Bitte ankreuzen/*Please tick*:

☐ **Abschlussbericht Impulse-Forschungsvorhaben/*Final Report Impulse Grants***

☐ **Abschlussbericht M8 Post-Doc-Initiative PLUS-Förderung/*Final Report M8 Post-Doc-Initiative PLUS Grants***

☐ **Zwischenbericht Fokusprojekte/*Interim Report Focus Projects***

☐ **Abschlussbericht Fokusprojekte/*Final Report Focus Projects***

☐ **Zwischenbericht Explorationsprojekte/*Interim Report Exploratory Projects***

☒ **Abschlussbericht Explorationsprojekte/*Final Report Exploratory Projects***

Berichtszeitraum/*Reporting period*:
Projektbeginn/*Project start* 05.01.2015 bis/*date until* 30.04.2017

1) Projektinformation/*Project information*
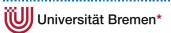
Projekttitel/*Project title*	ITTCPS Implementable Testing Theories for Cyber-physical Systems
Antragsteller/Projektleiter ***Applicant/Project leader*** Name/*Name* FB/Institut/*faculty/institute* Telefon/*phone* E-Mail-Adresse/*e-mail address*	Jan Peleska FB3 -63961 peleska@uni-bremen.de
Förderlinie/*Funding line*	M4
Projektbeginn/*Project start*	01.05.2015
Projektende/*Project end*	30.04.2017

2) Projektaktivitäten und -ergebnisse/*Project activities and results*

a) Zwischenbericht/*Interim Report*
Bitte geben Sie einen kurzen Überblick über die Aktivitäten im Berichtszeitraum (max. ½ Seite), inkl. Workshops, Konferenzteilnahmen, Feldforschung, Zusammenarbeit mehrerer Antragsteller/professoraler Arbeitsgruppen usw.
Please provide a brief overview of activities during the reporting period (no more than ½ page), including workshops, conference participation, fieldwork, cooperation of several applicants/professorial research groups etc.
b) Abschlussbericht/*Final Report*

Bitte geben Sie einen kurzen Überblick über die Aktivitäten im Berichtszeitraum (max. 1 Seite), inkl. Workshops, Konferenzteilnahmen, Feldforschung, Zusammenarbeit mehrerer Antragsteller/professoraler Arbeitsgruppen, Zusammenfassung zentraler Ergebnisse, ggf. Anschlussaktivitäten usw.

Please provide a brief overview of activities during the reporting period (no more than 1 page), including workshops, conference participation, fieldwork, cooperation of several applicants/professorial research groups, summary of central achievements, follow-up activities (if applicable) etc.

Summary of Results

All topics planned in the proposal could be comprehensively investigated, and the number of research results obtained surpassed our original expectations (see publication list). Two main results have been obtained: (A) We could show that every complete testing theory established for finite state machines gives rise to a likewise complete testing theory for a class of far more general systems operating with conceptually infinite input domains (see references 3, 4 in publication list). (B) We could also show that the completeness properties established for FSM testing theories in the past do not really depend on FSM models, but on a far more general class of modelling formalisms that can be characterised via their input/output language (published in 1, 8).

Practical Implications

The theoretical results have significant practical implications. (1) We developed algorithms for the efficient generation of new test test suites with guaranteed fault coverage properties. These algorithms have also been adopted by industry: they are now integrated in Verified Systems International's test automation tool RT-Tester (In 1998, Verified Systems has been founded asa Spin-off company of the TZI at the University of Bremen). For this integration, Verified Systems received the runner-up trophy of the EU Innovation Radar Innovation Price 2015. The new testing strategies are applied in verification and validation projects performed by the company for Airbus and Siemens. (2) We have shown how systems that are far more complex than finite state machines (e.g. railway interlocking systems) can be effectively tested with the algorithms from (1). This has been experimentally evaluated and confirmed, as published in 2, 9, 13, 14, 15. (3) The test strategies obtained from (A) and (B) can also be used for the effective verification of infinite-state models by model checking, see 6.

International Collaboration

The ITTCPS research project has led to new or intensified collaborations with the universities of Swansea, York, Leicester, and Newcastle (UK) and Aarhus and Lungby (DK). Follow-up projects on European and national level are currently in the planning stage.

Publications

The research results elaborated during the project have been published in 5 journal articles, 9 peer-reviewed conference papers, and in 1 peer-reviewed book chapter (see publication list below). In addition, a significant portion of the results have been documented in the lecture notes 16 (see publication list below) which are used in our lecture on Test Automation and Model-based Testing. We expect to publish these notes in 2019 as a monograph.

