Table of Contents

Preface.	Preface xi		
Part I.	Foundation and Building Blocks		
1. Dat	a Engineering Described	3	
Wl	nat Is Data Engineering?	3	
I	Data Engineering Defined	4	
Т	he Data Engineering Lifecycle	5	
F	volution of the Data Engineer	6	
Ι	Data Engineering and Data Science	11	
Da	ta Engineering Skills and Activities	13	
	Data Maturity and the Data Engineer	13	
Т	The Background and Skills of a Data Engineer	17	
	Business Responsibilities	18	
	echnical Responsibilities	19	
	The Continuum of Data Engineering Roles, from A to B	21	
	ta Engineers Inside an Organization	22	
	nternal-Facing Versus External-Facing Data Engineers	23	
	Oata Engineers and Other Technical Roles	24	
	Data Engineers and Business Leadership	28	
	nclusion	31	
Ad	ditional Resources	32	
2. The	Data Engineering Lifecycle	35	
Wl	nat Is the Data Engineering Lifecycle?	35	
Т	he Data Lifecycle Versus the Data Engineering Lifecycle	36	
(Generation: Source Systems	37	

	Storage	40
	Ingestion	41
	Transformation	45
	Serving Data	46
	Major Undercurrents Across the Data Engineering Lifecycle	50
	Security	51
	Data Management	52
	DataOps	61
	Data Architecture	66
	Orchestration	66
	Software Engineering	68
	Conclusion	70
	Additional Resources	71
3.	Designing Good Data Architecture	73
	What Is Data Architecture?	73
	Enterprise Architecture Defined	74
	Data Architecture Defined	77
	"Good" Data Architecture	78
	Principles of Good Data Architecture	79
	Principle 1: Choose Common Components Wisely	80
	Principle 2: Plan for Failure	81
	Principle 3: Architect for Scalability	82
	Principle 4: Architecture Is Leadership	82
	Principle 5: Always Be Architecting	83
	Principle 6: Build Loosely Coupled Systems	83
	Principle 7: Make Reversible Decisions	85
	Principle 8: Prioritize Security	86
	Principle 9: Embrace FinOps	87
	Major Architecture Concepts	89
	Domains and Services	89
	Distributed Systems, Scalability, and Designing for Failure	90
	Tight Versus Loose Coupling: Tiers, Monoliths, and Microservices	92
	User Access: Single Versus Multitenant	96
	Event-Driven Architecture	97
	Brownfield Versus Greenfield Projects	98
	1 71	100
		100
		103
	,	104
		105
	Lambda Architecture	106

	Kappa Architecture	107
	The Dataflow Model and Unified Batch and Streaming	107
	Architecture for IoT	108
	Data Mesh	111
	Other Data Architecture Examples	112
	Who's Involved with Designing a Data Architecture?	113
	Conclusion	113
	Additional Resources	113
4.	Choosing Technologies Across the Data Engineering Lifecycle	. 119
	Team Size and Capabilities	120
	Speed to Market	121
	Interoperability	121
	Cost Optimization and Business Value	122
	Total Cost of Ownership	122
	Total Opportunity Cost of Ownership	123
	FinOps	124
	Today Versus the Future: Immutable Versus Transitory Technologies	124
	Our Advice	126
	Location	127
	On Premises	127
	Cloud	128
	Hybrid Cloud	131
	Multicloud	132
	Decentralized: Blockchain and the Edge	133
	Our Advice	133
	Cloud Repatriation Arguments	134
	Build Versus Buy	136
	Open Source Software	137
	Proprietary Walled Gardens	141
	Our Advice	142
	Monolith Versus Modular	143
	Monolith	143
	Modularity The Distribute Living Box	144
	The Distributed Monolith Pattern	146
	Our Advice	146
	Serverless Versus Servers	147
	Serverless	147
	Containers	148
	How to Evaluate Server Versus Serverless	149
	Our Advice	150
	Optimization, Performance, and the Benchmark Wars	151

