Technology Transfer

David Basin and Thai Son Hoang

Institute of Information Security, ETH Zurich, Switzerland

Abstract. This paper presents our experience of knowledge and technology transfer within the context of the DEPLOY project. In particular, we describe some of the challenges that we faced over the course of the project and the decisions that we made, along with their justification. We also summarise the lessons learned and what we would do differently in future technology transfer projects.
Keywords: Technology, Knowledge, Transfer, DEPLOY

1 Introduction

Technology transfer is essential for bridging the gap between academic research and industrial practice. It is the core of any successful deployment project. Moreover, it is especially relevant in the context of deploying formal methods, where industrial uptake is often quite slow.

Technology transfer is a two-way street. If the industrial partners are to be able to apply the project methods and tools, they must understand them and gain experience in using them. Only after this will they be capable of carrying out larger development projects on their own. Conversely, if the technology providers are to provide adequate methods, tools, and the accompanying technology transfer material that meets the industry partners' real needs, they must understand these needs and the kinds of domain-specific problems that the industrial partners wish to solve. The technology providers therefore benefit from a chance to acquire this knowledge. The aim of technology transfer within the DEPLOY project was to carry out technology transfer through this two-way flow of information.

One of the main challenges that we faced in the DEPLOY project was the diversity of the deployment partners' backgrounds. Another challenge was the difference between the academic research environment and the industrial context. These challenges posed difficulties in preparing knowledge transfer material and complicated the technology transfer process.

This paper describes our experience of technology transfer within the DEPLOY project, focusing on how technology transfer was managed throughout the project, given the different deployment sectors. The rest of this paper is structured as follows. In Section 2, we give an overview of our technology transfer context. In Section 3, we discuss the management of technology transfer within the DEPLOY project. In Section 4, we draw conclusions, including the lessons learned and what we would do differently with regard to technology transfer in future projects.

2 Context Overview

In this section, we present the context for technology transfer within the DEPLOY project, including our initial decisions regarding our approach to knowledge transfer.

As mentioned earlier, one of the challenges we faced was the diversity of the deployment partners' backgrounds. Within the scope of DEPLOY, there were four industrial partners from different deployment sectors:

- Automotive sector: Bosch (Germany)
- Rail transportation sector: Siemens Transportation Systems (France)
- Space systems sector: Space Systems Finland (Finland)
- Business information sector: SAP AG (Germany)

Moreover, halfway through the project, after a refocus meeting, the project members agreed to have additional "DEPLOY Associates" (DAs). The task of technology transfer was extended accordingly to cover the group of DAs, which included two partners: Critical Software

Technologies Ltd (UK) and Grupo AeS (Brazil). Our resource allocation had to be adjusted to accommodate these changes. The partners had different levels of expertise in formal methods and, in particular, in Event-B. Moreover, diversity characterised not only the industrial partners' teams as a whole, but also members of the same team.

The technology provider within the project was a group of five academic partners: Newcastle University (UK), Åbo Akademi University (Finland), ETH Zurich (Switzerland), the University of Düsseldorf (Germany) and the University of South-ampton (UK). They included researchers who had laid the foundation for many formal methods and tools, in addition to having been involved in several successful industrial applications. While there is a shared knowledge base among the academic partners, which comprises refinement-based modelling methods, e.g. Event-B, the technology provider's expertise also includes various techniques for developing dependable systems, e.g., requirement engineering and model checking. Moreover, midway through the project, another two academic partners joined the project: the University of Bucharest and the University of Pitesti (both in Romania). The two additional academic partners further strengthened the technology provider team.

From the start, we employed the following technology transfer approach:

1. First, some introductory courses were organised for all industrial partners. The intended purpose of these was to introduce the industrial partners to all required aspects of the relevant existing DEPLOY methods and tools.
2. Subsequently, several mini-pilots were introduced by the industrial partners, and technology transfer was done through tackling these. The mini-pilots acted as the bridge between the industrial partners and the technology provider by clarifying domain-specific problems and by showing how to apply the techniques taught in the initial phase.