3) Projektmanagement/*Project management*

Bitte geben Sie einen kurzen Überblick über den Projektstatus im Berichtszeitraum (max. ½ Seite) und erläutern Sie, auf welche Probleme Sie gestoßen sind und wie Sie diese gelöst haben (sofern zutreffend).

Please give a brief overview of the project status for the reporting period (no more than ½ page) and elaborate on the problems and how they have been addressed (if applicable).

The project has been performed as stated in the original proposal. We did not encounter any unexpected problems. On the contrary, we obtained more results than originally expected. The focus of the two main topics of research has been slightly biased in favour of the topic "semantic navigator" and its implications for model-based testing. The reason for this is that (a) an unexpectedly high number of research results could be elaborated in this field, and (b) the response of the research community was very much in favour of this topic, so that new prospects for international cooperations came up.

4) Forschungsbudget/*Research budget*

	Verfügbares Budget im Berichtszeitraum laut ihrem Bewilligungsschreiben (in EUR) *Available budget during the reporting period according to your grant letter (in EUR)*	Eingesetztes Budget im Berichtszeitraum (in EUR) *Budget spent during the reporting period (in EUR)*
Personal *Personnel*	167.300,00 €	156.542,00 €
Sachkosten* *Consumables incl. Equipment**	12.700,00 €	0,00 €
Summe *Total*	**180.000,00 €**	**156.542,00 €**

Bitte geben sie kurz an, wie sich die Ausgaben im Berichtszeitraum entwickelten, verglichen mit dem ursprünglichen Budget in Ihrem Projektantrag. Jedwede relevante Umverteilung zwischen Budgetkategorien sowie Mehr- oder Minderverbrauch sollte erklärt werden.

Please specify briefly how the expenses incurred during the reporting period have developed in comparison with the original budget in your project proposal. Any relevant reallocation between budget categories as well as over- or under-consumption should be explained.

Travel costs were paid from other sources, therefore the project was completed without exhausting the budget.

5) Publikationen
Publications

ITTCPS – Implementable Testing Theories for Cyber-physical Systems

Project-related publications by Prof. Dr. habil. Wen-ling Huang and Prof. Dr. habil. Jan Peleska

Articles in journals (peer reviewed):

1. Wen-ling Huang and Jan Peleska. Model-based testing strategies and their (in)dependence on syntactic model representations. Software Tools for Technology Transfer, 2017. Accepted for publication

2. Felix H¨ubner, Wen-ling Huang, and Jan Peleska. Experimental evaluation of a novel equivalence class partition testing strategy. Software & Systems Modeling, Mar 2017. doi=10.1007/s10270017-0595-8

3. Wen-ling Huang and Jan Peleska. Complete model-based equivalence class testing for nondeterministic systems. Formal Aspects of Computing, 29(2):335–364, 2017

4. Wen-ling Huang and Jan Peleska. Complete model-based equivalence class testing. Software Tools for Technology Transfer, 18(3):265–283, 2016

5. Claus Ballegaard Nielsen, Peter Gorm Larsen, John Fitzgerald, Jim Woodcock, and Jan Peleska. Systems of systems engineering: Basic concepts, model-based techniques, and research directions. ACM Comput. Surv., 48(2):18:1–18:41, September 2015

Articles in proceedings of conferences/workshops (peer reviewed):

6. Niklas Krafczyk and Jan Peleska. Effective infinite-state model checking by input equivalence class partitioning. In Nina Yevtushenko, Ana Rosa Cavalli, and H¨usn¨u Yenig¨un, editors, Testing Software and Systems - 29th IFIP WG 6.1 International Conference, ICTSS 2017, St. Petersburg, Russia, October 9-11, 2017, Proceedings, pages 38–53, 2017

7. Wen-ling Huang and Jan Peleska. Safety-complete test suites. In Nina Yevtushenko, Ana Rosa Cavalli, and H¨usn¨u Yenig¨un, editors, Testing Software and Systems - 29th IFIP WG 6.1 International Conference, ICTSS 2017, St. Petersburg, Russia, October 9-11, 2017, Proceedings,

pages 145–161, 2017

8. Jan Peleska and Wen-ling Huang. Model-based testing strategies and their (in)dependence on syntactic model representations. In Maurice H. ter Beek, Stefania Gnesi, and Alexander Knapp, editors, Critical Systems: Formal Methods and Automated Verification - Joint 21st International Workshop on Formal Methods for Industrial Critical Systems and 16th International Workshop on Automated Verification of Critical Systems, FMICS-AVoCS 2016, Pisa, Italy, September 2628, 2016, Proceedings, volume 9933 of Lecture Notes in Computer Science, pages 3–21. Springer, 2016