Big Datafor the 1990s	152
Nonsensical Cost Comparisons	152
Asymmetric Optimization	152
Caveat Emptor	153
Undercurrents and Their Impacts on Choosing Technologies	153
Data Management	153
DataOps	153
Data Architecture	154
Orchestration Example: Airflow	154
Software Engineering	155
Conclusion	155
Additional Resources	155
Part II. The Data Engineering Lifecycle in Depth	
5. Data Generation in Source Systems	159
Sources of Data: How Is Data Created?	160
Source Systems: Main Ideas	160
Files and Unstructured Data	160
APIs	161
Application Databases (OLTP Systems)	161
Online Analytical Processing System	163
Change Data Capture	163
Logs	164
Database Logs	165
CRUD	166
Insert-Only	166
Messages and Streams	167
Types of Time	168
Source System Practical Details	169
Databases	170
APIs	178
Data Sharing	180
Third-Party Data Sources	181
Message Queues and Event-Streaming Platforms	181
Whom You'll Work With	185
Undercurrents and Their Impact on Source Systems	187
Security	187
Data Management	188
DataOps	188
Data Architecture	189

	Orchestration	190
	Software Engineering	191
	Conclusion	191
	Additional Resources	192
6.	Storage	193
	Raw Ingredients of Data Storage	195
	Magnetic Disk Drive	195
	Solid-State Drive	197
	Random Access Memory	198
	Networking and CPU	199
	Serialization	199
	Compression	200
	Caching	201
	Data Storage Systems	201
	Single Machine Versus Distributed Storage	202
	Eventual Versus Strong Consistency	202
	File Storage	203
	Block Storage	206
	Object Storage	209
	Cache and Memory-Based Storage Systems	215
	The Hadoop Distributed File System	215
	Streaming Storage	216
	Indexes, Partitioning, and Clustering	217
	Data Engineering Storage Abstractions	219
	The Data Warehouse	219
	The Data Lake	220
	The Data Lakehouse	220
	Data Platforms	221
	Stream-to-Batch Storage Architecture	221
	Big Ideas and Trends in Storage	222
	Data Catalog	222
	Data Sharing	223
	Schema	223
	Separation of Compute from Storage	224
	Data Storage Lifecycle and Data Retention	227
	Single-Tenant Versus Multitenant Storage	230
	Whom You'll Work With	231
	Undercurrents	232
	Security	232
	Data Management	232
	DataOps	233

	Data Architecture	234
	Orchestration	234
	Software Engineering	234
	Conclusion	234
	Additional Resources	235
7.	Ingestion	237
	What Is Data Ingestion?	238
	Key Engineering Considerations for the Ingestion Phase	239
	Bounded Versus Unbounded Data	240
	Frequency	241
	Synchronous Versus Asynchronous Ingestion	242
	Serialization and Deserialization	243
	Throughput and Scalability	243
	Reliability and Durability	244
	Payload	245
	Push Versus Pull Versus Poll Patterns	248
	Batch Ingestion Considerations	248
	Snapshot or Differential Extraction	250
	File-Based Export and Ingestion	250
	ETL Versus ELT	250
	Inserts, Updates, and Batch Size	251
	Data Migration	251
	Message and Stream Ingestion Considerations	252
	Schema Evolution	252
	Late-Arriving Data	252
	Ordering and Multiple Delivery	252
	Replay	253
	Time to Live	253
	Message Size	253
	Error Handling and Dead-Letter Queues	253
	Consumer Pull and Push Location	254 254
	Ways to Ingest Data Direct Database Connection	254 255
	Change Data Capture	255
	APIs	258
	Message Queues and Event-Streaming Platforms	259
	Managed Data Connectors	260
	Moving Data with Object Storage	261
	EDI	261
	Databases and File Export	261
	~ www.wo-o-o-wiiw i iiv iiip oit	

