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1 Introduction

1.1 Role of deliverable
This deliverable describes the measures that CRYSTAL employs to establish the sustainability of the project results. The primary goals of the sustainability model are:

- Ensure that the results can be used by the project partners
- Ensure that CRYSTAL results can be used by future related projects
- Ensure that CRYSTAL specifications become official open standards
- Ensure that these standards are maintained
- Ensure that these standards are implemented in tools
- Ensure that these tools are used in the industry

1.2 Relationship to other CRYSTAL Documents
This document is highly related to this Interoperability Specification deliverables D601.021, D601.022 and D601.023, and the standardization reports D601.031, D601.032, D601.033. It is also related with the PB specification deliverable D602.022.

1.3 Structure of this document
Chapter 2 elaborates the goals of the sustainability model, while Chapter 3 lists the measures that CRYSTAL employs to achieve these goals.
Chapter 4 describes the sustainability model with respect to the individual CRYSTAL results.
Chapter 5 describes the IOS Coordination Forum (ICF) which is a cornerstone of a cross-project sustainability strategy for IOS-related projects (developed in cooperation with the CP-SETIS project).
Chapter 6 describes the business rationale with respect to the individual stakeholders and the individual CRYSTAL results.

1.4 What is new in this deliverable
This document is an update of deliverable D102.060. Changes to the previous deliverables have been marked with [Y3] ….. [Y3].

The major new contribution to this deliverable are:

- Chapter 5 (The IOS Coordination Forum – ICF): The CRYSTAL project has developed in cooperation with the CP-SETIS project a cross-project sustainability strategy for IOS-related project results. The ICF is a cornerstone of this sustainability strategy and is described in this section.
- Chapter 6 (Business Rational): This entire section has been refined and extended.
2 Goals of the CRYSTAL Sustainability Model

Before deciding on a sustainability model for the CRYSTAL project, the Technical Board and the Steering board agreed on a set of concrete goals that should be achieved by that model. These goals are elaborated in this chapter.

- **Ensure that the results can be used by the project partners**: This point is the most obvious. If the project results should be of any value for the future, it has to be assured that the project partners have the adequate access rights to the Intellectual Property (IP) that constitutes the foreground of the CRYSTAL project and that there are no legal hindrances for exploitation.

- **Ensure that CRYSTAL results can be used by future related projects**: The industry and the European and national funding agencies commit to large investments in current and future projects. To get out the maximum of these investments the CRYSTAL sustainability model has to ensure that future projects can re-use the CRYSTAL results such that re-inventing the wheel is avoided. This can only be achieved if the results are documented in a well-structured way and if a significant subset of the results is publically available.

- **Ensure that CRYSTAL specifications become official open standards**: Achieving interoperability via open standards is at the core of the CRYSTAL strategy. In the project we are developing specifications allowing loosely-coupled software tools and repositories to interlink and exchange their data in a common, standardized way. To ensure acceptance and confidence in the industry, these specifications have to evolve into stable and clearly defined standards.

- **Ensure that these standards are maintained**: CRYSTAL is a three year project, and therefore has a limited lifetime. A standard on the other hand should have a much longer life-cycle and must be considered as "living" document. It has to adapt to new circumstances and requirements and therefore has to be maintained by a group of well-organized stakeholders.

- **Ensure that these standards are implemented in tools**: A standard brings value only if there are enough companies and organizations committing to this standard. For an interoperability standard this means that the standard has to be adopted by a critical number of tool vendors.

- **Ensure that these tools are used in the industry**: Typically tool-related standards cannot be simply pushed by the tools providers, instead they should address a need (pull) from the tool users. Therefore the sustainability model also has to consider the end users (e.g., OEMs) and raise their awareness regarding the benefits that result from using open interoperability technologies like the CRYSTAL Interoperability Specification. Customer demand has always the highest effect in the market.
3 General Measures of the Sustainability Model

Based on the goals defined in Section 2, the Technical Board and the Steering Board defined a set of measures to achieve sustainability. These measures are described in this section and constitute a snapshot of the CRYSTAL sustainability model at M24. The list of measures will be refined and extended in the final sustainability model at M36.

3.1 The CRYSTAL Consortium Agreement

With 70 project partners it was a huge challenge and took several months to develop a consortium agreement that was acceptable for every partner. Among other things, the consortium agreement regulates the Intellectual Property Rights (IPR) with respect to the foreground that is developed in the project. This makes the consortium agreement one of the cornerstones of the CRYSTAL sustainability. It ensures that the potential usage of the project results by the project partners is regulated upfront and in a transparent way. The IPR regulations in the consortium agreement have to be considered in any business or exploitation plan. Please note, that the consortium agreement is not a public document and only shared between the project partners. Therefore we cannot include any further details about the agreement in this deliverable.

3.2 Public Deliverables

Setting up collaboration with stakeholders outside a project consortium is always a quite complex task when it comes to confidentiality regulations. In a project like CRYSTAL, the communication with stakeholders across the project boundaries is of utmost importance since CRYSTAL is working on open standards for interoperability. In particular, the communication and collaboration with standardization organizations and other projects is an integral part of the CRYSTAL implementation strategy.

To make such collaboration efficient and easy, the consortium followed a straight-forward principle. We identified the project results that are essential for collaboration and marked them as public, so that they can be shared with anyone without undergoing any complex process.

Among others, the set of public deliverables contains the following:

- **Interoperability Specification**: This document contains the most relevant information to be exchanged. It is the central document for our collaboration with standardization bodies and with other IOS-related projects.

- **Public Use Case Deliverables**: Due to its generic nature, which ensures applicability across multiple industry domains, the IOS alone is difficult to apply without understanding the context of the specification. Therefore, CRYSTAL produces a set of public use cases (one in each industrial domain) that serve as an example and provide a guideline for applying the IOS in the relevant context. The public use cases comprise a collection of various aspects (e.g., engineering methods, IOS implementations, etc.) of all domain use cases, but they are scrubbed from any IP that the IP owners needs to protect. Therefore these Public Use Cases can be classified as public.

- **Platform Builder Deliverables**: The CRYSTAL platform builder is based on meta-models describing relevant properties of a System Engineering Environment. They can be used also by external stakeholders, for example by external tool providers to formally describe their interoperability capabilities in a CRYSTAL-compliant way.

3.3 Dissemination Events and Publications

The performed CRYSTAL dissemination activities constitute a significant part of our sustainability model. The consortium managed to reach a large number of major decision makers in the industry (board members, CTOs, marketing directors, technical experts …) and successfully promoted the developed technology. In particular the awareness of OSLC as an open standard for life-cycle interoperability was dramatically increased by CRYSTAL.
3.4 Prototypical Implementations in the CRYSTAL Use Cases

The CRYSTAL sustainability model employs prototype implementations of integrated Software Engineering Environments to demonstrate the business value of IOS-compliant tools with respect to development time and cost. The project produces prototype implementations in each developed use case. All use cases represent real-life challenges that the use case owners are facing in their daily business or which are expected to arise due to the increased functionality of future products. The use cases serve as proof-of-concept and constitute a major step towards operational use of CRYSTAL technology in the industry. Demonstrating that a technology works and that it brings added value is crucial for achieving sustainability.

