An Introduction to Simulation Using GPSS/H

Thomas J. Schriber

Professor of Computer and Information Systems School of Business Administration University of Michigan





Contents

1 Perspectives on Simulation and GPSS/H

- 1.1 Preview 1
- **1.2** The General Character of Simulation **2**
- **1.3** The Application Scope of Simulation **3**
- 1.4 The Importance of Simulation in Operations Research 3
- **1.5** Simulation Versus the Alternatives **5**
- 1.6 The Advantages and Disadvantages of Simulation 7
- 1.7 Steps in a Simulation Study 10
- 1.8 The Skills and Work Environment of a Simulation Professional 14
- 1.9 About the GPSS/H Modeling Language and Its Applications 15
- 1.10 The Scope of This Book 18
- 1.11 Activities 19

2 Transactions: Their Creation, Movement, and Destruction

26

- 2.1 Preview 26
- 2.2 Approach to Model-Building in GPSS/H 26
- 2.3 Transactions: Units of Traffic in GPSS/H Models 27
- 2.4 The Nature of Transaction Movement 29
- 2.5 The Simulation Clock 30
- 2.6 The Structure of Blocks 32
- 2.7 Creating Transactions: The GENERATE Block 33
- 2.8 Transaction ID Numbers 35

2.9	Destroying Transactions: The TERMINATE Block and the Model's
	Termination Counter 36
2.10	A Two-Block GPSS/H Model 36
2.11	Block, Control, and Comments Statements, and Model Files 37
2.12	The Structure of Control Statements 37
2.13	The Format of GPSS/H Statements 38
2.14	The SIMULATE, START, and END Control Statements 39
	2.14.1 The SIMULATE Control Statement 39
	2.14.2 The START Control Statement 40
	2.14.3 The END Control Statement 41
2.15	The Top-Down Order of Statements in a Basic GPSS/H Model File $~~41$
2.16	A Complete GPSS/H Model File 41
2.17	Keying GPSS/H Model Files 42
2.18	Batch-Mode vs. Test-Mode Use of GPSS/H 43
2.19	The Steps Followed by GPSS/H in a Batch-Mode Simulation 43
2.20	The User's Role in a Test-Mode Simulation 45
2.21	Running GPSS/H Under DOS 46
2.22	Tracing Transaction Creation and Destruction in Test Mode 47
2.23	Logging the Dialog Window in a Disk File 53
2.24	Exercises 56
2.25	More About the User's Role in a Test-Mode Simulation 57
2.26	Bug Clinic 58
	Alternative Organization and Management
Mor 3.1 3.2	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time:
Mor 3.1 3.2	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60
Mor 3.1 3.2 3.3	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62
Mor 3.1 3.2 3.3 3.4	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64
Mor 3.1 3.2 3.3 3.4 3.5	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66
Mor 3.1 3.2 3.3 3.4 3.5 3.6	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 3.11	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70 The GENERATE Block's Priority-Level Operand 71
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 3.11 3.12	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70 The GENERATE Block's Priority-Level Operand 71 Exercises 72
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 3.11 3.12 3.13	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70 The GENERATE Block's Priority-Level Operand 71 Exercises 72 The Labeling of Blocks 72
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 3.11 3.12 3.13 3.14	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70 The GENERATE Block's Priority-Level Operand 71 Exercises 72 The Labeling of Blocks 72 Nonsequential Movement of Transactions in a Model 72
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 3.11 3.12 3.13 3.14 3.15	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70 The GENERATE Block's Priority-Level Operand 71 Exercises 72 The Labeling of Blocks 72 Nonsequential Movement of Transactions in a Model 72 Exercises 73
Mor 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10 3.11 3.12 3.13 3.14 3.15 3.16	e About Transaction Creation and Movement Preview 60 Suspending Transaction Movement for a Specified Time: The ADVANCE Block 60 Tracing ADVANCE-Block Operation in Test Mode 62 Using a Step Count with the Step Command 64 Exercises 66 The GENERATE Block's Offset-Interval and Limit-Count Operands 67 Exercises 68 Bug Clinic 69 When Two or More Transactions Move at the Same Simulated Time 69 Exercises 70 The GENERATE Block's Priority-Level Operand 71 Exercises 72 The Labeling of Blocks 72 Nonsequential Movement of Transactions in a Model 72 Exercises 73 Bug Clinic 74

3

4

.

.