	Practical Issues with Common File Formats	262
	Shell	262
	SSH	263
	SFTP and SCP	263
	Webhooks	263
	Web Interface	264
	Web Scraping	264
	Transfer Appliances for Data Migration	265
	Data Sharing	266
	Whom You'll Work With	266
	Upstream Stakeholders	266
	Downstream Stakeholders	267
	Undercurrents	267
	Security	268
	Data Management	268
	DataOps	270
	Orchestration	272
	Software Engineering	272
	Conclusion	272
	Additional Resources	273
R	Queries, Modeling, and Transformation	275
0.	Oueries	276
	What Is a Query?	277
	The Life of a Query	278
	The Query Optimizer	279
	Improving Query Performance	279
	Queries on Streaming Data	285
	Data Modeling	291
	What Is a Data Model?	292
	Conceptual, Logical, and Physical Data Models	293
	Normalization	294
	Techniques for Modeling Batch Analytical Data	298
	Modeling Streaming Data	311
	Transformations	313
	Batch Transformations	314
	Materialized Views, Federation, and Query Virtualization	327
	Streaming Transformations and Processing	330
	Whom You'll Work With	333
	Upstream Stakeholders	333
	Downstream Stakeholders	334
	Undercurrents	334

	Security	334
	Data Management	335
	DataOps	336
	Data Architecture	337
	Orchestration	337
	Software Engineering	337
	Conclusion	338
	Additional Resources	339
9.	Serving Data for Analytics, Machine Learning, and Reverse ETL	341
	General Considerations for Serving Data	342
	Trust	342
	What's the Use Case, and Who's the User?	343
	Data Products	344
	Self-Service or Not?	345
	Data Definitions and Logic	346
	Data Mesh	347
	Analytics	348
	Business Analytics	348
	Operational Analytics	350
	Embedded Analytics	352
	Machine Learning	353
	What a Data Engineer Should Know About ML	354
	Ways to Serve Data for Analytics and ML	355
	File Exchange	355
	Databases	356
	Streaming Systems	358
	Query Federation	358
	Data Sharing	359
	Semantic and Metrics Layers	359
	Serving Data in Notebooks	360
	Reverse ETL	362
	Whom You'll Work With	364
	Undercurrents	364
	Security	365
	Data Management	366
	DataOps	366
	Data Architecture	367
	Orchestration	367
	Software Engineering	368
	Conclusion	369
	Additional Resources	369

Pa	rt III. Security, Privacy, and the Future of Data Engineering	
10.	Security and Privacy	373
	People	374
	The Power of Negative Thinking	374
	Always Be Paranoid	374
	Processes	375
	Security Theater Versus Security Habit	375
	Active Security	375
	The Principle of Least Privilege	376
	Shared Responsibility in the Cloud	376
	Always Back Up Your Data	376
	An Example Security Policy	377
	Technology	378
	Patch and Update Systems	378
	Encryption	379
	Logging, Monitoring, and Alerting	379
	Network Access	380
	Security for Low-Level Data Engineering	381
	Conclusion	382
	Additional Resources	382
11.	. The Future of Data Engineering	. 383
	The Data Engineering Lifecycle Isn't Going Away	384
	The Decline of Complexity and the Rise of Easy-to-Use Data Tools	384
	The Cloud-Scale Data OS and Improved Interoperability	385
	"Enterprisey" Data Engineering	387
	Titles and Responsibilities Will Morph	388
	Moving Beyond the Modern Data Stack, Toward the Live Data Stack	389
	The Live Data Stack	389
	Streaming Pipelines and Real-Time Analytical Databases	390
	The Fusion of Data with Applications	391
	The Tight Feedback Between Applications and ML	392
	Dark Matter Data and the Rise ofSpreadsheets?!	392
	Conclusion	393
A.	Serialization and Compression Technical Details	395
В.	Cloud Networking	. 403
Ind	lov	407