3.5 Cooperation with non-CRYSTAL members to use the IOS

Since the IOS is an open specification and the IOS deliverables are public, CRYSTAL has a sound basis for the collaboration with tool providers outside of the consortium. By relying on the public deliverables, CRYSTAL partners can easily engage in a cooperation with external partners without complex IPR-related and contractual issues. Several cooperations are already underway, but will not be further explained in this document.

3.6 Cooperation with standardization organizations and other European initiatives

Part of our sustainability strategy is the transfer of IOS specifications to existing standardization organizations. These activities are ongoing (e.g., OASIS-OSLC WG & Steering Committee; ReqIF implementer forum at ProSTEP iViP)

Furthermore, CRYSTAL collaborates with other European initiatives like EIT-ICT Labs; ARTEMIS; ITEA3 …

3.7 Actively support the creation of relevant ecosystems

CRYSTAL is actively supporting the creation of ecosystems that can support the sustainability of the CRYSTAL results after the end of the project. A particular success story is the partnership of the OASIS OSLC Member Section and the Prostep iViP association.

The OASIS OSLC Member Section has established a formal partnership with the Prostep iViP association to jointly drive interoperability issues under the Prostep iViP “Codex of PLM Openness”. Some CRYSTAL partners are members of both organization and have a vital interest that a common approach is taken. CRYSTAL members helped to establish this partnership. Planning for a joint event for fall 2015, on Interoperability between Prostep iViP, OASIS-OSLC and European funded projects (including CRYSTAL) is in progress. This event also aims to promote and foster the acceptance of the OSLC standard, which is part of the CRYSTAL IOS specification.
4 Detailed Sustainability Model

This chapter lists concrete activities towards sustainability of the IOS, the RTP and the platform builder.

4.1 IOS

The strategy for ensuring the sustainability of the IOS includes the following major topics:

4.1.1 Build on a technically sound foundation

A sound technical foundation is the prerequisite for any successful standard. CRYSTAL is based on successful principles like the Linked Data principles defined by the W3C (World Wide Web Consortium). Also for the implantation we are using existing technologies as a basis. A prominent example is Eclipse Lyo which is an SDK to help to adopt OSLC (Open Services for Lifecycle Collaboration) specifications and build OSLC-compliant tools1.

4.1.2 Reach a critical mass

For establishing a standard, an initial critical mass is required. CRYSTAL motivated a large group of stakeholders to make initial investments in the technology. The Artemis Innovation Pilot Project (AIPP) itself includes already 69 partners who committed to the IOS, but CRYSTAL was also able to motivate non-CRYSTAL stakeholders to get on board. Examples include cooperation with large tool vendors like Mentor Graphics.

4.1.3 Ensure openness & stability

An important aspect of the sustainability model is to establish confidence that the underlying specifications are open and stable.

- CRYSTAL actively supported the creation of eco-systems that creates and govern open standards (e.g. OSLC, FMI, ASAM …) based on the developed specifications. The concrete standardization-related activities that were conducted in the scope of CRYSTAL are described in detail within deliverable D601.033
- The major goal of CRYSTAL was to provide pre-standard specifications and not final standards. Therefore the sustainability model has to support also standardization activities that occur after the end of the project. For this purpose CRYSTAL has engaged in a cooperation with the CP-SETIS project, which has the objective to set up a sustainable structure for coordinating all IOS-related activities across the boundaries and the runtime of individual projects.

4.1.4 Facilitate uptake by new stakeholders

The CRYSTAL sustainability model includes several activities to reduce the initial barrier of new potential stakeholders who want to get involved:

- CRYSTAL provides tools to ease the adoption of the technology. These tools include the platform builder for configuring an SEE as well as SDKs and code generators for developing IOS adaptors.
- CRYSTAL provides reference solutions that show the IOS can be applied in an industrial environment. These reference solutions include the public industrial use cases as and the generic engineering methods (gEMs).
- CRYSTAL builds up a developer community joining forces and reducing redundant work with respect to IOS implementation.

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1 http://www.eclipse.org/lyo/
4.2 RTP

The RTP can be viewed as a library of technology bricks (e.g. IOS-compliant tools or connectors) which are typically maintained by the respective company that owns the tool. Therefore, also the sustainability of the individual tools is in the responsibility of the owning company. Nevertheless, the CRYSTAL sustainability model includes also RTP-related activities on project-level:

4.2.1 Provide a sustainable tool catalog for the RTP

Due to IP-related issues there will be no central repository where all the tools can be downloaded. The individual tools will still be maintained and sold by the companies owning the tool.

- To encourage the industrial uptake of IOS-based solutions, CRYSTAL will provide a tool catalog, listing all the tools and their IOS-related interoperability capabilities.
- The tool descriptors will be formally described such that they can be automatically interpreted by the platform builder implementation.
- The tool catalog will be provided at the end of the project.

4.2.2 Generic Engineering Methods as reference solutions

- CRYSTAL provides generic engineering methods (gEMs) that serve as a reference for using IOS-compliant tools in an integrated System Engineering Environment.
- The gEMs will be included in the IOS V3 deliverable (D601.023).

4.2.3 Open source solutions

- CRYSTAL will provide open source solutions as part of the RTP (e.g. adaptors).
- A list of open source contributions will be provided in the final report.

4.2.4 Business rationale

- CRYSTAL will provide a public business rationale for different stakeholders for RTP and the IOS.
- The final business rationale will be provided at the project end. A draft version is included in Annex I of this deliverable.
- CRYSTAL issued a formal request to CP-SETIS to maintain the business rationale in a sustainable database at the project end.

4.3 Platform builder

The Platform Builder method is implemented in the Platform Builder Modeler (PB Modeler) application as a set of java plugins on top of EPF Composer version 1.5.1.5.

The CRYSTAL sustainability model foresees the following activities for supporting the PB Modeler:

4.3.1 Demonstration of industrial applicability

In CRYSTAL project, the Platform Builder prototype and the Platform Builder methodology have been used in several use cases (one per domain) in order to specify the SEE to be used. In this way, the Platform Builder has served for defining the production process (composed by several Engineering Methods) to be applied in the use case, select the set of tools that will support them, and specify the required interactions (based on IOS) among those tools in order to speed up the production process while ensuring the process and product quality.

The assessment process has been carried in four use cases:
- SP2 (Aerospace): UC202 - Preliminary Design for a new Regional TurboProp
- SP3 (Automotive): UC304 - Test case definition interlinked with model based requirement engineering.
- SP4 (Healthcare): UC401 - Medical procedures in an interventional X-ray system
- SP5 (Railway): UC501 - ERTMS/ETCS Interoperable testing.

As result of using the Platform Builder prototype and the Platform Builder methodology, each use case has been able to obtain the SEE specification for their use case in xml and html format, some of them have been included as part of the use case report. Currently, this information can be used for helping companies to configure and build up the SEE to be used.

Moreover, the people participating in the assessment have reported their experiences, detected issues, and ideas for Platform Builder improvement (both tool prototype and methodology) and have been collected in D602.032 V2. From gathered feedback, it can be said that the Platform Builder goes in the right direction, and it is foreseen a high potential.

4.3.2 Public documentation and meta models

The Platform Builder method is documented in three different deliverables that encompass meta-models, specification and design, prototyping of PB Modeler. For a software application, as it is the PB Modeler, the sustainability model addresses also maintainability aspects, and then these documents include information to maintain and develop a new PB Modeler release beyond the CRYSTAL project.