To smooth the technology transfer process, we set up a platform for communication and for exchanging technology transfer material [8]. The components of this technology transfer platform are as follows:

1. The project set up an *internal* platform (only visible to project members). This included a shared space for exchanging documents, presentations and so on, and a set of mailing lists, both structured by workpackages.
2. The project set up a *public* web platform [7]. This platform includes essential information about the DEPLOY methods and tools, for example, the Event-B modelling method, the Rodin platform and various useful plug-ins to the platform. Another part of this public web platform is a *repository* for storing publications and developments related to the DEPLOY project. The repository is organised by subject (e.g., Event-B, industrial deployment, methodology, tool development and training) and type (e.g., articles, books, deliverables, conference or workshop items, and Rodin platform archives). Another important element of this web platform is the *documentation system* in the wiki-style [6], which can be updated by registered users. The documentation system is specifically dedicated to Event-B and its supporting Rodin platform.

The technology transfer platform allows partners and other contributors to share various types of material with different audiences. Project-related (internal) documents were shared using the internal shared space and discussed via internal mailing lists. More general material was made available publicly to a wider audience via the web platform. An advantage of the wiki-style documentation system is that it also attracts contributions from outside the project. While the internal platform was only available for the project duration, we expect the external web platform to last beyond the lifetime of the project.

3 On Technology Transfer

3.1 The Initial Block Course

The importance of intensive initial knowledge transfer was recognised in the early project phases. Initial training is the basic building block for success in the later project phases. Two months after the start of the project, a three-day training course was organised, which was attended by all industrial partners [2]. The training material was carefully prepared in order to address the differences in the participants' backgrounds [9]. An important decision made when designing material for the initial training was that it should be generic and reusable. As a result, the same material was later used to train new members of the project.

The subsequent evaluation revealed that the course was judged by all attendees to be useful for their understanding of the method (Event-B) and the supporting tool (the Rodin platform). However, it was apparent that we would have benefited from having a longer course with more intensive training, which would have helped our deployment partners to better master the DEPLOY methods and tools. Indeed, the original plan for the initial block course was to have a longer period (two weeks or at least one week) of intensive training. This would have required not only extensive effort from the academic partners in preparing materials, but also a greater commitment from the industrial partners in terms of resources for the attendees of the course. The latter was the main reason why the initial block course was not as long as planned originally.
Despite having a shorter course, we took several measures to make the most of the opportunity. Pre-reading material was sent in advance to the participants, including all the texts and slides for the course. This helped them prepare for it and familiarise themselves with the material to be taught beforehand. Note that it was important that the pre-reading material was at the right level in terms of technical details and quantity as heavy and excessive material has an undesired effect. In particular, it discourages the participants from engaging in learning before attending the course.

3.2 A Support Model

After the initial block course, several kick-off meetings were organised by the deployment partners to introduce the mini-pilots, as envisaged in the second phase of technology transfer. Typically, several academic partners were involved with one deployment partner. However, to strengthen the link between the deployment partners and the technology provider, we defined a model where each deployment partner is associated with one academic partner as the main contact point for conducting continuous training. For the DEPLOY project the links were as follows:

- Bosch was associated with Newcastle University;
- Siemens Transportation System was associated with the University of Southampton and later with the University of Düsseldorf;
- Space Systems Finland was associated with Åbo Akademi University;
- SAP AG was associated with ETH Zurich;
- DAs were associated with the University of Southampton.

Our intention was not to prevent other direct contact between academic partners and deployment partners. Rather, this model allowed us to consolidate the results of the initial training, and provide a basis for giving more direct support to industrial partners for tackling their problems. This direct support model also complemented the use of various mailing lists. Whereas mailing lists are an excellent method for announcing and broadcasting information, they may lead to a lack of responsibility or prompt response to problems raised in the course of the project. By having a direct link to an academic partner, the industrial partners were assured that their problems would be addressed in a timely manner. Notice that this does not mean that the associated partner had to solve the problem by themselves; it was possible to delegate responsibility to other qualified academic partners. A danger of this direct support model is that it can lead to a lack of focus within the project. The reason for that is that despite sharing a common knowledge base, academic partners often have different research interests.

