

Understanding Complex Systems

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Understanding Complex Systems

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Hubert Anton Moser

Systems Engineering, Systems Thinking, and Learning

A Case Study in Space Industry

 Springer

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Foreword

Nowadays system development is multi-disciplinary. Disciplinary knowledge, perspectives and thinking no longer suffice to develop systems in an efficient and effective way. Development team members need to consider the system as a whole and work together closely across disciplinary boundaries, and systems engineers are required that know enough of the disciplines involved to ensure the total quality of the system.

Although the concepts of systems engineering and systems thinking have been around for several decades, an understanding of how developers actually work together across disciplinary boundaries and how they learn from each other, is still lacking. What does it mean to think in terms of systems in the context of a highly integrated system in which partial, disciplinary solutions affect each other? How do developers *learn* from each other in such a multi-disciplinary environment, i.e., how does systems thinking evolve? And most importantly, how can we improve this process: How can systems thinking be learned more effectively and efficiently given the fact that our education is essentially disciplinary?

These questions are addressed in this book in a unique way as part of a PhD project executed within space systems industry. To understand systems thinking, methods from educational and social sciences were used in an engineering context, multiple real development projects in industry were analyzed, and the analysis covered an extended period of time. A multi-level analytical framework was developed, based on activity theory, allowing a detailed analysis of multidisciplinary interaction over time. Short and long term mechanisms essential for learning to think in systems were identified, and finally, a strategy called WAVES (Work Activity for a Versatile Evolution of Systems engineering and thinking) was developed to improve the evolution of systems thinking.

This book is an excellent resource for researchers and practitioners interested in systems thinking and in solutions to support its evolution. It not only provides an extensive overview of the developments in this field, but provides a unique and rich account of the practice of interaction between disciplines and learning across disciplinary boundaries. Of particular interest for researchers is the developed analytical framework, which is applicable for the analysis of a wide variety of work activities in the context of engineering design and beyond. Of particular interest for industry is the proposed human resource development strategy, WAVES, to improve the development process by improving the effectiveness of interaction between disciplines, the speed of systems thinking development, and the quality of boundary management.

When Hubert contacted me with his idea for a research project, we could not have anticipated the richness of the project and the results. Not only did the

research deal with multidisciplinary in an engineering context, it was multidisciplinary in its own right, involving concepts, methods and strategies from yet other, non-engineering disciplines. The dedicated involvement of LuxSpace and my colleague Gudrun Ziegler have been essential in achieving the depth and quality the topic requires. Most of all, however, Hubert has to be credited with actually crossing boundaries, venturing into unfamiliar disciplines, bringing everything together, and providing the reader with a unique account of systems thinking and a solution for its improvement.

20 October 2013
Luxembourg

Lucienne Blessing

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Contents

Foreword	V
Acknowledgements	VII
List of Acronyms.....	XVII
Part I: Introduction of the Research Project.....	1
1 Introduction	3
1.1 Motivation	3
1.2 Objectives and Research Question	5
1.3 Scope	5
1.4 Structure of the Book	7
References	8
2 Systems Engineering and Learning	11
2.1 Systems Engineering	11
2.1.1 System.....	11
2.1.2 Characteristics of Systems Engineering	13
2.1.3 Systems Engineering within Multi-disciplinary Teams	21
2.1.4 Conclusion.....	22
2.2 Systems Thinking, Knowledge, and Interaction in Engineering	22
2.2.1 Systems Thinking	23
2.2.2 Knowledge	28
2.2.3 Interaction	30
2.2.4 Conclusion.....	33
2.3 Learning in Engineering.....	33
2.3.1 Definitions and Theories of Learning.....	33
2.3.2 Models of Learning	36
2.3.2.1 Circular Models of Learning	36
2.3.2.2 Non-circular Models of Learning.....	40
2.3.3 Conclusion.....	42
2.4 Space	42
2.4.1 Space Missions and Systems Engineering	42