- The documentation of the platform builder will be released as a public document.
- CRYSTAL will issue a formal request to CP-SETIS maintain the platform builder documentation in a sustainable database at the project end. Open source release.
- The Platform Builder Modeler is an application that is implemented as set of java plugins on top of EPF Composer version 1.5.1.5. The partners who are involved with the platform builder have identified two types of license to release the entire implementation as open source:
  - source code is distributed under GPL (General Public License)
  - source code is distributed under LGPL (Lesser General Public License)
- Both options exclude the EPF Composer that is under EPL 1.0 (Eclipse Public Licence) and it is used as it is.

4.4 Implementer Forum

In order to align the development activities within the project as a whole and to provide guidance for the application of the IOS, a moderated implementer forum was created.

The purpose of the forum is to:

- share experiences with respect to IOS application,
- improve project-wide communication at working level,
- make applicable (ideally proven in use) solutions and approaches visibility on a project-wide level, and to
- bring challenging problems to the attention of project leadership and expert groups.

The implementer has proven to be an integral enabler for the implementation and application of the IOS technologies.
5 The IOS Coordination Forum (ICF)

Considering the nature and the ambition of the IOS, it was clear from the very beginning of CRYSTAL, that an adequate sustainability model has to be conceived across the boundaries of a single project. In order to develop and implement a cross-project strategy for IOS-related activities, especially the formal standardization and further extensions of the IOS, several CRYSTAL partners, including the coordinator, submitted together with stakeholders from other projects a proposal for an innovation action in the H2020-ICT-2014-1 call, called CP-SETIS (please see Annex II for further details on the innovation action). As the largest IOS-focused project, CRYSTAL is a major contributor to the joint strategy. The first version of the cross-project sustainability strategy has been successfully released and has been accepted at the first annual review of CP-SETIS.

A cornerstone of the sustainability model is the **IOS Coordination Forum (ICF)** which will be described in detail in the following sections.

Please note, that the contents of the following sections are (slightly modified) excerpts of the related CP-SETIS deliverables (CP-SETIS D1.2 and CP-SETIS D1.3). The creation of the content of these deliverables was a joint effort of CRYSTAL and CP-SETIS which has been also officially stated at the CP-SETIS Annual review.

5.1 Overview and Basics

Figure 1 above depicts the structure and activities of the IOS Coordination Forum. The ICF is conceived as an open platform/forum, where all IOS stakeholders can meet to ...
a) get consistent and up-to-date information about the IOS, from technical specifications, documentations, status of standardization, etc., up to success stories, related events, workshops, consultation, and similar;

b) meet experts and be part of a community and
c) be able to harmonize and coordinate their IOS related activities, especially regarding extensions of the IOS and formal standardization of its parts.

For an initial set up of ICF, activities and scope of ICF have been chosen deliberately such as to cover the very basic necessities of a harmonization and coordination platform/forum, while at the same time giving a maximum of added value and benefits to stakeholders. Especially, ICF will focus on the IOS specification, its extensions and standardisation, and not on the implementation part (i.e., the creation of IOS enabled tools).

ICF will set up and maintain the following two assets:

- **IOS database.** A structured collection of the technical specification of all IOS parts, where each part contains information about the status of that part with respect to current version, maturity and standardization activities.

- **IOS Information Collection.** A collection of all IOS related information, ranging from documentation resp. dissemination material via use cases employing IOS enabled tools, pointers to IOS enabled tools, and up to lists of events, workshop, and other IOS related information.

Using these assets, ICF will support the following activities:

- **Maintain the current IOS Snapshot.** The goal of this activity is to have the IOS database reflect the actual status of the IOS at all times. To this end, IOS related activities in projects (e.g., development of IOS extensions, successful application of IOS enabled tools in use cases, prototype implementations of IOS enabled tools, etc.), in standardization bodies (i.e., inclusion of new IOS parts in existing standards, creation of new standards out of IOS part specifications), and by tool vendors (i.e., adoption of IOS in their tools) will be monitored. Whenever new results are achieved, the IOS database will be updated accordingly, i.e., information about new IOS parts will be added and/or the status of existing parts will be updated.

- **Support extensions of IOS.** The content of the IOS database will be used to identify gaps in IOS coverage thus giving raise to the creation of new parts, new extensions or modification of existing parts, or creation of IOS enabled tools and their application to industrial use cases etc. Existing projects in which these gaps can be filled will be identified or new projects created. These projects will be supplied with the current snapshot/baseline of the IOS. After finishing their tasks, the results will be collected and the IOS database updated accordingly.

- **Enable and support standardisation of IOS.** Although the standardisation of IOS parts will (and must) be stakeholder driven, ICF will support these activities by coordinating these activities, supplying contacts to standardisation bodies and cooperate with them, and supplying all necessary information about the specific processes of the standardisation bodies.

- **Community building.** ICF will be the contact point and information hub for all IOS related information and activities and build an IOS Community recognizable by all stakeholders.

These assets and activities are expected to be on the one hand the basic necessities that an IOS Coordination Forum must perform in order to achieve added value and thus commitment and participation from the stakeholders, and on the other hand still allow ICF to be implemented as a low overhead, lightweight structure, for which sustainability will be comparably easy to achieve. Potential extensions for ICF are currently under discussion, i.e., additional assets that could be maintained and additional activities that could be supported by ICF. Once the first version of ICF has proven successful, we will evaluate together with the participating stakeholders which of these extensions (if any) will be implemented within ICF.

### 5.2 Detailed Description of Assets and Activities

As explained in the last chapter, we present here a more detailed view on the assets and activities of ICF. We deliberately leave some details and options open, and will use these descriptions as a basis for setting up an initial bootstrapping version of the IOS database and some of these processes. This will then be used
in a ‘learning-by-doing’ process to collect concrete feedback, modifications and concretisations from stakeholders.

### 5.2.1 Asset: IOS database

The IOS database is the central asset of ICF. It contains all information about the technical specifications that the IOS comprises.

The IOS Database will contain each specification or extension together with the following additional information:

- **Unique Identifier**, consisting of a name, a type (i.e., standard, extension or bridge, possibly more types will be identified in the future), a version number, and similar.
- A description of the part, including an overview and the (link to the) complete technical specification.
- Additional information about the **character** of the part. This may include:
  - Information about whether ICF actively supports development and standardisation of this part or merely monitors development by external organisations (e.g., if for example Autosar becomes a part of the IOS).
  - Information about whether this IOS part is considered **normative** (i.e., this part is or will become part of a formal standard) or **informative** (i.e., there is no need for this part to become part of a formal standard).
- Additional information about the **maturity level** (or adaptation status) of this part. A proposal for an initial set of maturity levels used for this attribute is presented below. Essentially this contains information about how much this part has proven its usefulness and how much it is accepted by the community.
- Information about the **development history** of this part (i.e., pointer to the previous version, if that exists and the project/set of stakeholders that created this version).
- Associated **standardization** organization and description (or pointer to) standardization activities that have been conducted so far (if applicable, i.e., for mandatory parts).
- Information about a contact point for this part, i.e. a (group of) persons or companies who have set up/defined this part.
- Possibly additional attributes to be defined at a later stage, especially pointers to tools implementing this part of the IOS.