3.3 Technology Transfer Is Driven by Domain-Specific Problems

After the initial phase of general training, the second phase of technology transfer was working on the mini-pilots. The mini-pilots acted as the medium for sharing knowledge between the technology provider and the deployment partners. While the technology provider focused on understanding domain-specific problems, the deployment partners needed to see how the DEPLOY methods and tools could help them with these. The feedback for technology transfer in the first year of DEPLOY is detailed in [1]. The report contains the views of both deployment and academic partners. One of the main points raised in the report by the deployment partners is that technology transfer should address domain-specific issues that are key to deployment success in different industrial sectors. In other words, technology transfer should be directed by the need to solve domain-specific topics that are required for the deployment of formal methods in industry. Technology transfer should be adapted to meet this need and, as a result, there should be different technology transfer materials prepared for diverse audiences in different contexts.

Because of the differences between the domain-specific issues, one should not expect a single method or approach to meet all the needs of the deployment partners, in particular, across different sectors. Instead, there might be the need to adapt existing methods, create new methods, and even combine them. The supporting tools should be adapted as the methods evolve and as different alternatives need to be explored. As a result, the corresponding technology transfer material must also be updated as part of the process. While substantial effort is devoted to the evolution of methods and tools, the task of keeping technology transfer material up-to-date is also time-consuming and should not be neglected. Keeping technology transfer material up-to-date increases the effectiveness of methods and tools, helping transfer them to the relevant audiences more easily. In reality, however, updating technology transfer material is often overlooked.

3.4 A Procedure for Tracking Technology Transfer Needs

To manage technology transfer at the project level, and to avoid duplicated efforts, we defined a procedure centred around a "wishlist" that is maintained within the internal platform for technology transfer. This contains information about what material is available and what material is requested, which partner is responsible and how much time is expected to be necessary to fulfil the request. More information about this procedure is presented in [5].

The wishlist and the accompanying procedure helped ensure that the industrial partners' requests related to training were taken into account and managed accordingly. The requests that we received were mainly for adding and updating documentation, and varied in urgency. There are several ways of responding to requests, including providing new documentation, pointing to existing documents, courses or presentations, and private communication. In particular, some requests required long-term investigations of methods and tools.

What worked well in this procedure was that the initial response to a request was very fast. It was almost always possible to find a partner willing to take responsibility for a request. Some existing documents were corrected when minor problems were discovered through requests. These documents also helped the industrial partners find the right documentation.

A limitation of this procedure is that documentation is created or updated on demand, i.e., only when there is an explicit request for it. This does not ensure the quality and promptness of the delivered documentation. It was up to the individual involved to keep their commitment to fulfilling a request. As a result, commitments were not always met in a timely manner, e.g., due to interference of other project duties.

In fact, the industrial partners pointed out that while documentation was sufficient for carrying out the pilots, it did not meet the common standards for industrial-strength software. It was a real challenge to produce documentation given the resource constraints on the academic partners, who also were involved in method and tool development. The main difficulty with documentation for academics is that it is often not credited as research output. Publications, which are the measure for academic research, are not necessarily suitable as user documentation, and vice versa. As a result, the wishlist model works for minor requests. For more complicated problems, clear rules on responsibilities and financial compensation are necessary.

3.5 A Project for Improving the Documentation

As mentioned earlier, documentation quality is a key aspect of technology transfer. Midway through the DEPLOY project, feedback from one of the industrial partners stated that the documentation does not allow an engineer to start using the tools *without significant support*. It was clear that the documentation needed to be improved, and the task was coordinated by the University of Düsseldorf. The main aim of this documentation subproject was to "minimize the access to an expert that a user of Event-B/Rodin needs to be productive" [10]. The project was scheduled for six months, involving representative stakeholders from both industrial partners and academic partners. While the work concentrated on the Event-B modelling method and the Rodin platform, there were also ways for plug-in developers to contribute documentation of their extensions to Rodin.

An essential part of the project was to have continuous feedback from various users (both beginners and experts) of the Rodin platform. As a result, the project was divided into four iterations. After each iteration, the result was frozen for reviews and giving feedback. This ensured that the documentation could be examined at the earliest possibility and comments could be offered and taken into account during the development of the handbook. Over the course of the project, feedback was received from various users; many of them are from the DEPLOY industrial partners.