2.4.2	Multi-disciplinary Interaction in Space Systems	
	Engineering	45
2.4.3	Microspace	47
2.4.4	Conclusion.....	48
2.5	Conclusion	48
	References	49
3	Research Approach	59
3.1	Research Questions	59
3.2	Research Methodology, Strategy, Methods, and Plan.....	60
	3.2.1 Research Methodology.....	60
	3.2.2 Research Strategy and Methods	61
	3.2.3 Research Plan	62
3.3	Data Collection and Processing Approach.....	63
	3.3.1 Overview of Considered Data Collection Methods.....	64
	3.3.2 Prioritisation of Data Collection Methods.....	65
	3.3.3 Processing of Multiple Data Sources	67
3.4	Analysis Framework	68
	3.4.1 Frameworks for Analysing Human Activity	68
	3.4.1.1 Levels and Units of Analysis	68
	3.4.1.2 Actor Network Theory	68
	3.4.1.3 Distributed Cognition.....	69
	3.4.1.4 Activity Theory	70
	3.4.1.5 Comparison	70
	3.4.2 Analysing Work with Activity Theory.....	71
	3.4.2.1 Activity-Action-Operation	71
	3.4.2.2 Models of Activity Systems	72
	3.4.2.3 Five Principles of Activity Theory.....	74
	3.4.2.4 Matrix of Situatedness.....	75
	3.4.2.5 Conclusion	77
	3.4.3 Systems Thinking Taxonomy for Analysing Change of Knowledge	77
	3.4.3.1 Modification of the Taxonomy of Anderson et al. (2001).....	78
	3.4.3.2 Combination with Different Fields of Knowledge	80
	3.4.3.3 Conclusion	81
	3.4.4 Analysis Framework	81
3.5	Analysis Approach.....	82
	3.5.1 Activity-Theoretical Analysis	83
	3.5.1.1 Description of the ASN.....	83
	3.5.1.2 Identification of Contradictions.....	84
	3.5.2 Theme-and-Key-Event Analysis	86
	3.5.2.1 Key Event Identification and Link to Themes	86

3.5.2.2	Analysis Zoom with Three Levels of Analysis	87
3.5.2.3	Ethnographic Statistics	92
3.6	Credibility of Research	92
3.7	Conclusion	93
	References	94

Part II: Analysis and Findings of the Empirical Studies..... 91

4	Description of Empirical Studies	101
4.1	Empirical Studies Overview.....	101
4.2	Preparatory Study 1 (PS1).....	103
4.2.1	Purpose and Design of PS1	103
4.2.2	Setup of PS1	103
4.2.3	Data Collection and Processing.....	104
4.3	Preparatory Study 2 (PS2).....	104
4.3.1	Purpose and Design of PS2	104
4.3.2	Setup of PS2.....	105
4.3.3	Data Collection and Processing.....	106
4.4	Study 1 (S1)	106
4.4.1	Purpose and Design of S1	106
4.4.2	Setup of S1	107
4.4.3	Data Collection and Processing.....	116
4.5	Study 2 (S2)	118
4.5.1	Purpose and Design of S2	118
4.5.2	Setup of S2	118
4.5.3	Data Collection and Processing.....	119
4.6	Reflection on Data Collection and Research Ethics.....	121
4.7	Conclusion	122
	References	122
5	Activity-Theoretical Analysis and Findings	125
5.1	Activity Systems Network of Preparatory Study 1 (ASN-PS1)	125
5.1.1	ASN-PS1 Activity of Interest.....	126
5.1.2	ASN-PS1 Objective.....	128
5.1.3	ASN-PS1 Subjects.....	128
5.1.4	ASN-PS1 Tools.....	128
5.1.5	ASN-PS1 Rules and Regulations	128
5.1.6	ASN-PS1 Division of Labour.....	129
5.1.7	ASN-PS1 Community	129
5.1.8	ASN-PS1 Contradictions.....	129
5.1.9	Conclusion.....	132

