SPiCE in Action

Experiences in Tailoring and Extension

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Abstract: Experiences are reported in the use of ISO 15504 both in tailoring the standard for particular industrial sectors and in expanding the process assessment approach into new domains. In particular, three projects are discussed:

- SPiCE for SPACE, a ISO/IEC TR 15504 [IS98a] conformant method of software process assessment developed for the European space industry,
- SPiCE-9000 for SPACE, an assessment method for space quality management systems, based on ISO 9001:2000 [IS00], and
- NOVE-IT, a project of the Swiss federal government to establish and assess processes covering IT procurement, development, operation, and service provision.

All three of these projects use the concepts of process assessment from ISO 15504; however, in each case, different strategies to apply the international standard were selected. Some of the issues faced in these different domains are described and their resolutions presented.

1 Introduction

By improving their development processes, software organisations increase their ability to repeatably achieve schedule, budget and quality goals. To gain insight into the maturity of their software development processes, organisations (and their customers) rely on the objective measure of process capability that is provided by software process assessment using ISO 15504. Process assessment methods such as ISO 15504 or CMMI contain generic assessment models of development processes, which provide a basis to rate an organisation's capability. These process models are founded on best practices proven across the entire software industry.

When applying process assessment to specialised areas of software development, better results may be provided by using a tailored process model that reflects the particular practices of the industry. Likewise, when expanding of process assessment to domains outside of software development, it may be necessary to derive an original process model reflecting the best practices of the new domain.

In the following chapters, experiences are reported on adapting process assessment to the production of space software, to establishing space quality management systems, and to

IT procurement, development, operation, and service provision. A common theme in all three of these projects is the adaptation of specialised process models.

Note that, in this paper, 'ISO 15504' is used to indicate the standard in general terms. When a specific version of the standard is referred to, such as the current Technical Report ISO/IEC TR 15504 or the emerging international standard IS 15504, it is referenced explicitly.

2 SPiCE for SPACE

As part of a programme for software process improvement sponsored by the European Space Agency (ESA), a method for software process assessment has been developed that is conformant with the requirements of ISO/IEC TR 15504. An initiative of the Product Assurance and Safety Department in cooperation with the Mathematics and Software Division of the European Space and Technology Centre (ESTEC), the SPiCE for SPACE (S4S) method aims to encourage the production of the best possible software products and services within the European space industry.

The S4S method includes an *assessment model* incorporating space software practices following European space standard requirements for the production of space software, a *documented approach* to guide space assessors and a software assessment *tool* together with templates of key outputs that support the performance of S4S assessments. The assessment method is published by ESA in the form of a two-part Technical Note [VC02] (ESTEC Contract Number 10662/93/NL/NB CCN5).

Four pilot assessments of space software projects were performed in late 1999 to validate the method, followed by a series of eight trial assessments in 2000 and 2001. In addition, a further programme of assessments encouraging the use of S4S over the next three years has already begun.

2.1 The S4S Assessment Model

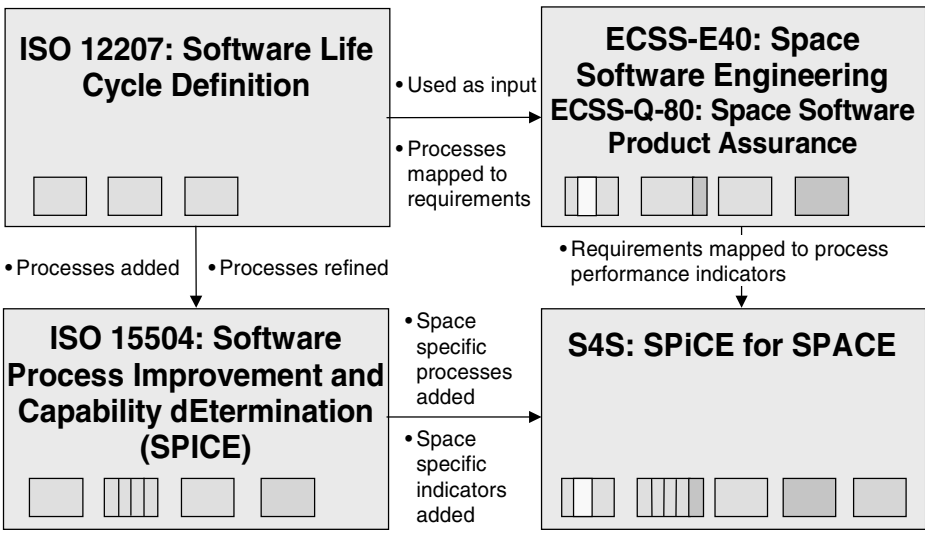
In designing the S4S assessment model, the exemplar model from ISO/IEC TR 15504 [IS99] was taken as a reference point. This exemplar model was then tailored using both requirements on the production of space software and software process models developed by ESA in previous study projects, as described in the following sections. The capability dimension in S4S was adopted from the exemplar assessment model as-is with no modifications or additions.