The work described here aimed not only to reorganise the existing documentation, but also to improve its presentation. This involved introducing an editorial process with corrections by a native English speaker. The effort that this required can be justified by the notable improvement in the quality of the documentation.

The important lesson that we have learned from this exercise is that there must be documentation for different audiences, including industrial engineers. *Providing industrial-strength documentation is a complex task.* While academics who develop the methods and tools should provide the initial documentation, it still requires substantial effort to bring the documentation to the level needed by industrial engineers. It requires genuine commitment to plan and deliver resources for the task. Note that, to meet industrial standards, more collaboration is required between the documentation team, developers and experts on the documented topics.

4 Conclusion

We have presented our experience in carrying out technology transfer within the DEPLOY project. Technology transfer played an important role in the success of the deployment process since it is the means of equipping the industrial partners with the necessary knowledge of methods and tools. Undergoing initial training as a block course followed by continuous work with mini-pilots proved to be a successful approach to technology transfer. The initial training provided general knowledge to the industrial partners, while the mini-pilots were the medium for exchanging information about domain-specific topics. Moreover, we also committed to technology transfer by appropriately addressing requests from industrial partners, and providing necessary additional support.

The first lesson that we learned was that for an effective transfer, it is essential to *establish a strong link* between industrial partners and academic partners. Bowen and Hinchey [4] also highlighted the importance of this link: technology transfer from formal methods research to practice starts by having more *real* links between industry and academia. Moreover, it is essential to maintain these links throughout the project, in order to facilitate bidirectional dialogue between the industrial and academic partners.

Secondly, it is extremely important to *plan for technology transfer early* in a deployment project, in particular by designing *initial training.* The value of using more resources for the initial training (including committing industrial engineers to training) will exceed the cost. The initial training provides the foundation for the later phases of the deployment process. Within the DEPLOY project, we had a strong focus on the initial training, investing effort in the preparation and delivery of the block course, as well as the course participants' time and energy.

Thirdly, technology transfer should be *driven by industrial problems.* The domain-specific issues should be the main target for knowledge transfer. While general knowledge is necessary for deployment, the goal of the deployment process in the long term is solving domain-specific problems. That is why after the initial training we used the mini-pilots as focal points for directing technology transfer.

Fourthly, another important lesson learned is about the *quality of documentation*: high-quality documentation is essential for knowledge transfer to industrial engineers. Clearly, there are different levels of documentation necessary for different audiences. Moreover, for successful deployment of methods and tools within industry, the technology transfer material must meet the standards required by industry. Producing high-quality documentation demands substantial resources and is often overlooked. Hence the plan for upgrading documentation should be designed into the overall strategy for technology transfer as early as possible. As for the DEPLOY project, we should have carried out the subproject of updating documentation in an earlier project phase.

Last but not least, we learned that *academic and industrial partners have different interests*, especially when it comes to documentation. It is understandable that industrial partners desire high-quality documentation. However, most academic partners are unwilling to spend time polishing documentation. Having wrong expectations often leads to frustration, which is harmful for a collaboration project.

Based on the experience gained through the DEPLOY project, we believe that our results would have been better if we had conducted a longer block course for the initial training. The main difficulty that we faced was the need for commitment from the course participants. Given that the participants are from industry, it was a real challenge to motivate them to attend the training course for one or two weeks. Another important fact was that the three-day block course for all industrial partners was organised at ETH Zurich. Some deployment partners stated that they would have opted for a longer course with more attendees if it had been held at their industrial site. Given that there are four different industrial partners in DEPLOY, this would have required four block courses. A disadvantage therefore would have been the longer time needed to complete the training for all industrial partners. This would have also required significant resources from the academic partners.