5.2	Activity Systems Network of Preparatory Study 2 (ASN-PS2)	132
5.2.1	ASN-PS2 Activity of Interest.....	134
5.2.2	ASN-PS2 Objective.....	134
5.2.3	ASN-PS2 Subjects.....	135
5.2.4	ASN-PS2 Tools.....	135
5.2.5	ASN-PS2 Rules and Regulations	136
5.2.6	ASN-PS2 Division of Labour.....	136
5.2.7	ASN-PS2 Community	137
5.2.8	ASN-PS2 Contradictions.....	137
5.2.9	Conclusion.....	140
5.3	Activity Systems Network of Study 1 (ASN-S1).....	140
5.3.1	ASN-S1 Activity of Interest	141
5.3.2	ASN-S1 Objective.....	143
5.3.3	ASN-S1 Subjects.....	143
5.3.4	ASN-S1 Tools	146
5.3.5	ASN-S1 Rules and Regulations	148
5.3.6	ASN-S1 Division of Labour.....	150
5.3.7	ASN-S1 Community	150
5.3.8	ASN-S1 Contradictions	151
5.3.9	Conclusion.....	154
5.4	Activity Systems Network of Study 2 (ASN-S2).....	155
5.4.1	ASN-S2 Activity of Interest	155
5.4.2	ASN-S2 Objective.....	156
5.4.3	ASN-S2 Subjects.....	157
5.4.4	ASN-S2 Tools	158
5.4.5	ASN-S2 Rules and Regulations	159
5.4.6	ASN-S2 Division of Labour.....	159
5.4.7	ASN-S2 Community	159
5.4.8	ASN-S2 Contradictions.....	160
5.4.9	Conclusion.....	162
5.5	Summary of Findings from the Activity-Theoretical Analysis.....	162
5.6	Conclusion	164
	References	164
6	Contradiction-Driven Theme-and-Key-Event Analysis.....	165
6.1	Overview of Contradictions and Selected Themes.....	165
6.2	Description of Themes	165
6.2.1	Interproject	166
6.2.1.1	Macrolevel Analysis of Theme Interproject.....	168
6.2.2	Harness.....	174
6.2.2.1	Macrolevel Analysis of Theme Harness.....	174
6.2.2.2	Mesolevel Analysis Key Event Harness d901.....	175

6.2.2.3	Mesolevel Analysis Key Event Harness d920.....	176
6.2.3	Li-Ion Cells	179
6.2.3.1	Macrolevel Analysis of Theme Li-Ion Cells	179
6.2.4	EMC & Mechanics.....	180
6.2.4.1	Macrolevel Analysis of Theme EMC & Mechanics	180
6.2.5	EMC & Power.....	181
6.2.5.1	Macrolevel Analysis of Theme EMC & Power.....	181
6.2.6	Sun Sensor.....	182
6.2.6.1	Macrolevel Analysis of Theme Sun Sensor	183
6.2.7	Accommodation	183
6.2.7.1	Macrolevel Analysis of Theme Accommodation	184
6.2.8	Stiffness.....	184
6.2.8.1	Macrolevel Analysis of Theme Stiffness	185
6.2.8.2	Mesolevel Analysis of Key Event Stiffness d892.....	186
6.2.8.3	Mesolevel Analysis of Key Event Stiffness d899.....	189
6.2.9	Radio	191
6.2.9.1	Macrolevel Analysis of Theme Radio.....	192
6.2.9.2	Mesolevel Analysis of Key Event Radio d794.....	194
6.2.10	AOCS-Fuel.....	198
6.2.10.1	Macrolevel Analysis of Theme AOCS-Fuel	198
6.2.10.2	Microlevel Analysis of an Instance in Key Event AOCS-Fuel d2_1149.....	201
6.2.10.3	Mesolevel Analysis of Key Event AOCS-Fuel d2_1154.....	203
6.2.11	Oculter	208
6.2.11.1	Macrolevel Analysis of Theme Oculter.....	209
6.2.11.2	Mesolevel Analysis of Key Event Oculter d2_1717	210
6.2.11.3	Microlevel Analysis of Key Event Oculter d2_1717	213
6.3	Detailed Description of Contradictions	214
6.3.1	Multiple Roles	214
6.3.2	Parameter Definition and Impact.....	216
6.3.3	Differences in Work Approaches and Ways of Interacting	218
6.3.4	Clash of Standards.....	220
6.3.5	Trust and Doubts in Extra-Disciplinary Decisions.....	221
6.3.6	Awareness of Diversity and Orientation towards Extra-Disciplinary Interactors	223