ESA space systems must be developed according to the requirements published by the European Cooperation for Space Standardization (ECSS). These standards are to be applied in the management, engineering, and product assurance of space projects and applications. The standards are written in the form of requirements and expected outputs. All of the ECSS Level One standards [EC96a] were used as primary input in developing the S4S assessment model. Of particular importance were the two standards that focus on software, ECSS-E-40, '*Space Engineering - Software'*, and ECSS-Q-80, '*Space Product Assurance - Software Product Assurance*' [EC99, EC96b].

In forming the S4S process dimension, all processes and base practices were adopted as-is from the ISO 15504 exemplar assessment model in Part 5 of ISO/IEC TR 15504

[IS99]. Requirements from ECSS documents or activities from space software process models were matched with exemplar model processes and base practices. In addition, the process dimension was augmented with processes, base practices and notes created to reflect activities not present in the exemplar model. All of the exemplar model work products were either matched with the expected outputs of ECSS requirements or, where no match was found, were kept in S4S as-is. New work products and work product characteristics were formed to represent ECSS outputs not covered by the exemplar model. These new processes and process indicators incorporate space software needs into S4S. The common origin of ECSS-E-40 and ECSS-Q-80 (i.e. ISO 12207 [IS95]) made this tailoring approach feasible. Figure 1 shows indicates the relationship between S4S, ECSS-E-40, ECSS-Q-80, ISO 12207, and ISO/IEC TR 15504.

Figure 1: The relationship between S4S, ECSS-E-40, ISO 12207, and ISO/IEC TR 15504.



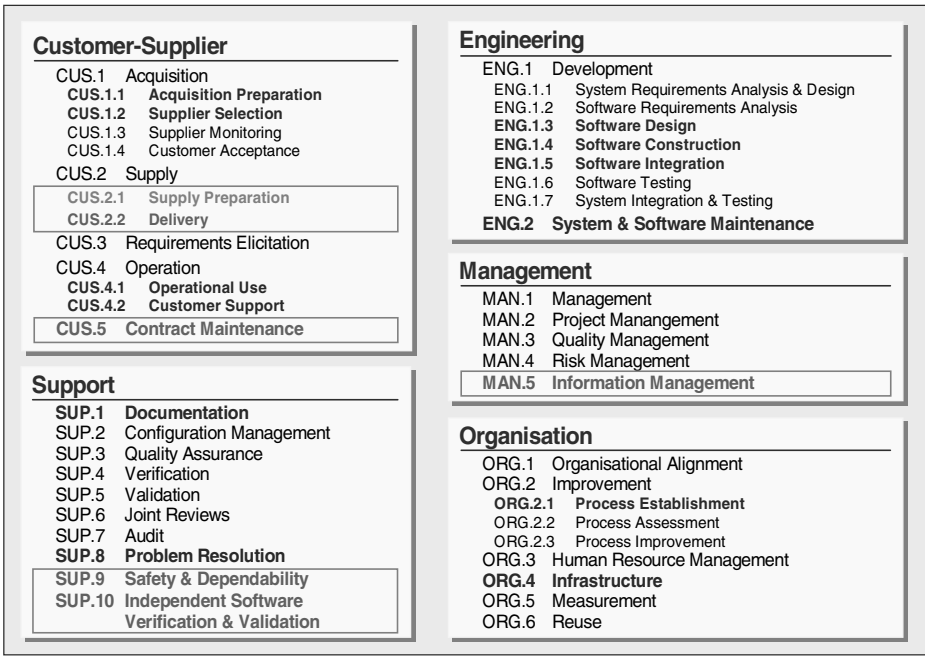
As a result of these efforts, the process dimension of S4S has been considerably expanded from the exemplar model. Four new processes, about new 50 base practices, and about 60 new notes have been added to reflect ECSS requirements. The process dimension of the S4S model is shown in figure 2.