As for the **maturity level** (or adaptation status), we suppose to start with the following levels:

- **Proposed**
  - The Standard or Specification or Extension or Bridge or … is proposed to become a part of the IOS.
- **Tracked**
  - The proposed part fits into the IOS (i.e., there is a gap in the IOS that this part will fill, overlap with existing parts is not too big or even non-existent, there are no other obvious obstacles for including this proposal as a part of the IOS, and
  - a certain number of Stakeholders support this proposal
- **Considered**
  - A sufficient number of stakeholders (exact number to be defined) decided to ‘invest’ in this part. The part is (a) under development, or (b) evaluated for applicability to a particular use case or (c) implemented by a (prototype) tool, or (d) prepared to become a formal standard, adopted by a Standard Development Organisation.
- ** Adopted**
  - A considered part is adopted in the IOS by the IOS community, based on a sufficient number of evaluations and a formal adoption (i.e., voting) process of the Stakeholders.
The type and maturity information about the IOS parts can be depicted in a kind of radar chart, similar to the radar chart used by the ASD Strategic Standardization Group (see http://www.asd-ssg.org/radar-chart). Figure 2 depicts a visualization of an example database content.

Figure 2: Visualization of an example database, showing IOS parts, their maturity and character information. The 'proposed' maturity level is not visualized, since for proposed parts the character information is not available yet (Please note that this is the proposed visualization of an example database!).

### 5.2.2 Activities: Maintaining the current IOS snapshot

This activity will be driven by the ICF with strong support from the IOS Stakeholders. Its goal is to have the IOS database (described above) reflect the actual status of the IOS at all times. To this end, IOS related activities in projects, standardization bodies, and with tool vendors, will be monitored and whenever new results are achieved, they will be used to update the database accordingly.

Regarding the technical development and the maturity level of IOS parts, the process to maintain and update the IOS database will be as follows (with possible extensions and concretizations defined at a late stage):

- Any IOS stakeholder can propose a standard and/or extension and/or other proposal to be looked at, which is then put into maturity level ‘Proposed’. Sufficient data has to be supplied by the proposer to fill in a meaningful database entry.
- A quick check by an ICF team decides which proposals to accept as ‘Tracked’. The check will include a check of the criteria of the category ‘Tracked’ (i.e., fitness, minimal overlap with existing parts, sufficient support of a number of stakeholders).
  - Although additional criteria for the category ‘Tracked’ might be decided upon in the future, in general it should be easy for a group of stakeholders to move a supported IOS part into the tracked category. The check by the ICF team should not be very resource intensive.
In a more detailed analysis, a technical review team decides whether a formal evaluation process of the standard/extension should be started. This leads to the part becoming a ‘Candidate’. The formal evaluation can take many forms:

- **Support.** Commitment of a sufficient number of Stakeholders (exact number to be defined) decide to ‘invest’ in this part, i.e. start and support the evaluation.
  - **Applicability**
    - definition or selection of an existing industrial use case for the evaluation
    - implementation of a prototype/prove of concept/reference implementation with the use case
    - review of the use case and prototype/reference implementation by a technical team
  - **Dissemination and Standardisation**
    - Initiate implementation of the part in commercial tools
    - Find a SDO where the standard will be maintained and or where it can be included into an existing standard
  - Some of these evaluations might be done in a public funded project. Modifications/technical extensions/etc. of the IOS part needed to pass the evaluation might also be done in a public funded project (c.f. activity Project Incubation).

- Based on the results of the evaluation process ICF members can vote to adopt the standard, which then becomes ‘Adopted’.
  - Additional prerequisites for level ‘Adopted’ might be defined.

Figure 3 below depicts this process. It should be noted that most of the effort in these activities is with the IOS stakeholders, which need to supply all the necessary data for the IOS part and its evaluation. The ICF team deciding about the tracked structure is a small one and does not need to do a detailed evaluation. However, evaluation of the Candidate parts will take more effort, which is why this should and probably will be done mostly in funded projects (by stakeholders).

![Diagram of IOS parts maturity level advancement](image)

Updating and maintaining the other information and attributes of the IOS database is relatively straightforward. Especially the standardisation related attributes will be supplied by the Standardisation bodies or the stakeholders driving the standardisation. Technical descriptions and contact points for each part will (must) be supplied by the proposing stakeholder and will also be updated by them if needed.

### 5.2.3 Activities: Support extension of IOS

ICF will support Stakeholders in incubating IOS related project, i.e., projects in which extensions of the IOS are further developed and/or candidate parts are evaluated.
For these activities, Project incubation Workshops will be held regularly (in the same way as they are currently very successfully held in Competence Clusters like SafeTRANS or EICOSE). During these workshops, Stakeholders will, based on the content of the IOS database

- Identify gaps in IOS coverage
  - Which give rise to the development of new specifications resp. new IOS parts
- Identify the need to move IOS part(s) to a higher maturity level
  - Which give rise to the evaluation of IOS parts, implementation in prototype tools, identification of use cases and application of tools to these, etc.
- For each gap or need for higher maturity, identify a set of stakeholders that want to ‘invest’ in filling the gap resp. moving the respective IOS part to higher maturity
- Identify existing projects or create new projects filling these gaps, with the identified set of stakeholders as consortium partners
- Identify existing funding programs to which these proposals can be submitted

For successful projects, the participating stakeholders will regularly report on the advances made wrt. IOS. Latest at the end of the project, but possibly even earlier once the respective result has been reached, the IOS database will be updated accordingly.

5.2.4 Activities: Enable and support standardisation of IOS

Inclusion of IOS parts into formal standards must be a Stakeholder driven activity. Yet, ICF will pave the way and ease the process of formal standardisation for those parts of the IOS that Stakeholders deem standardization necessary. This will probably be every IOS part, that is already an extension of a formal standard, but a definite decision of stakeholders to invest in this activity is needed.

ICF will support these activities in several ways:

- For each existing Standard that is a part of the IOS
  - ICF will establish contacts to the appropriate standardisation bodies
    - The goal here is twofold: (a) ICF should be made visible as _the_ coordination forum where a set of standards concerning IOS is being worked upon by stakeholders and (b) Information about the standardisation body (see below) will be made available to Stakeholders
  - It will supply ‘how-to’ information to stakeholders, describing for each standardisation body
    - how to extend/modify/influence standards of that body
    - the specific way of working of that body.
- For each extension of an existing standard that is part of the IOS
  - ICF will cooperate with the appropriate standardisation bodies
    - The cooperation here can take many forms, e.g., associated memberships, contribution in steering boards and technical committees, etc.
  - ICW will support the process to include this extension into the standard
    - i.e., stakeholders will participate in appropriate standardisation bodies (working groups, user groups,…, according to processes of that standardization organisation) to include this extension into the standard

Within CRYSTAL and CP-SETIS, we have already established contacts to various standardisation bodies, namely to OASIS (owner of the OSLC standard, on which the majority of the current IOS parts is based), ASAM and ETSI (both associated members in CP-SETIS). Especially, we have initiated and continued ties and cooperations with OASIS, where

- CP-SETIS members (OFFIS, AIT,…) have become associated members in OASIS
The CP-SETIS partners that already were tightly interwoven with OASIS and especially the OSLC Technical Committees have continued their work of integrating IOS specificatons into the OSLC standard.

Information about the way of working of OASIS and especially about the way in which OASIS standards can be influenced has been provided.