The link that was established and maintained within the DEPLOY project was carefully designed so that industrial partners and academic partners were able to communicate ideas and share material smoothly. However, communication, in particular, responses to requests from industrial partners, could have been better. The use of mailing lists and shared internal space does not itself ensure satisfactory responsiveness. In particular, in the early phases of the project, when industrial partners usually had many questions about the methods and tools, responsiveness was critical for maintaining the links between industrial and academic partners. Our support model, i.e., having one academic partner responsible for each industrial partner, helped improve the situation dramatically. Despite this, the link could be further strengthened by having more direct support for the industrial partners, e.g., by having some academics working together with engineers at industrial sites. Again, this would require significant resources from the academic partners, but would speed up the deployment progress.

Acknowledgements

We would like to thank Jean-Raymond Abrial for his generosity in providing technology transfer material related to his Event-B book [3]. We also thank Andreas Fürst and Matthias Schmalz for their comments on the early drafts of this paper.

References

1. Abrial J.-R., Bryans J., Butler M., Falampin J., Hoang T. S., Ilic D., Latvala T., Rossa C., Roth A. and Varpaaniemi K.: JD1 Report on knowledge transfer. DEPLOY deliverable. http://www.deploy-project.eu/html/deliverables.html, January 2009.
2. Abrial J.-R., Hoang T. S. and Schmalz M.: D10.1 Teaching material. DEPLOY deliverable. http://www.deploy-project.eu/html/deliverables.html, January 2009.
3. Abrial J.-R. *Modeling in Event-B: System and Software Engineering*. Cambridge University Press, May 2010.
4. Bowen J. P. and Hinchey M. G.: Seven more myths of formal methods. *IEEE Software*, 12(4):34–41, 1995.
5. Butler M., Hoang T. S., Iliasov A., Jones C., Laibinis L., Leuschel M., Nummila L., Plagge D., Räsänen T., Schmalz M., Snook C. and Wei W.: D10.4 Report on training experience. DEPLOY deliverable. http://www.deploy-project.eu/html/deliverables.html, January 2011.
6. Event-B.org. Event-B and Rodin documentation wiki. http://wiki.event-b.org.
7. Event-B.org. Event-B and the Rodin platform. http://event-b.org.

8. Hoang T. S. and Clabaut M.: D10.2 Design and implementation of the technology transfer platform. DEPLOY deliverable. http://www.deploy-project.eu/html/deliverables.html, January 2009.
9. Hoang T. S.: D10.3 Initial port of technology transfer material. DEPLOY deliverable. http://www.deploy-project.eu/html/deliverables.html, July 2009.
10. Jastram M., Ladenberger L., Plagge D. and Clark J.: The Rodin handbook. http://handbook.event-b.org/, 2012.

Appendix

Below is a list of the available technology transfer materials.

- *Material related to Abrial's Book [3]* (http://wiki.event-b.org/index.php/Event-B_Language). The material includes sample chapters of the book, slides and Rodin platform archives of developments corresponding to several chapters of the book.
- *The Rodin Handbook* (http://handbook.event-b.org/). This is an overhauled version of the original Rodin tutorial with additional information about Event-B and the Rodin platform.
- *The Event-B and Rodin documentation wiki* (http://wiki.event-b.org/index.php/Main_Page). The main wikiportal for material related to the Event-B modelling method and the Rodin platform. This is available for both users and developers of Event-B/Rodin. Contributions are made by registered users both inside and outside of the DEPLOY project.
- *Rodin at Sourceforge.net* (http://sourceforge.net/projects/rodin-b-sharp/). The home page of the Rodin platform and plug-ins. Several mailing lists are hosted at sourceforge.net, including the Rodin users' and the Rodin developers' mailing lists.
- *Materials for the three-day block course.* These are used for the three-day initial training of the DEPLOY partners.
  - Pre-reading material (sent in advance to the attendees): http://deploy-eprints.ecs.soton.ac.uk/53/
  - Lectures: http://deploy-eprints.ecs.soton.ac.uk/54/
  - Exercises and solutions: http://deploy-eprints.ecs.soton.ac.uk/55/
  - Rodin platform archives: http://deploy-eprints.ecs.soton.ac.uk/56/

  More information on this is given in [2].

- *The DEPLOY repository.* Various training materials are available at http://deploy-eprints.ecs.soton.ac.uk.