9. Jan Peleska, Wen-ling Huang, and Felix H¨ubner. A novel approach to HW/SW integration testing of route-based interlocking system controllers. In Thierry Lecomte, Ralf Pinger, and Alexander Romanovsky, editors, Reliability, Safety, and Security of Railway Systems. Modelling, Analysis,Verification, and Certification - First International Conference, RSSRail 2016, Paris, France, June 28-30, 2016, Proceedings, volume 9707 of Lecture Notes in Computer Science, pages 32–49. Springer, 2016

10. Jan Peleska and Wen-ling Huang. Industrial-strength model-based testing of safety-critical systems. In John S. Fitzgerald, Constance L. Heitmeyer, Stefania Gnesi, and Anna Philippou, editors, FM 2016: Formal Methods - 21st International Symposium, Limassol, Cyprus, November 9-11, 2016, Proceedings, volume 9995 of Lecture Notes in Computer Science, pages 3–22, 2016

11. Anne E. Haxthausen and Jan Peleska. On the feasibility of a unified modelling and programming paradigm. In Tiziana Margaria and Bernhard Steffen, editors, Leveraging Applications of Formal Methods, Verification and Validation: Discussion, Dissemination, Applications - 7th International Symposium, ISoLA 2016, Imperial, Corfu, Greece, October 10-14, 2016, Proceedings, Part II, volume 9953 of Lecture Notes in Computer Science, pages 32–49, 2016

12. Ana Cavalcanti, Wen-ling Huang, Jan Peleska, and Jim Woodcock. CSP and kripke structures. In Martin Leucker, Camilo Rueda, and Frank D. Valencia, editors, Theoretical Aspects of Computing - ICTAC 2015 - 12th International Colloquium Cali, Colombia, October 29-31, 2015, Proceedings, volume 9399 of Lecture Notes in Computer Science, pages 505–523. Springer, 2015

13. Felix H¨ubner, Wen-ling Huang, and Jan Peleska. Experimental evaluation of a novel equivalence class partition testing strategy. In Jasmin Christian Blanchette and Nikolai Kosmatov, editors, Tests and Proofs - 9th International Conference, TAP 2015, Held as Part of STAF 2015, L'Aquila, Italy, July 22-24, 2015. Proceedings, volume 9154 of Lecture Notes in Computer Science, pages 155–172. Springer, 2015

14. Linh H. Vu, Anne E. Haxthausen, and Jan Peleska. Formal modeling and verification of interlocking systems featuring sequential release. In Cyrille Artho and Peter Csaba ¨Olveczky, editors, Formal Techniques for Safety-Critical Systems, volume 476 of Communications in Computer and Information Science, pages 223–238. Springer International Publishing, 2015

Chapters in books (peer reviewed):

15. Anne Elisabeth Haxthausen and Jan Peleska. Model checking and model-based testing in the railway domain. In Rolf Drechsler and Ulrich K¨uhne, editors, Formal Modeling and Verification of

Cyber-Physical Systems, 1st International Summer School on Methods and Tools for the Design of Digital Systems, Bremen, Germany, September 2015, pages 82–121. Springer, 2015

Monographs:

16. Jan Peleska and Wen-ling Huang. Test Automation - Foundations and Applications of Modelbased Testing. University of Bremen, January 2017. Lecture notes, available under http://www.informatik.uni-bremen.de/agbs/jp/papers/test-automation-huang-peleska.pdf

6) Aus dem Projekt wurde eine Promotion entwickelt (nur bei Fokus- oder Explorationsprojekten)/*The project has led to a dissertation (Focus or Exploratory Projects only)*

☐ **Das Promotionsvorhaben wurde abgeschlossen am/**
The PhD project has been completed on:
Bitte fügen Sie dem Bericht eine Kopie vom Deckblatt und Inhaltsverzeichnis der Dissertation bei/.
Please attach a copy of the title page and the table of contents of the dissertation to the report.

☐ **Das Promotionsvorhaben wurde abgebrochen am/**
The PhD projects has been abandoned on:

☐ **Das Promotionsvorhaben wird weiterverfolgt/***The PhD project is being continued*.

7) Kommentare/*Comments*

Falls Sie Kommentare und Verbesserungsvorschläge für uns haben, geben Sie uns gerne Bescheid.

Please let us know if you have any comments or suggestions for improvements.