4.1 Preview 76

76

xiii

	4.2	Transaction Chains 76	
	4.3	The Current Events Chain 77	
	4.4	The Future Events Chain 78	
	4.5	A Broad View of Transaction Movement 79	
	4.6	GENERATE-Block Initialization 80	
	4.7	The Test-Mode Display Command 81	
	4.8	The Test-Mode "Tran Scan" Command 82	
	4.9	A Test-Mode Demonstration of GENERATE-Block Initialization 83	
	4.10	The Use of Arrow and Function Keys to Scroll 88	
	4.11	Exercises 90	
	4.12	Updating the State of a Model at the Current Simulated Time:	
		The Scan Phase 92	
	4.13	Moving Ahead in Simulated Time: The Clock Update Phase 94	
	4.14	A Test-Mode Demonstration of the Scan and Clock Update Phases 95	
	4.15	Exercises 102	
	4.16	The Timing of GENERATE-Block Execution 104	
	4.17	Zero Interarrival Times at a GENERATE Block 105	
	4.18	A Chain-Oriented View of a Transaction's Location 105	
	4.19	A Test-Mode Demonstration of Zero Interarrival Times at a	
		GENERATE Block 106	
	4.20	Exercises 112	
5	Addi	itional Test-Mode Capabilities	115
	5.1	Preview 115	
	5.2	Stepping Through a Simulation, Transaction-by-Transaction 115	
	5.3	Exercises 120	
	5.4	More About Test Mode 122	
	5.5	Exercises 122	
	5.6	Specifying a Clock-Based Interrupt Condition 123	
	5.7	Exercises 128	
6	Fund	damental Modeling of Single Servers	130
	6.1	Preview 130	
	6.2	The Nature of Servers 130	
	6.3	Logical Considerations Involved in Modeling a Single Server 132	
	6.4	Modeling Servers Individually: The Facility Entity 133	
	6.5	Other Blocks for the Facility Entity 136	
	6.6	Facility Reports 136	
	6.7	More About the Steps Followed by GPSS/H in a Batch Simulation 138	
	6.8	Running GPSS/H in Batch Mode Under DOS 139	
	6.9	Documentation Pattern for Case Studies 139	
	6.10	Case Study 6A: Modeling a Widget-Manufacturing System 140	
	6.11	Displaying the Postsimulation Report 146	
,		6.11.1 Use of GPSS/H in Test Mode 147	

÷

	6.12 6.13	 6.11.2 Use of an Editor 147 6.11.3 Use of a Printer 147 6.11.4 Use of a Sideways Utility 147 Exercises 147 Bug Clinic 149 	
7	Mor	e About How Transactions Are Managed by GPSS/H	151
	7.1 7.2 7.3 7.4 7.5 7.6 7.7	Preview 151 Restarting the Scan During a Scan Phase 151 The Model's Status-Change Flag 153 Blocks Whose Execution Turns On the Model's Status Change Flag 154 Unique Blocking and a Transaction's Scan-Skip Indicator 154 A Test-Mode Demonstration of the Status Change Flag and Scan-Skip Indicators 156 Exercises 164	
8	Mor	e Imaginative Modeling of Single Servers	165
	8.1 8.2 8.3 8.4 8.5 8.6 8.7 8.8 8.9 8.10 8.11	Preview 165 When the Block Following GENERATE Can Deny Entry 165 Using Identical Blocks at Multiple Points in a Model 167 Exercises 167 The Use of Consecutive Blocks Which Can Deny Entry 169 Zero-Time Blocks 170 Dummy Facilities 171 The Use of Overlapping SEIZE/RELEASE Blocks 172 Unequal Numbers of Complementary Blocks 173 Exercises 175 Bug Clinic 177	
9	Gath	hering Information About Transactions	178
	9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8	Preview 178 The Nature of the Queue Entity 178 Starting and Ending Membership in a Queue: QUEUE and DEPART Blocks 180 Queue Reports 180 More Examples of Queue Use 182 Case Study 9A: Alternative Service Orders at a Tool Crib 183 Exercises 187 Bug Clinic 191	-
10	Exp	anding the Set of Test-Mode Capabilities	192
	10.1	Preview 192	

xiv

.