For ICF, this work will continue. The ultimate goal ist to (a) make ICF become the contact point for standardisation bodies for IOS related standards and (b) ease the way for stakeholders to formaly standardize the respective IOS parts.

Example How-To: How to create new OSLC domains / Propose changes to existing specifications

We here provide an example of a description of the specific way that a standardisation body is working. The standardisation body is OASIS and the concerned standard OSLC.

1. Change an existing OSLC Domain Spec
   - OSLC Domain Specs are developed in OASIS OSLC Technical Committees (TC)
   - TCs can own one or more OSLC Domain Specs
   - TCs can create Sub-Committees (SC) to split the work
   - All activities of the TCs are scenario driven.
     - In order to motivate a change, a new scenario has to be provided
     - Ideally such a new scenario is agreed upon between multiple stakeholders of a OSLC User Group (see 3)
   - OASIS members can propose a change by providing a description and the new scenario to the chair of the corresponding TC (*1)
   - The TC decides to accept the scenario or put the scenario back into the hands of an existing User Group to first look at and vet further or to create a User Group to discuss the scenario.
   - Voting members of the TC will decide whether the requested change will be accepted and planned for a future release of the Domain spec

   (*1) Some of the OSLC V2 Domain Specs are not migrated to an OASIS OSLC TC yet. If a proposed change affects one of these specs, the OSLC V2 Domain specs have to be migrated first by either handing them over to an existing TC or creating a new TC (see 2.). It is not planned to make any more modifications to the existing V2.0 specs under the governance rules of open-services.net unless there are some severe bug fixes required.

2. Create a new OSLC Domain Spec
   - A new OSLC Domain Spec can either be developed in the context of an existing TC (or a Subcommittee) or a new TC can be created (according to the OASIS and OASIS-OSLC rules and procedures).
   - In both cases at least one scenario has to be provided in order to motivate the new OASIS-OSLC Domain. Ideally new scenarios are agreed between multiple stakeholders of an OSLC User Group (see 3).
   - OASIS members can propose a new OSLC Domain by providing a description and the scenarios to any of the existing TC.
   - Voting members of the TC will decide whether the new OSLC Domain will be accepted by the TC; The chair of the TC has to request approval with the OASIS OSLC Steering Committee (StC) for the new OSLC Domain.
• If none of the existing TC is willing to accept the proposal for the new OSLC domain, a new TC can be created (see OASIS rules for creating a new TC: e.g., charter and a minimum support of 5 OASIS members are required).
• New TCs developing OSLC Specs need to request association with the OASIS OSLC Member Section. In order to do this a motion has to be moved to the StC (OASIS OSLC MS RoPs apply: e.g. accepting StC and OSLC Core TC governance, naming convention of the TC, etc).

3. Create a new OSLC User Group
• In order to prepare a change to an existing OSLC Domain Spec or create a new one, an interest group (called OSLC User Group) can be created on open-services.net (see: http://open-services.net/wiki/steering-committee/OSLC-User-Groups-Reference/)
• Goals of OSLC User Group are
  o provide input for the specification writing TCs (e.g. agreed scenarios to motivate a change or creation of an OSLC Domain Spec) and/or
  o present and share best practices and discuss interoperability issues.
• No OASIS membership is required to participate in an OSLC User Group on open-services.net
• To create a OSLC User Group, a charter has to be provided describing the aim and the purpose of the User Group and including a statement about no IP relevant contribution.
• The motion with the charter and the list of supporters has to be moved to the OASIS OSLC StC.
• The StC decides about the creation of the User Group.

For a process as this, ICF will provide support and initiate the appropriate actions as follows:
• Knowledge Transfer: Make these processes known to stakeholders, provide knowledge about proven ways of interaction with the standardization body, provide point of contacts (ideally: IOS stakeholders that already are a member of an OASIS TC or User Group or Steering Baord or…)
• Coordination: Identify group of stakeholders that are willing to further a particular IOS part as an (extension of an) OSLC standard. Provide consultation to this group wrt. the above information.
• Point of entry: Identify the best point of entry: Which existing TC, which existing user groups matches most closely to the scope of the IOS part.
• User Group: Support process of creating a new OSLC User Group, support work of existing user groups by providing the appropriate IOS information.
• Support creation of scenarios by providing information about existing use cases and/or other IOS information.
• Level of Trust: By repeatedly acting as a supportive organization for IOS related standards in this particular standardization group, ICF will build up a level of trust which might positively influence any decisions that the bodies of the standardisation organization have to take.

5.2.5 Asset: IOS Information Collection
The IOS Information Collection will be a collection of all IOS related information, ranging from documentation resp. dissemination material via use cases employing IOS enabled tools, pointers to IOS enabled tools, and up to lists of events, workshop, and other IOS related information. It will contain at least the following information (e.g., on a public website)

<table>
<thead>
<tr>
<th>Version</th>
<th>Nature</th>
<th>Date</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>V01.00</td>
<td>R</td>
<td>2016-08-11</td>
<td>20</td>
</tr>
</tbody>
</table>
- Description of IOS, its purpose, its parts, associated formal standards, status of standardisation, links to technical descriptions, links to contact points
  o Some of this information is directly from the IOS database
  o All of this information will be openly accessible, but for access to some information a registration might be mandatory
- Advertising IOS uptake: Success stories, documentation of implemented use cases, advertisement and pointer to IOS enable tools, pointers to Implementer Forums, contacts to IOS experts
  o Some of the information will only be provided in later versions, if ICF extends its focus from IOS specifications to IOS implementation.
- Dissemination material: Poster, Flyer, Slides, etc.
- Description of ICF, its structure, functions and activities, incl. success stories and how-to participate
- Announcements and Advertisements about IOS related events, workshops, conferences; where to meet the experts, etc.

Next to the IOS database, which contains all the technical details of the IOS, this Information collection is a very valuable resource for IOS stakeholders. For the first time, all IOS related information will be available at one point, always up-to-date, always reliable, always consistent.

5.2.6 Activities: Community building

As the IOS Information collection is a very valuable resource, so the activity of Community building is the single most important activity of ICF: IOS Stakeholders must be enabled to feel as a closely cooperating group of trusted people/organisations with the same set of goals and a strong determination to reach these goals, in order to be able to efficiently and successfully drive IOS extensions and standardisations.

ICF will therefore aim to build an ‘IOS Community’ recognizable by all stakeholders, by

- Collecting and maintaining the IOS Information Collection and making it accessible to the public (especially to the IOS Stakeholders)
- Successfully drive its activities of IOS database maintenance and update and supporting IOS standardisation, thus also provide success stories for stakeholders to participate in ICF
- organize Events, Workshops, Conferences, Marketplaces
- lobby Tool Providers to adopt IOS
- Support projects in adopting IOS
- Provide information to the European Commission, Public Authorities, Funding Organizations
- Evangelize IOS concepts to community / other stakeholders/ standardization bodies outside IOS, etc.
- Initiate/facilitate IOS related cooperations between Stakeholders, Standardisation organisations, projects

Again, some of these activities – especially the ones that concern IOS implementation – may only be taken up at a later time. But even without them, these activities will heavily contribute to forming a large IOS community comprising many, if not all IOS stakeholders.

5.2.7 Roles

As was already hinted at in the description of the various activities that ICF will support and perform, most of these activities will rely heavily on support of the stakeholders, i.e. it will be the stakeholders who have to perform them, with ICF playing only a supportive and integrating role.