Two of the four new processes, *Independent Software Verification and Validation* (*ISVV*) and *Safety and Dependability Assurance* extend the exemplar model to cover issues particular to the highly complex and often safety and mission critical software produced by the space industry. The remaining new processes, *Contract Maintenance* and *Information Management,* address general customer and management activities not found in the exemplar model. Finally, two new component processes arose from splitting the exemplar model process CUS.2 *Supply* process into two processes, CUS.2.1 *Supply*

Preparation and CUS.2.2 *Delivery*. More detail about the design of the S4S process dimension may be found in [Ca00].

In addition to the new processes, references to ECSS requirements and notes explaining their application have been added throughout the assessment model. Inputs and outputs of the S4S processes reflect the ECSS expected outputs. This fusion of ECSS with a comprehensive process framework makes the S4S assessment model a useful guide not only for space companies currently in transition between the former ESA software engineering standards PSS-05-0 [PS91] and the ECSS standards but also for companies preparing to enter the space software market.

Figure 2: S4S Process Categories and Processes. New Processes are placed in Boxes. Processes with Base Practices added are printed in Bold.



2.2 S4S Assessment Model Challenges

Certain challenges arose in adopting a pre-existing process model (such as the exemplar model from ISO/IEC TR 15504) to the space software practices required in the ECSS documents. Although it was found in general that the ECSS requirements matched well to the base practices of exemplar model processes, the expected outputs of the ECSS requirements are much more specific than the work product types defined in ISO/IEC TR 15504. In particular, it was frequently observed that ECSS expected outputs correspond to particular instantiations of generic work products in the exemplar model. For example, while in the exemplar model there is a single work product named *Analysis Results*, in

ECSS, many analyses are specified, such as *Human Dependability Analysis*, *System Level Functional Analysis,* and *Numerical Errors Analysis*.

In order to incorporate ECSS expected outputs into the pre-existing ISO/IEC TR 15504 work product structure, a new type of work product was added: ECSS instances. ECSS instances inherit generic characteristics of the ISO/IEC TR 15504 work product type but have additional characteristics to reflect specific elements from ECSS.

2.3 S4S Conclusions

SPiCE for SPACE contains an assessment model where the ISO/IEC TR 15504 exemplar assessment model was adopted as-is and elements were added to adapt it to the practices of a particular sector of the software industry. As both the exemplar model and the S4S model share a focus on software development, this made for a natural approach in designing a process model that has been highly successful in subsequent trial and field applications.

3 SPiCE-9000 for SPACE

In this chapter, a rather different strategy in developing an assessment model is described for an assessment model focusing on quality management systems for product and service provision (including, but by no means limited to, software).

In January 2001, a study project was launched by ESA to create a new assessment method to determine the capability of space software suppliers in the area of quality assurance and quality management (ESTEC Contract Number 14617/NL/CK). The method, known as S9kS, or SPICE-9000 for SPACE, incorporates a quality management assessment model created from the quality management system requirements of IS 9001:2000 and European requirements for space product assurance (as reflected in the standard ECSS-Q-20, 'Space Product Assurance - Quality Assurance' [EC96c]) into the assessment framework of IS 15504, the emerging international standard.

The responsibility for the S9kS project is shared by an industrial consortium that includes IS 9001 lead auditors and competent SPiCE assessors. The S9kS method, including the assessment model, a comprehensive set of templates and material, and guidance on how to prepare and perform a quality management assessment, will be published in the form of an ESA Technical Note [Vö02] upon completion of the project. At the time of writing, the first pilot applications were underway to validate the framework.

