader, at that time churches and schools and colleges sponsored rifle teams and even supplied many of the guns! Even the University of California at Berkeley had a rifle club when I started there in 1961. Firearms and the people (including the young) who enjoyed shooting them had not yet been portrayed as they are today. I also became an avid hand loader in my teenage years (and still am today), and many of my weekends during those years involved informal target practice in various remote locations in the Mojave Desert of California. All the time I was observing and learning things about firearms and ammunition that would become useful in later years and that are now incorporated between the covers of this book.

After receiving my degree in chemistry from Cal-Berkeley, I discovered the field of Criminalistics through several courses at California State University at Long Beach and realized for the first time that I could apply and utilize my interest in firearms professionally. I began interviewing and taking tests to join the staff of several crime laboratories in Southern California, where I was living at the time. In 1965 a position for a second person in the then small Phoenix Police Crime Lab opened up. It was the classic case of being at the right place and the right time.

During the years I worked in the Phoenix Lab, I was able to apply my interest in firearms to casework. I quickly became a member of AFTE (the Association of Firearm and Tool Mark Examiners) and began giving presentations at annual meetings and writing articles for the AFTE Journal. I started assembling handout materials for classes and workshops dealing with firearms’ evidence and the reconstruction of shooting incidents for various organizations.

Colleagues, students from these classes, and my wife Sandi all urged me to put these things together in the form of a book. This I have now done. But there is an additional reason and it arises as a consequence of my many years of reviewing the work of others who were most often employed by government laboratories. A very troubling change has been taking place in these laboratories over the last 30 years. They are taking on the properties of a clinical laboratory where the detective or investigator selects from a menu of tests (e.g., identify the fired bullet or cartridge case with the submitted gun, measure the trigger pull of the submitted gun, check the gun’s safety system for proper operation).

In this strictly reactive role, the forensic scientist no longer functions as a scientist at all. Rather, his or her role has been reduced to that of a technician. Little or no discussion between the submitter and the laboratory examiner takes place regarding the details and issues associated with the case. The technician in this “clinical lab” is simply responding to the submitter’s requests. He or she may be doing the requested tests correctly and in accordance with some approved, standardized, certified, or accredited methodology, but is not fulfilling the true role of a forensic scientist.
It is the author’s hope that this book not only will acquaint the reader with the many reconstructive aspects of firearms evidence but will also inspire and reorient the forensic scientists who examine such evidence. Firearms, expended cartridge cases, fired bullets, the wounds they inflict, the damage they produce, and the damage they sustain all tell a story. This book is intended to serve as a guide to understanding their language.

A couple of abbreviated quotes from G.G. Kelly, the first arms and ballistics officer for the New Zealand Police, say it all:

The gun speaks . . . and the message of the gun is there to read by one who knows the language.

The gun is a witness that speaks but once and tells its story with forceful truth to the interpreter who can understand the language.

Everything that has a basis in physics is capable of being explained. All we have to do is to find the explanation.

Lucien C. (Luke) Haag

Reference and Further Reading