ł

÷

- **10.3** Examples of Break Use **193**
- **10.4** Exercises **194**

10.5 The Test Mode Un/Trap Xact Commands **195**

- 10.6 A Summary of Display Modifiers 196
- 10.7 Exercises 196
- 10.8 At-Points and At-Lists 197
- 10.9 Exercises 199

11 Modeling Groups of Identical Servers

11.1	Preview	200
------	---------	-----

- 11.2 Single Servers vs. Groups of Identical Servers 200
- 11.3 Using a Server in a Group of Identical Servers: ENTER and LEAVE Blocks 201
- 11.4 Specifying Group Size: The STORAGE Control Statement 202
- **11.5** Facilities vs. Storages with a Capacity of 1 **204**
- **11.6** The Vocabulary Used with Storages **204**
- **11.7** The Operation of ENTER and LEAVE Blocks **205**
- **11.8** The Type of Queuing System Which a Storage Models **205**
- 11.9 Requesting/Freeing More than 1 Server in a Group at a Time 206
- **11.10** Other Blocks for the Storage Entity **208**
- 11.11 Storage Reports 208
- 11.12 Estimating the Minimum and Maximum Number of Servers 209
- 11.13 Case Study 11A: Ships Un/Loading Cargo at a Harbor 209
- 11.14 Exercises 214
- 11.15 Bug Clinic 217
- **11.16** Dummy Storages **217**
- **11.17** Overlapping ENTER/LEAVE Blocks **218**
- 11.18 Exercises 218
- **11.19** Admitting Transactions into a Model Only When Needed **218**
- 11.20 Exercises 219

12 Additional Blocks for Controlling Transaction Direction and Timing 221

- **12.1** Preview **221**
- **12.2** The Statistical-Mode TRANSFER Block **221**
- 12.3 Case Study 12A: A Quality Control Model 223
- 12.4 Exercises, 224
- 12.5 Bug Clinic 228
- 12.6 The BOTH-Mode TRANSFER Block 228
- 12.7 Examples Using BOTH-Mode TRANSFER 229
- 12.8 Exercises 230
- 12.9 Modifying a Transaction's Priority Level: The PRIORITY Block 234
- **12.10** The Correct Location for PRIORITY Blocks in a Model **237**
- **12.11** Case Study 12B: An Equipment Balancing Problem **238**

12.12	Exercises 242
12.13	Use of Priority Levels to Control the Order of Model Updating 244
12.14	Exercises 246
12.15	The ALL-Mode TRANSFER Block 247
12.16	Exercises 249
Mod	eling with Nonuniform Probability Distributions
13.1	Preview 250
13.2	A Visualization of Simulated Sampling from a Population 250
13.3	The GPSS/H Uniform Random Number Generators 251
13.4	Transparent Sampling at GENERATE and ADVANCE Blocks 252
13.5	Use of RN1 at Statistical TRANSFER Blocks 254
13.6	Sampling from the Exponential Distribution: RVEXPO 254
13.7	The Relationship Between the Exponential and Poisson
	Random Variables 256
13.8	Sampling from the Erlang Distribution 257
13.9	Case Study 13A: A Model of a Hospital's Emergency Room 258
13.10	Exercises 263
13.11	Sampling from the Normal Distribution: RVNORM 265
13.12	Sampling from the Triangular Distribution: RVTRI 268
13.13	Using Limited Data to Characterize Distributions 269
13.14	Exercises 271
13.15	Sampling from Discrete Distributions: D-Functions 271
13.16	Using Discrete Functions at GENERATE and ADVANCE Blocks 275
13.17	Other Applications for Discrete Random Variables 276
13.18	Use of a Function to Determine a Transaction's Next Block at Random
13.19	Other Applications for Functions 277
13.20	Sampling from Continuous Distributions: C-Functions 277
13.21	Sampling from Continuous Uniform Distributions with C-Functions
13.22	Sampling by the Method of Inversion 280
13.23	Case Study 13B: A Job Shop Model 280
13.24	EXERCISES 20/
13.25	Nonzero GENERATE and ADVANCE B Operands when A Operands
	are function keterences 289

13.26 Function-Modified GENERATE and ADVANCE Blocks 290

13.27 Exercises 290

14 Statistical Experiments with Single-System Models

291

276

279

250

- 14.1 Preview 291
- 14.2 Performing Replications with a Simulation Model 291
- 14.3. The CLEAR Control Statement 293
 - 14.3.1 The Format of a CLEAR Statement 293
 - 14.3.2 The Positioning of CLEAR Statements in a Model File 294
 - 14.3.3 The Effect of CLEAR-Statement Execution 295