A version of the assessment model (SPiCE-9000, or S9k) has been developed that contains only those indicators pertaining to IS 9001. Thus, as a by-product of the space study project, S9kS offers organizations in all industries a process assessment model based solely on IS 9001. This feature broadens the potential application of S9kS to a wide range of companies outside of the space industry. The use of assessment for determining the capability of the processes of a quality management system provides a valuable tool to all organizations interested in implementing, maintaining and improving a quality management system based on IS 9001.

3.1 Creating the S9kS Process Model

In contrast to what has been done in developing the S4S model, where European space software requirements were integrated into the exemplar assessment model from ISO/IEC TR 15504; in S9kS, the assessment model was created 'from scratch'. It was known that the process dimension would have to be created, as no equivalent process model existed already, but, in addition, certain problems were found with the ISO/IEC TR 15504 capability dimension that prevented its use as well. Thus, the S9kS model was built from the 'bottom-up', as indicators of process performance and process capability such as practices, work products and work product characteristics were derived directly from requirements in IS 9001 and ECSS-Q-20. The following describes in greater detail how the process model was created.

An initial exploratory study recommended basing the top level S9kS architecture on IS 9001, it being the more general of the two input standards [VD01]. Requirements from ECSS-Q-20, as more specific to space organizations, would provide the detailed part of the process model, as 'special extensions' to IS 9001 requirements.

Next, a comprehensive comparative analysis of IS 9001 requirements to ECSS quality assurance standards requirements was performed [Zi01]. This mapping between IS 9001, ECSS-Q-20 and the lower level standard ECSS-Q-20-09 [EC96d] indicated overlaps and similarities between the standards. Similarities were observed, for example, in quality assurance activities throughout the product development and production activities, especially for activities concerned with interfaces to the customers and suppliers. As a general rule, the ECSS requirements were found to be much more detailed and specific than the requirements from IS 9001. They also specified requirements for additional activities such as risk analysis and the assurance of space system operation.

The structure of the S9kS assessment model was outlined based on analysis of this mapping. Requirements were grouped together and candidate process categories and candidate processes were proposed [Vö01].

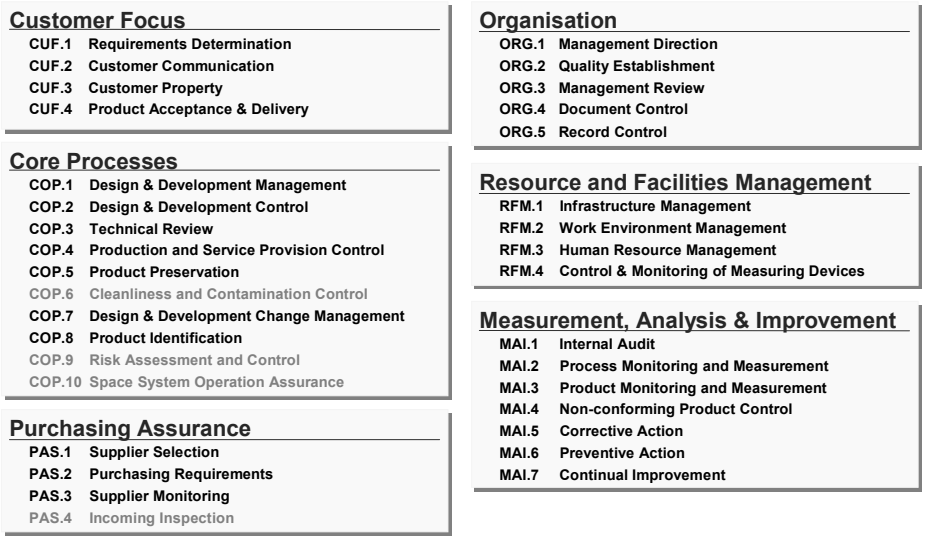
To establish the indicators of the S9kS assessment model, all requirements from IS 9001 and ECSS-Q-20 were translated into practices. Practices were categorized as *generic practices*, i.e. those applicable to all processes, or *process-specific practices*, those practices only applicable to a particular process.