Essentially, this is a positive statement, since it will provide an ultimate measure of stakeholder commitment, which is absolutely necessary for the IOS to be successful. A standard that is set up by others than the intended users will not be taken up. An Interoperability Specification that is not driven by tool end-users and tool vendors will exist, but have no impact. Therefore, active stakeholder participation and commitment is of
utmost importance, since the ICF should not be created for its own sake, but to enable the community to reach the target goals.

We know from other examples, that these in-kind contributions of stakeholders work quite well, if (and only if) a sense of benefits and (tangible or ideal) return of investment exists. Examples of these kind of structures are

- Competence Networks like SafeTRANS or associations like ARTEMIS-IA, which work with a very small set of employees in a supportive office, but where the major work (in Steering Bodies, Board of Directors and Working Group) is done by members (who even pay membership fees).
- Standardisation Bodies like OASIS or ASAM, which also are driven mostly by member participation and rely on small supportive staff in their office.

Thus, we think that relying on the contribution of stakeholders for the roles mentioned in the activity descriptions above (IOS experts, IOS evaluation team, …), for driving IOS extensions and IOS standardisation, and for participating in decision structures and decision bodies of ICF is not only feasible, but is rather a pre-requisite for successful IOS uptake.

5.3 Hosting Structure for the ICS

Even though most of the ICF activities will be performed by Stakeholders, some supporting effort must be provided by ICF:

- Technical Maintenance of IOS database, IOS Information Collection, Website, Mailinglist, etc.
- Organisational Support for Events, Workshops, Conferences, Meetings
- Support for managing ICF, i.e., Initiate meetings, workshops, conferences, initiate stakeholder activities, provide content-wise overview of ICF activities, project results, and in general being the ‘recognizable face’ of ICF.

Such activities can only be coordinated if the ICF is embedded in an adequate hosting structure. This section outlines our process of selecting and assessing potential hosting structures for ICF (please see the CP-SETIS deliverable “CP-SETIS D1.3” for more details on the selection process and status).

5.3.1 Criteria for ICF Hosting Structures

For the ICF to become widely accepted, a potential hosting structure has to fullfil several criteria. It is important to notice that most of these criteria are not metric or even binary (fulfilled/not fulfilled). ‘Trust’ for example, as required by the first criteria, cannot be measured absolutely. However, for all the criteria we can find indicators whether or not they are met for a certain potential hosting organization; we can also use them to compare different potential hosts. Thus, they server their purpose of helping us to short list the set of potential hosts identified in the next subsection.

Criteria:

**Trustworthyness.** Stakeholders must be able to put trust in the hosting structure. They must especially be able to trust the aspects of **sustainability, openness and fitness** described below. It would be good if the hosting structure would already be a trusted organization in some area related to ICF activities, ie. in standardization, community building, project incubation or similar, since this trust would in all likelihood be transferred to ICF and thus ease the process of getting commitment for ICF from the stakeholders. For this, the potential hosts should already have a **high visibility** and a **high industrial acceptance** in some area related to ICF activities. It should also already **cover** in its previous activities many, if not all of the **industries, domains and engineering disciplines** touched by ICF. To a lesser extent, the **regional scope** of the (previous activities of the) hosting structure might also influence the trust stakeholders put in it. However, here the impact might be in two opposite directions: On the one hand, IOS has been developed within Europe, using a large European investment both in man power and money, and adopting a standard like IOS would certainly give a competitive advantage to whatever community is using it (ie., European Tool...
providers and European End-Users). On the other hand, most of these companies act globally and a standard like IOS should certainly be a world-wide standard eventually. It is still to be determined which of these two factors will impact stakeholder trust more.

**Sustainability.** The hosting structure must be sustainable in order to guarantee

- sustainability of ICF
- long term assessibility of the (IOS related) data collected by ICF
- and thus a continued ‘return on investment’ for stakeholders for their commitment to ICF.

Sustainability implies a solid financial foundation, a sufficient large member base, existence of appropriate governance structures for the structure and similar.

**Thematical Fitness.** Potential hosts should also have a thematical fitness to the ICF activities, i.e., they should ideally already be active in areas related to ICF and IOS. Thus, they should have experience in at least one of the areas community building, project incubation, standardization or similar, and/or be active in at least one of the industrial, application and engineering domains that the IOS covers. The idea behind this requirement is that experiences in this area would be beneficial for ICF in at least three ways: It increases the chance that stakeholders of IOS are already members in the potential hosting structure, thus making it easier for them to support ICF within this structure. Second, being a member or knowing the host and its activities by some other means would also increase the trust level of stakeholders in the ability of the host to handle ICF. Last, but not least, thematical fitness would increase the ease of integrating ICF within the host.

**Openness.** ICF should be an open platform, i.e., it should allow all stakeholders to participate and harmonize their IOS related activities. This implies a number of requirements: First, ICF itself – and therefore the hosting organization, too – should be neutral and independent, and thus not have any commercial interests in the IOS, besides perhaps insofar as needed for directly financing their own activities. Especially, the hosting organization should neither be a tool provider nor an End-User of the IOS resp. of IOS enabled tools. A non-profit organization would be an ideal choice here, but other legal forms could be envisioned. Second, the hosting structure should not impose to many restrictions on membership, i.e., on who can become a member of ICF and who can't. Membership should especially not be constrained to stakeholders from specific regions, or from specific industrial domains or engineering disciplines. Ideally, there would even be a possibility for non-members of the hosting organisations to participate in ICF. The criteria of openness also applies to the ‘output’ of ICF wrt. Intellectual Property Rights (IPR), i.e., if the hosting structure imposes a certain IPR or licensing model, these should be compatible with the purpose of ICF of creating and supporting open specifications and standards.

**Organizational issues.** The final set of criteria for an ideal hosting organization applies to organizational issues of integrating ICF into the hosting structure and of operating ICF within that structure. Since ICF will not be its own legal entity, the host has to be one, in order to be able to issue invoices and collect money (i.e., membership fees or in kind contributions, possibly also EU funding or other contributions in case ICF partcipates in funded projects, and similar), employ staff, buy infrastructure (i.e., server, office supplies,…), etc., all on behalf of ICF and its activities. The hosting organizations should have an appropriate substructure that allows easy integration of ICF, for example as a working group, a committee, or some other kind of subgroup, but still leave ICF as a recognizable entity in its own right. It would also be beneficial if subgroups like ICF were allowed to define their own procedures and manner of working as much as possible – of course there would certainly be the need for an interface to the overall governing structure(s) of the host, but internal procedures should be as free as possible, as long as they do not compromise the overall structure and procedures of the host. Last, but not least, it would be beneficial if the hosting structure could support ICF by supplying infrastructure resources (i.e., usage of existing infrastructure like webservers, offices, or similar), or personnel resources, e.g., for organizing meetings, etc., or even financial resources (i.e., furthering member fees, etc.).
5.3.2 Initial List of Potential Hosting Structures and Organisations

The following organizations and structures have been selected for an initial list of potential hosting structures, based on previous experiences of CP-SETIS core partners with them and their activities in areas closely related to ICF and IOS.

- **ARTEMIS-IA** – a dutch non-profit organisation that organizes the ARTEMIS ETP (the European Technology Platform for Embedded and Cyber-Physical Systems) and serves as the one resp. one of three private partner(s) in the Joint Undertaking ARTEMIS and ECSEL. Many projects in which the IOS was developed have been funded by ARTEMIS, many stakeholders are already ARTEMIS members.