	14.4	14.3.4 Achieving Replications with the Case Study 12A Model 296 Replicating with DO /FNDDO Control Statements and Integer	
	14.4	Ampergariables 296	
		Ampervariables 250	
		14.4.1 DO/ENDLO Control Statements 296	
		14.4.2 Ampervariables 299	
		14.4.3 An Example of the Use of DO/ENDDO for Replications 300	
	14.5	The UNLIST CSECHO Compiler Directive 302	
	14.6	The PUTPIC Control Statement 302	
	14.7	Exercises 305	
	14.8	Types of Simulations 306	
		14.8.1 Terminating Simulations 306	
		14.8.2 Steady-State Simulations 307	
		14.8.3 Summary 309	
	14.9	Interval Estimates of Expected Values 309	
		14.9.1 The Meaning of an Interval Estimate 309	
		14.9.2 Small-Sample Confidence Intervals 310	
		14.9.3 Satisfying the iid-Normal Assumptions in Simulation 311	
		14.9.4 Large-Sample Confidence Intervals 312	
		14.9.5 Automating the Calculation of Confidence Intervals in GPSS/H 312	
	14.10	Exercises 312	
	14.11	The Use of Pilot Studies to Estimate Required Sample Size 313	
	14.12	Understanding and Controlling the GPSS/H Random Number Generators 314	
		14.13.1 The Lehmer Random Number Generator in GPSS/H 314	1
		14.12.2 The RNG Report 316	
		14.12.3 The RMULT Control Statement 318	
	14.13	Case Study 14A: Use of a Pilot Study with the SPT Tool Crib 319	
	14.14	Exercises 322	
15	The	Use of Antithetic Variates in Single-System Modeling	324
	1 - 1	Duration 204	
	15.1	$\begin{array}{c} \text{Preview} 324 \\ \text{The } \mathbf{C} \\ 1 \\ \mathbf{C} \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ $	
	15.2	The Concept of Antithetic Variates 324	
	15.3	Providing Antithetic Inputs in Simulation 320	
	15.4	Obtaining Antithetic 0-1 Uniform Random Numbers in GPSS/H 327	
	15.5	Synchronized Use of 0-1 Uniform Random Numbers 327	
	15.6	Computing Operand Values in RMULT Control Statements 328	
	15.7	Case Study 15A: Antithetic Replications with the SPT Tool Crib 330	
	15.8	Exercises 333	
10	Ctat	etical Experiments with Medels of Competing Alternatives	
01	Sial		335
	16.1	Preview 335	
	16.2	Uncorrelated Paired-t Comparison of Two Alternatives 335	
	16.3	Other Confidence Intervals for the Difference in Expected Values in Two	
		Populations Based on Independent Samples 337	
	16.4	Exercises 338	

÷

- 16.5 Correlated Paired-t Comparison of Two Alternatives 339
- 16.6 Using Common Random Numbers to Induce Positive Correlation 341
- 16.7 Exercises 344
- 16.8 Selecting the Probable Best from k Competing Alternatives 346
- 16.9 Case Study 16A: Selecting the Probable Best from Four Proposed Production Systems 349
- **16.10** Exercises **356**

17 Epilogue

- 17.1 Preview 360
- 17.2 Availability/Unavailability of Resources 360
- **17.3** Preemptive Use of Facilities **361**
- 17.4 Logic Switches 361
- 17.5 Standard Numerical and Logical Attributes 361
- 17.6 Transaction Attributes 362
- 17.7 Explicit Testing 362
- 17.8 Selection of Qualifying Entity Members 363
- **17.9** Counting Qualifying Entity Members **363**
- 17.10 The Table Entity 363
- 17.11 Ampervariables 364
- 17.12 Computational Capabilities 364
- 17.13 Arithmetic Expressions 364
- 17.14 Boolean Expressions 365
- 17.15 Input/Output Capabilities 365
- 17.16 The Control-Statement Language 365
- 17.17 Block Forms of Control Statements 365
- 17.18 Two-Dimensional Data Structures 366
- 17.19 Extended Possibilities for Supplying Operand Values 366
- **17.20** Other Types of Functions **366**
- 17.21 Modeling Complex Service Orders 367
- 17.22 The Cloning of Transactions 368
- 17.23 Assembly Sets 368
- 17.24 The RESET Control Statement 369
- 17.25 SAVE and READ Control Statements; Checkpoint and Restore Test-Mode Commands 370
- 17.26 Transaction and Numeric Groups 370
- 17.27 Animation 371
- 17.28 Further Study of GPSS/H 371
- 17.29 Epilogue to the Epilogue 372

Appendix A: Installing and Checking Out Student DOS GPSS/H	373
Appendix B: Commands and Options for Running GPSS/H	
Models Under DOS	378
Appendix C: Solutions to Selected Exercises	383
References	421
Author Index	
Subject Index	425

·

.