Most of the *process-specific practices* were taken as process indicators for the achievement of Process Attribute 1.1, *Process Performance*. Associated with processes, these practices became indicators of the process dimension, together with the base practices, work products and work product characteristics. Work products were assigned as the inputs or outputs of the processes as appropriate. Meanwhile, *generic practices* were derived from the revised process attributes for the higher capability levels.

During the early phase of this study, the candidate processes and process categories underwent considerable rework in several iterations until the present version was achieved (shown in figure 3). Once the process list appeared to be stable and the process-specific practices were established, process descriptions were written in the format of process purposes and outcomes. As a result of this effort, a process reference model was created that reflects and fully covers the contents of either IS 9001 or ECSS-Q-20, or both standards together.

The process reference model includes processes that pertain to both standards such as *Quality Establishment*, *Customer Communication*, *Production Assurance*, and *Product Identification*, as well as processes that are only addressed by the relevant ECSS documents, like *Risk Assessment and control*. At the time of writing, there are also processes that only refer to IS 9001, such as *Management Review,* which is not addressed by the ECSS standards within the scope of the project. In addition, there is some overlap between the processes of S9kS and those of ISO/IEC TR 15504, which remains to be resolved. The complete set of S9kS processes is still subject to change during the validation phase.

Figure 3: S9KS Process Reference Model.



For the capability dimension, it was decided that the first three capability levels should completely cover all IS 9001 requirements; that is, that achievement of Level 3 for all S9kS processes would ensure that all of the requirements of IS 9001 are satisfied. Early in the project it became evident that the capability dimension published in Part 2 of ISO/IEC TR 15504 [IS98b] could not be adopted as-is, because of inconsistencies between IS 9001 and the process attributes of ISO/IEC TR 15504.

Examples of activities that are required in IS 9001 but that are not found in the capability dimension of ISO/IEC TR 15504 include:

- the *communication* of roles, responsibilities, and authority ([IS00] 5.5.1, 7.3.1)
- the management of interfaces between groups ([IS00] 7.3.1), and
- the identification of sequences and interactions of processes ([IS00] 4.1b).

These inconsistencies were documented and passed on by S9kS project members to the ISO Working Committee responsible for IS 15504 via the ISO national bodies in the

form of comments to ISO/IEC FCD 15504-2 (Final Committee Draft) [ISoj], which was circulated for ballot in October 2001. As a consequence, the ISO group has revised the measurement framework of IS 15504. This new version will be used by S9kS.

3.2 Conclusions on S9kS

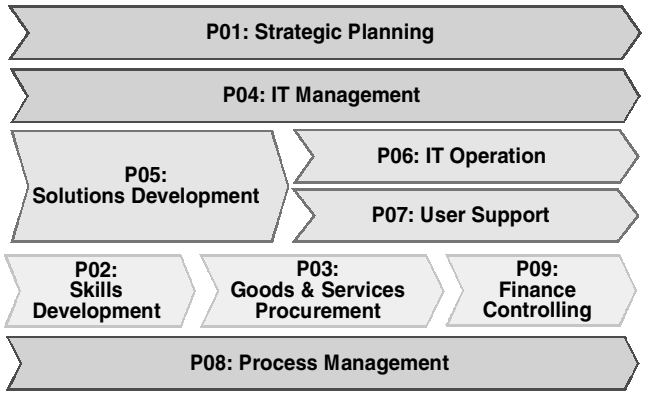
As an assessment method, S9kS remains faithful to the concepts of process assessment described in ISO/IEC TR 15504. However, compared to projects that have developed industry-specific process models (such as S4S), the strategy followed by the project in developing the S9kS assessment model represents a large departure, in as much as it addresses a different domain from software development. Indeed, in lieu of adopting parts or all of the standard as-is, the S9kS project has instead contributed to the evolution of IS 15504.

4 NOVE-IT

The final approach discussed here represents yet again the extension of ISO/IEC 15504 into a new domain, that of IT services in general.