- **Eclipse Foundation Europe** – a small SME that is the German/European branch of the global acting Eclipse Foundation that hosts the Eclipse projects. Many stakeholders of IOS are already involved in Eclipse – by formal membership or other means – and they have a large experience in community building and open source projects.

- **EICOSE** – European Institute for COmplex safety critical Systems Engineering. A cooperation of national (German, French, Austrian, Spain) clusters resp. Pole de Competitivites, which cooperate on a European level wrt. roadmapping for safety critical systems in the transportation domain, project incubation and sustainability of project results. Many IOS stakeholders are members of at least one of the comprising clusters, many IOS projects have been incubated within EICOSE. EICOSE is closely linked to ARTEMIS; it is in fact one of only a few Centers of Innovation Excellence of ARTEMIS-IA.

- **ETSI** – European Telecommunications Standards Institute, is a French based standardization institute producing globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and Internet technologies.

- **INCOSE** – The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization founded to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems. They are especially experienced in community building and in the engineering discipline of Systems Engineering.

- **OASIS** – Is a nonprofit consortium that drives the development, convergence and adoption of open standards for the global information society. It promotes industry consensus and produces worldwide open standards for security, Internet of Things, cloud computing, energy, content technologies, emergency management, and other areas. OASIS is the host for the OSLC standard, on which the vast majority of the current IOS specifications is based.

- **OMG** – The Object Management Group (OMG) is an international, open membership, not-for-profit technology standards consortium. They host standards like UML (Unified modelling languages) and MDA (Model Driven Architecture), which are largely known and used in industry.

- **ProSTEP iViP** – The ProSTEP iViP Association is an international association that has committed itself to developing innovative approaches to solving problems and modern standards for product data management and virtual product creation.

- **SafeTRANS** – SafeTRANS is a German competence network that comprises large industry, SMEs and research organisations active in the development of safety critical Embedded and Cyber-Physical Systems. Next to roadmapping and project incubation, SafeTRANS supports sustainability and standardization of project results. SafeTRANS is a founding cluster of EICOSE. Many IOS stakeholders are SafeTRANS members and SafeTRANS has furthered IOS development by supporting appropriate project incubation activities of EICOSE.
The evaluation process for the hosting structures is still on-going and will continue within the frame of CP-SETIS even after the project end of CRYSTAL. More details on selection process (questionnaire that very used in the assessment process, preliminary feedback and results …) can be found in the CP-SETIS deliverable “CP-SETIS D1.3”.

[Y3]
6 Annex I – Business Rationale

Y3 – (The entire business rationale has been refined)

In order to promote the CRYSTAL results, the RTP team has worked on a document which describes the business rationale with respect to the individual stakeholders and the individual CRYSTAL results. This document will be also made publically available on the project homepage.
Authors: Sytze Kalisvaart, Linda Oosterheert, Adeline Schaefer

6.1 Introduction

The Crystal project focuses on accelerating system engineering for safety critical systems such as found in the aerospace, automotive, healthcare and rail domain.
This this webpage explains why it is a good idea to use the CRYSTAL results, such as interoperable tools and interoperability specification, in your business. It answers the most common questions that arise when considering using the results that CRYSTAL came up with. It is organized along the views of the major roles related to a system engineering environment and ends with frequently asked questions.

6.1.1 Stakeholder perspectives

The following roles and use cases were defined for using the CRYSTAL results:
6.1.2 CRYSTAL results

The CRYSTAL project delivers the means that you need to address these use cases. This set of results supports the loosely coupling of system engineering tools to share and interlink their data. The complexity of the engineering process is reduced because these results enable interoperability among various life cycle domains.

CRYSTAL is a strongly industry-oriented project and is driven by real-world industrial use cases from the automotive, aerospace, rail and healthcare sector. With a consortium of 71 partners ranging from OEMs, suppliers, tool vendors and academia, the results are supported by all relevant stakeholders in the safety-critical systems engineering process. The cross-domain reusability of the results is ensured by the involvement of partners from the four different industry domains.

The CRYSTAL results that are available for you are:
- Engineering methods
- IOS
- Tool library
- Platform builder

Figure 4 Use cases for CRYSTAL results for various stakeholders
6.1.3 Engineering methods

Each of the industrial use cases within CRYSTAL deals with engineering methods. An engineering method is a technical description of approach and capabilities needed for a specific repeatable activity in a use case from an end user perspective. The engineering method describes the general task, preferred workflow and artefacts involved, not limited to interoperability.

The engineering methods are good examples of reusable workflow for system engineering. The examples show how you can turn engineering processes into IOS services. In order to ease the identification of commonalities among the different engineering methods, the engineering methods were grouped and classified according to the life cycle processes in ISO15288. This standard was chosen due to its adoption in industry. After the classification, some engineering methods have been consolidated into so-called generalized Engineering Methods (gEM) which can be applied across different industry domains.

You can visually navigate the CRYSTAL engineering methods using this website (Temporary address of EM visualisation).
Figure 5 ISO 15288 covered by CRYSTAL engineering methods (solid line)

6.1.4 IOS

The CRYSTAL Interoperability Specification defines the common machine readable neutral language that tools can use to easily share and interlink their data with other tools. A common and standardized language improves interoperability between tools and makes them exchangeable. Especially the heterogeneity of engineering tools, their involvement in different development platforms and their use in different phases of
the engineering life cycle asks for this Interoperability Specification. The current version of the IOS can be found on the CRYSTAL website.

6.1.5 Tool library
Within the CRYSTAL project, multiple tool vendors have worked on making their tools more interoperable. These tools tackle challenges that are identified in the industry use cases. In the CRYSTAL project a library has been developed of interoperable system development tools that comply with the IOS standard. This library not only consists of actual tools or products, but also includes components to build tools or interfaces and means to establish interoperability such as adapters for tools to be IOS compatible. The library is also available on the CRYSTAL website.

6.1.6 Platform builder
The CRYSTAL Platform Builder is a means to help you select the most suitable tools for supporting your engineering processes. Your engineering processes can be defined in the Platform Builder and based on your definition a system engineering environment can be configured and validated. The previously mentioned tool library can be imported in the Platform Builder to use interoperable, IOS compatible tools in your configuration. Based on the engineering tool functions that the tools offer a suitable set of tools can be selected to support your engineering process.
6.2 Engineer perspective

As an engineer you just want to do your work. You want to use tools that are most appropriate for the work you are doing. You do not want to be bothered by unnecessary (re)work caused by making data consistent or inefficient processes. It would be really beneficial for you to be able to reuse data from other parts of the engineering cycle, in order to assess the impact of changes.

CRYSTAL offers solutions that tackle the problems that engineers encounter.

Drivers:
- Remove barriers in using engineering tools
- Smooth collaboration with others in the engineering cycle
- As few as possible errors and rework

Each discipline uses its own set of tools and wants to keep it that way. One solution in which everyone uses the same tool is not feasible in practice and this tool simply does not exist. With the IOS it is possible for everyone to use their own tools with proprietary data formats but tools can understand each other’s data. If you want to switch from your current tool to another tool that is also easily done! Integration of the new tool in the complete tool chain is facilitated by IOS and a lot easier than before. Point to point tool integrations are no longer needed, only one IOS adapter needs to be built for the new tool.