- 6.3.7 Velocity and Availability of Information 226
- 6.4 Summary and Discussion of Findings 227
 - 6.4.1 Expert-Novice Practices 228
 - 6.4.2 Multi-disciplinary Interaction..... 230
 - 6.4.2.1 Multi-disciplinarity 231
 - 6.4.2.2 Types of Multi-disciplinary Interaction 231
 - 6.4.2.3 Techniques of Multi-disciplinary Interaction 232
 - 6.4.2.4 The Quality of Multi-disciplinary Interaction 234
 - 6.4.2.5 Conclusion 237
- 6.5 Statistics on the Frequency of Multi-disciplinary Discussion 238
 - 6.5.1 Frequency of Multi-disciplinary Discussion Occur within Project Meetings of S1 238
 - 6.5.2 Frequency of Multi-disciplinary Discussion within S2 246
- 6.6 Conclusion 248
- References 248

Part III: Results, Intervention, and Contributions 251

7 Results and Discussion 253

- 7.1 How Does Systems Thinking Evolve in Multi-disciplinary Discussion? (RQ1') 254
 - 7.1.1 Multi-disciplinary Quality of Interaction 254
 - 7.1.1.1 Initiation of Multi-disciplinary Discussion 254
 - 7.1.1.2 Two of Four Constituents of Multi-disciplinary Quality of Interaction 255
 - 7.1.1.3 Multi-disciplinary Quality of Interaction and Its Influence on the Evolution of Systems Thinking 256
 - 7.1.2 Discussion of the Influence of Multi-disciplinary Quality of Interaction on the Evolution of Systems Thinking..... 257
 - 7.1.3 Conclusion..... 259
- 7.2 How Does Systems Thinking Evolve in Multi-disciplinary Interaction? (RQ2')..... 260
 - 7.2.1 Extending the Definition of the Multi-disciplinary Quality of Interaction 260
 - 7.2.2 Change of Reference Repertoire As Indicator of Past Learning 260
 - 7.2.3 Percentage Duration of Multi-disciplinary Discussion in Interaction 261
 - 7.2.4 Two Mechanisms of Knowledge Evolution in Multi-disciplinary Interaction..... 262
 - 7.2.4.1 Legitimate Peripheral Participation in Other Fields of Practice..... 263

7.2.4.2	Change of Procedural Knowledge in Expansive Learning	263
7.2.5	Discussion	264
7.2.5.1	Extended Definition of the Multi-disciplinary Quality of Interaction	264
7.2.5.2	Change of Reference Repertoire	265
7.2.5.3	Quantitative Results on Multi-disciplinary Discussion	265
7.2.5.4	Mechanisms of Knowledge Evolution	265
7.2.6	Conclusion.....	266
7.3	How and What Is Learned by Whom in Multi-disciplinary Engineering Teams?(RQ3).....	268
7.3.1	Knowledge of Different Types Evolves in Different Time Scales of Multi-disciplinary Interaction	268
7.3.2	Modes of Working in Multi-disciplinary Engineering Teams	270
7.3.3	Learning Individuals, Teams, and Organisations	271
7.3.4	Discussion	271
7.3.5	Conclusion.....	271
7.4	Concluding Remarks on the Answers to the Research Questions ...	272
7.4.1	Summary	272
7.4.2	Limitations	275
	References	276
8	Support: The WAVES Strategy	279
8.1	Development Approach of WAVES	280
8.2	Objectives of WAVES	280
8.3	Existing Support Available for WAVES.....	283
8.3.1	Knowledge Management.....	283
8.3.2	Knowledge Management in Space Industry	284
8.3.3	Social Knowledge Management in Space Industry	285
8.3.4	Developmental Work Research.....	287
8.3.5	Additional Techniques for Knowledge Management.....	287
8.3.6	Conclusion.....	289
8.4	Concept and Design of WAVES.....	289
8.4.1	Form and Structure of WAVES	290
8.4.2	Instruments of WAVES	291
8.4.3	WAVES – Intro.....	293
8.4.3.1	Introduction into Professional Life.....	294
8.4.3.2	Introduction into Space Industry	295
8.4.3.3	Introduction into an Organisation.....	296
8.4.3.4	Intro into a New Team and Intro of a New Team	297
8.4.3.5	Intro into a New Task.....	298