The goal of the 230 million Swiss franc project NOVE-IT [No] of the Swiss Federal Strategic Committee for Information Technology (*Informatikstrategieorgan Bund*) is to standardize the provision of IT services across the 7 departments of the Swiss government and the Federal Chancellery over the next 5 years. A process model for IT procurement, development, operation, and service provision (also called NOVE-IT) was developed in the first phases of the project (see figure 4). This model is being implemented by more than 100 governmental organizations across Switzerland.

Figure 4: NOVE-IT process model [Ke02], organized into Management processes (dark shading), Core processes (medium shading), and Support processes (light shading).



The performance of process assessments by external parties is a key part of the strategy of independent quality assurance that has been established for the realization phase of the

NOVE-IT project. NOVE-IT will use ISO 15504 conformant assessments as an external means of evaluating both the NOVE-IT processes themselves (as defined in the NOVE-IT process model and supported by various templates and tools) as well as their degree of implementation in the assessed organizational units. The main focus of the assessments will be on capability determination. The results however will later on be taken as input into the continuous process improvement cycle that is defined in the NOVE-IT process P08, *Process Management*.

For the NOVE-IT project, it was decided to use an assessment model consisting of a process dimension adopted as-is from the NOVE-IT process model and a capability dimension taken directly from Part 2 of ISO/IEC TR 15504. It is planned to conduct a total of approximately 45 assessments over the next 3 years, covering all NOVE-IT processes and the all entities of the federal government, making it perhaps the largest single assessment project ever conducted in Switzerland.

4.1 The NOVE-IT Process Model

While several examples of process models addressing IT operation only have been available for some time [Sc00, IT95], the recently developed NOVE-IT process model covers the entire range of activities for IT procurement, operation, and service provision. The model consists of nine top-level processes, shown in, and organized into the following 3 process categories:

- Management (P01, P04, P08),
- Core (P05, P06, P07), and
- Support (P02, P03, P09).

Each top-level process in the NOVE-IT model consists of following main elements (figures in parentheses indicate the approximate number of elements in the model):

- Sub-processes (35),
- Sub-sub-processes, optional (60),
- Activities (770),
- Interfaces (540),
- Results (200), some with Supporting Instruments,
- Role descriptions (60), and
- Measurements (95)

4.2 Assessments with NOVE-IT

ISO/IEC TR 15504 conformant assessments must be performed with respect to an assessment model that is compatible with the Reference model from ISO/IEC TR 15504. For the NOVE-IT project, it was decided to create an assessment model consisting of a process dimension adopted as-is from the NOVE-IT process model and a capability dimension taken directly from Part 2 of ISO/IEC TR 15504. The model is called NOVE-IT Capability dEtermination, or NiCE.

Rather than following the strategy of the SPiCE for SPACE project and forging a new process dimension reflecting both NOVE-IT and ISO/IEC 15504, for NiCE it was decided to take the NOVE-IT process model in its current version. The reasons were twofold. First, as the overall purpose of the project is to establish the NOVE-IT processes, it was deemed more in line with the project goals to adopt the process model as-is. It was considered that that sharing the NOVE-IT process model as a common basis would facilitate communication between the staff of assessed projects and the assessment team. An additional advantage was that the findings of NiCE process assessments could be taken directly as input to improvement programmes put in place both by the assessed organizations and by the NOVE-IT project itself, with no translation of results necessary.

Another key deciding factor was that the NOVE-IT process model is still under refinement at present. Updates of the process definitions are foreseen over the next two years, as experience is gained through their application and evaluation. By using the current version of the NOVE-IT process model alone, the effort of upgrading the assessment model is considerably less than that of upgrading a mixed model of NOVE-IT and ISO/IEC TR 15504. Eventually, it is envisaged to create a completely integrated IT process model that includes not only all of the processes and indicators of both ISO/IEC TR 15504 and NOVE-IT but also other related international standards and best practice guidelines. This work will only begin after the first three to five assessments have been performed with the current version of NiCE, in order to benefit from lessons learned.

As for the capability dimension, it was decided to adopt that found in Part 2 of ISO/IEC TR 15504. As the issues highlighted by the S9kS project did not have a direct impact on NOVE-IT, and it was necessary to begin performing conformant assessments with minimum delay, it was considered best to adopt the current baseline standard rather than to wait for the publication of IS 15504.

