

## Contents

---

<b>Cover</b>	<b>1</b>
<b>Acknowledgements</b>	<b>3</b>
<b>Abstract</b>	<b>5</b>
<b>Resumen</b>	<b>7</b>
<b>Resum</b>	<b>9</b>
<b>Contents</b>	<b>14</b>
<b>List of Figures</b>	<b>15</b>
<b>List of Tables</b>	<b>17</b>
<b>List of Listings</b>	<b>19</b>
<b>1 Introduction</b>	<b>21</b>
1.1 Secure partitioned systems . . . . .	21
1.1.1 Secure hypervisors . . . . .	21
1.1.2 Validation and verification of secure hypervisors . . . . .	22
1.1.3 Challenges on the validation of secure hypervisors . . . . .	24
1.1.4 Terminology . . . . .	26
1.2 Motivation and main goals . . . . .	26
1.3 Contributions of this thesis . . . . .	26
1.4 Outline of this thesis . . . . .	27
1.5 Research Context . . . . .	28

<b>2 Secure Hypervisor Verification</b>	<b>29</b>
2.1 Formal methods in secure hypervisors . . . . .	29
2.1.1 Deductive verification . . . . .	29
2.1.2 Theorem provers . . . . .	30
2.1.3 Static code analysis . . . . .	31
2.2 Formal methods in safety standards . . . . .	32
2.2.1 RTCA Standards . . . . .	32
2.2.2 IEC-61508 Standards . . . . .	33
2.2.3 ECSS Standards . . . . .	33
2.2.4 Common Criteria Framework . . . . .	34
2.3 Summary . . . . .	35
<b>3 XtratuM foundations: A formalisation approach.</b>	<b>37</b>
3.1 Introduction . . . . .	37
3.2 XtratuM Overview . . . . .	38
3.2.1 XtratuM Architecture . . . . .	38
3.3 Trustability enforcement . . . . .	39
3.3.1 Interrupt Model . . . . .	41
3.3.2 Fault Management Model . . . . .	42
3.3.3 System specification . . . . .	43
3.4 Hypervisor model . . . . .	45
3.4.1 Hypervisor state variables . . . . .	47
3.4.2 General properties . . . . .	48
3.4.3 Spatial isolation properties . . . . .	48
3.4.4 Temporal isolation properties . . . . .	49
3.4.5 Hypervisor state management . . . . .	50
3.4.6 Hypervisor pre- and post-conditions . . . . .	50
3.5 Conclusion . . . . .	51
<b>4 Formal Validation of XtratuM Components</b>	<b>53</b>
4.1 Introduction . . . . .	53
4.1.1 XtratuM Hypervisor core . . . . .	54
4.2 Deductive Formal Methods . . . . .	54
4.3 Proposed Approach . . . . .	55

4.3.1	Method . . . . .	55
4.3.2	Contract Specification . . . . .	56
4.3.3	The Frama-C Framework . . . . .	56
4.4	Approach Evaluation . . . . .	57
4.4.1	Code Refactor . . . . .	57
4.4.2	Contract Annotation . . . . .	57
4.4.3	Proof Verification . . . . .	58
4.4.4	Proof Results . . . . .	58
4.4.5	Results . . . . .	58
4.5	Conclusions . . . . .	59
<b>5</b>	<b>Analysing the Impact and Detection of Kernel Stack Infoleaks</b>	<b>61</b>
5.1	Introduction . . . . .	61
5.2	Related Work . . . . .	62
5.2.1	Protection Mechanisms . . . . .	62
5.2.2	Protection Techniques . . . . .	63
5.3	Classification of Information Disclosure Vulnerabilities . . . . .	64
5.3.1	The Anatomy Of An Infoleak . . . . .	64
5.3.2	Targets of Infoleaks . . . . .	65
5.3.3	Infoleaks Bug Causes . . . . .	65
5.3.4	Infoleaks Data Sources . . . . .	66
5.4	Analysis on the Impact of Stack Infoleaks . . . . .	67
5.4.1	The Anatomy of An Attack . . . . .	67
5.4.2	The Contents of the Kernel Stack . . . . .	68
5.4.3	Infoleak Based Attacks . . . . .	69
5.5	The Detection of Information Leak vulnerabilities . . . . .	70
5.5.1	Infoleak Vulnerability Model . . . . .	70
5.5.2	Semantic Patch Preparation . . . . .	71
5.5.3	Filter and Rank of matches . . . . .	71
5.5.4	Infoleak Code Review and Correction . . . . .	71
5.6	Experimental Evaluation of the Detection Technique . . . . .	72
5.6.1	Existing Infoleak Detection . . . . .	72
5.6.2	Discovery of Vulnerabilities . . . . .	72
5.6.3	Applications and Limitations of our Approach . . . . .	73
5.7	Conclusions and Further Work . . . . .	73

---

<b>6 Conclusions and open research lines</b>	<b>75</b>
6.1 Conclusions . . . . .	75
6.2 Research Lines . . . . .	76
6.3 Publications related to this thesis . . . . .	76
<b>Bibliography</b>	<b>79</b>
<b>Acronyms</b>	<b>87</b>
<b>Glossary</b>	<b>89</b>