8.4.4	WAVES – Conti.....	298
8.4.5	Conclusion.....	300
8.5	Implementation of WAVES.....	301
8.5.1	Combined Implementation and Evaluation Approach	301
8.5.2	Team-Wide Implementation with S1 Participants.....	302
8.5.2.1	Implementation during S1	302
8.5.2.2	Implementation after S1	302
8.5.3	Company L-Wide Implementation and Initial Evaluation of Support.....	303
8.5.4	Implementation within Company D's Concurrent Design Facility	304
8.5.5	Ongoing Assistance.....	304
8.5.6	Conclusion.....	304
8.6	Evaluation of WAVES	305
8.6.1	Initial Evaluation through Discussions.....	305
8.6.2	Concept of Comprehensive Evaluation	306
8.7	Conclusion	307
	References	307
9	Summary of Main Results, Contributions, and Outlook	311
9.1	Main Results	311
9.2	Contributions.....	313
9.2.1	Contributions to Research	313
9.2.2	Contributions to Engineering Education	313
9.2.3	Contributions to Industry	314
9.3	Outlook.....	314
Appendix A	Overview of Data Collection Methods.....	315
Appendix B	Complementary Information on S1	319
Appendix C	Complementary Information on S2.....	323
Appendix D	Basic information on themes	325

List of Acronyms

μ	Micro
AAR	After Action Review
AdminS	Activity system on team level representing members of the administrative staff of company L of Study 1 (S1)
AffectRe	Affective Response / Question
AOCS	Attitude and Orbit Control System
AODM	Activity-Oriented Design Method
AS	Activity System
ASN	Activity Systems Network
ASN-PS1	Activity Systems Network of Preparatory Study 1
ASN-PS2	Activity Systems Network of Preparatory Study 2
ASN-S1	Activity Systems Network of Study 1
ASN-S2	Activity Systems Network of Study 2
AutQue	Authentic Question
BA	Bachelor
CAD	Computer Aided Design
CDF	Concurrent Design Facility
CEF	Concurrent Engineering Facility
CengS	Activity system on team level representing engineers of Study 2 (S2)
CengS1	Activity system on team level representing engineers of Preparatory Study 2 (PS2)
CNES	Centre Nationale d'Études Spatiales
CustS	Activity system on team level representing customers of Study 1 (S1)

d	Day
DC	Direct Current
DICA	Dynamics in Interaction, Communication, and Activity
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DoD	Department of Defence
DoE	Department of Energy
DWRM	Developmental Work Research Methodology
ECSS	European Cooperation for Space Standardization
ElabExpla	Elaborate Explanation
EngS	Activity system on team level representing engineers of Study 1 (S1)
ES	Empirical Study
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
ExplTalk	Exploratory Talk
FE	FishEye
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
HCI	Human Computer Interface
HF	High Frequency
HR	Human Resource
IES	Intervention and Evaluation Study
INCOSE	International Council on Systems Engineering
IR	InfraRed
ISO	International Organisation for Standardisation
ISS	International Space Station
KISS	Keep It Simple, Stupid
KNOTS	KNOWledge development in complex Technological contextS

LF	Low Frequency
LXS	LuxSpace
MA	Master
MBSE	Model-Based Systems Engineering
NASA	National Aeronautics and Space Administration
OMG	Object Management Group
PaL	Pause and Learn
PhD	Doctor of Philosophy
PS1	Preparatory Study 1
PS2	Preparatory Study 2
RF	Radio Frequency
S1	Study 1
S2	Study 2
SciS	Activity system on team level representing scientists of Study 2 (S2)
SciS1	Activity system on team level representing scientists of Preparatory Study 2 (PS2)
SE	Systems Engineering
ShrdKnRe	Shared Knowledge Response / Question
SMA	SubMiniature version A
SoW	Statement of Work
SponS	Activity system on team level representing members of the sponsoring organisation of Preparatory Study 1 (PS1), Preparatory Study 2 (PS2), and Study 2 (S2)
STK	Satellite Tool Kit
SubcoS	Activity system on team level representing subcontractors of Study 1 (S1)
SysML	Systems Modelling Language
TutS	Activity system on team level representing tutors in Preparatory Study 1 (PS1)

UHF	Ultra High Frequency
UML	Unified Modelling Language
UV	Ultra Violet
VC	Video Conference
VHF	Very High Frequency