The overall benefit of this strategy was that the effort in demonstrating the compatibility of the assessment model with ISO/IEC TR 15504 would be limited to mapping the NOVE-IT model to the Part 2 Reference model and devising an algorithm for converting ratings of NOVE-IT processes to ratings of Reference model processes. Despite their apparent simplicity, certain challenges have arisen in performing these tasks, as described in the following section.

4.3 NiCE Challenges

As part of developing NiCE, the NOVE-IT process dimension was analysed for its compatibility with the ISO/IEC TR 15504 Reference model. An initial high-level mapping was performed between the purposes of Reference model processes and the purposes of NOVE-IT processes and sub-processes. Through this mapping it was found that part of the NOVE-IT model does not map to any part of the Reference model. This stems from the fact that the scope of NOVE-IT extends into areas well beyond software development, such as financial management.

Next, a more detailed mapping was made in which the goal was to identify those NOVE-IT process elements that matched with the outcomes of Reference model processes. These NOVE-IT process elements are used as the formal indicators of the assessment model process dimension as required by ISO/IEC TR 15504.

This detailed mapping led to the identification of not only Reference Model elements that are not covered in the NOVE-IT process model but also NOVE-IT elements that are not represented in the ISO/IEC TR 15504 Reference Model. One example where both models were found to be lacking was in the area of acquisition (addressed by NOVE-IT process P03 and the set of ISO/IEC TR 15504 processes CUS.1.0-1.4). Here it was decided to adopt the 17 new Acquisition Processes (ACQ) proposed as a future amendment to Part 2 of ISO/IEC TR 15504 [IS98c]. An internal study of best practices in procurement is currently being performed with the purpose of extending the NOVE-IT process model even further in this domain.

Through the detailed mapping, the structure of the two models was found to be sufficiently different that associations could not be consistently made between the process outcomes of the Reference Model and a set of elements at any single level of the NOVE-IT model. In practice, this means that Reference model process outcomes correspond either to NOVE-IT sub-sub-processes or to activities. It was also observed that the indicators of a given NOVE-IT process might map to outcomes of several Reference Model processes. The difference in structure of the two models combined with the *one to many* relationship between their processes creates a significant technical challenge in devising an algorithm to convert the ratings of NOVE-IT processes into ratings of ISO/IEC TR 15504 Reference Model processes. This algorithm is under development at present. A final challenge of the project rests in the sheer size of the NOVE-IT process model documentation as well as its current state of internal consistency.

5 Conclusions

The three projects examined (SPiCE for SPACE, SPiCE-9000, and NOVE-IT) provide useful case studies of the experience gained in tailoring ISO/IEC TR 15504 for a particular sector of software development or in extending the process assessment approach to activities outside of software development.

Overall, the projects demonstrate the variety of strategies available when designing a process assessment model. In each case, the strategy selected was strongly influenced by the industry- or domain-specific input materials at hand. In the SPiCE for SPACE and NOVE-IT projects, already existing process models were available and could be taken as baselines. On the contrary, in S9kS, an equivalent process model did not exist and thus had to be derived from scratch. Between the SPiCE for SPACE and NOVE-IT projects, however, differences arose over whether or not to integrate software development best practices (as reflected in ISO/IEC TR 15504) with the industry- or domain-specific practices. In SPiCE for SPACE, both generic and industry-specific process indicators are present in the assessment model. In NOVE-IT, the decision to use domain-specific indicators only was driven by the overall goals of the project. Finally, in both SPiCE for SPACE and NOVE-IT the capability dimension from ISO/IEC TR 15504 was adopted as-is, whereas the S9kS project derived its own capability dimension and, in the process, provided feedback to the standard itself.

All three projects share the common concept of process assessment as established by ISO/IEC TR 15504. The experiences of SPiCE for SPACE, SPiCE-9000, and NOVE-IT serve as pioneering examples of the adaptation of the standard for particular industrial

sectors and its extension into new domains and, conversely, of the influence projects may have on the evolution of the standard itself.

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