Currently teams share information by manually creating document based reports or point to point tool integration. Collaboration is easier with the use of IOS, as workflows that were previously disjoint can be connected. Tools are able to understand each other’s data, which makes it possible to share, search, link, analyze, track, and review all available design artefacts across the lifecycle. When more information is available for everyone in the engineering cycle more transparency is created and better decisions can be made. This makes the design process more efficient, as the chance that the design does not meet expectations is decreased. This also implies less rework for the engineer.

IOS enables early collaboration in the development process. This results in early detection of errors that were previously only discovered later during integration. And even across projects data can be reused and shared when the IOS is implemented. Incremental development can therefore be achieved with less effort. The impact of proposed changes is often uncertain. With IOS the impact of changes can be traced and made visible to all stakeholders. The IOS also makes it easier to document compliance to regulatory, industry or corporate standards. As no longer a lack of integration between tools exists, artefacts can be traced throughout the lifecycle. With IOS this is no longer a manual process and the process is less error-prone.
6.3 Process, methods and tools manager perspective

As a process, methods and tools manager your main concerns are efficiency and effectiveness. You know that a multitude of tools and methods are applied throughout various projects and that data is shared across lots of processes. It takes lots of time to manage the complete system engineering environment. You are open to and seeking for solutions that reduce the work load for managing the system engineering environment.

The solutions of CRYSTAL aim at reducing tool management time. The IOS provides a tool-independent language which makes it possible for different tools to share data in an efficient way. Previously you needed to come up with 1:1 solutions for all tools that shared data. With the IOS this is no longer necessary as it provides you with n:n solutions that reduce the effort of embedding new tools significantly. CRYSTAL aims at providing interoperability across tools in the system engineering cycle and solutions provided by CRYSTAL all contribute to this goal.

Although for each tool in your system engineering environment an adapter must be built that makes your tool compatible with IOS, this only has to be done once. This adapter translates the proprietary language the tool speaks into the independent language of IOS, which makes it possible to express the data that is stored in the tool in the IOS ‘language’. Once you have made the tool IOS compatible, it can connect with every other IOS compatible tool that uses the same data artefacts and all these tools can query the data within other tools.

Moreover, the IOS is based on the principle of Linked Data. This means that data is not copied from one tool to another. Instead of duplicating data, data sources that are used across various processes are connected and can be queried. This approach ensures consistency of data, which implies that everyone works with the same data and mistakes related to inconsistency are avoided.

<table>
<thead>
<tr>
<th>Corporate tool administrator</th>
<th>Head of Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you know how many tools our typical project now uses?</td>
<td>15?</td>
</tr>
<tr>
<td>Well, it’s 60 specialized tools and 8 regular office tools.</td>
<td>That’s a lot.</td>
</tr>
<tr>
<td>Moreover, each project may introduce 1 to 4 new ones.</td>
<td>Why?</td>
</tr>
<tr>
<td>New insights, demands of the project, many good reasons.</td>
<td>So they are keeping you busy. We need to bring that down.</td>
</tr>
</tbody>
</table>

"The IOS reduces the effort to integrate tools into customer specific tool chains and enables new applications with improved usability to support our engineers on the job."
Dr. Jürgen Schwarz - Daimler AG, Senior Manager, Safeguarding Hard- & Software

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I am usually not in a position to refuse a new tool. We may slow it down but it is a fact of life.

Right. How do you handle that?

Well, there is this new approach to tooling and data management that seems to make it a lot easier.

What is that?

It’s called the CRYSTAL IOS. Not the Apple one - an interoperability specification.

How would that help?

It separates the project data from the tools and let me edit the project data with any tool I like, given the tool is compatible.

So?

It means that I can combine existing and new IOS compatible tools as I like since they will all work with the data. This saves me tons of work in creating bridges between the tools.

Right! So the choice of tools becomes much less critical?

Indeed, it gives us a lot more flexibility in combining tools and reduces the risk of implementing a tool that you drop in a couple of years.

Great! Sounds good. So I can reduce your staff a lot?

Well, I think we can now focus on important things like reducing the project’s time to market. We may make sure that ICT is not in the critical path for system release and roll out variants faster.

Too good to be true. Anyway, can you provide me with a plan?

6.4 Project manager perspective

As a project manager, you want your team to release a good quality product in time and with minimal effort. This means that any overhead like managing system engineering tools is lost time. You may consider this an unavoidable reality – however, improvements are possible.

Drivers

- Make my team more productive
- Reduce time needed for managing project data across tools
- Use the tools my team wants with minimal overhead time
- Use the tools that have already proven to work

As a project manager, you often need to consolidate project information, which is usually stored in different tools. One recurring issue is that information stored in these tools usually diverges, what requires a lot of time for finding out which tool has the most accurate data and synchronizing the diverging data sets. As IOS is based on linked data, consistency of data is less of an issue, because data are not duplicated among the different tools. This implies no need for synchronization, which makes the consolidation of data more efficient and which makes team members spend less time making data.
consistent. This takes a lot of overhead out for using your tools in parallel. Any tool, even a web
browser, Excel or PowerPoint can have a query on IOS compatible data, as long as the query has the
right syntax.

IOS allows you to use the tools that you want or that have been proven to work. There is no need for
changing that. If a tool is IOS enabled, then it is possible to link its data to other tools in your tool chain which
also uses the IOS. If the chosen tool is not yet IOS-enabled, then you would need to invest in the creation of
the adapter, but this has to be done just once. Furthermore, the IOS uses existing standards, like FMI for simulations, which are well received and widely
adopted in automotive, aerospace and control engineering in general.

<table>
<thead>
<tr>
<th>Project manager</th>
<th>His internal client (e.g. development manager)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want to start using tool x.</td>
<td>Why? The old tools do not work anymore?</td>
</tr>
<tr>
<td>It brings this great feature that will save me a lot of time dealing with product variants / simulation management / other engineering tool function.</td>
<td>A true head ache topic, for sure. How will this help?</td>
</tr>
<tr>
<td>Well, the tool uses IOS which means that data is linked, not copied. So a variant will point to the same design data that underlies all variants. No local versions of a component for a variant anymore.</td>
<td>Sounds good. So you want a pilot to try it and a budget. I am not sure your project can carry that, given the strict deadline.</td>
</tr>
<tr>
<td>You’re right, the deadline is tight. I want one guy to work on it for two months with a go / no-go after 1 month. In the end, I expect it to save me time.</td>
<td>So fast? Is this realistic?</td>
</tr>
<tr>
<td>The tool is provided with a sample integration guide. It links to my existing data. It seems not overly complicated.</td>
<td>That’s what they always say.</td>
</tr>
<tr>
<td>Indeed, that’s why we have the go / no-go at one month.</td>
<td>Okay, it’s your project. You get one month’s budget.</td>
</tr>
<tr>
<td>Thanks. I think it’s worth the risk.</td>
<td>Keep me posted.</td>
</tr>
</tbody>
</table>

### 6.5 Development manager at industrial company

As a development manager the reduction of development costs and time to market is one of your main
concerns. A lack of interoperability involves huge costs. In a fast changing world, it is also important for you
to keep up with this pace and stay up-to-date and innovative. You do not want your business to rely on only
one tool vendor, as a lock-in will not allow you to be flexible.

As the world becomes more and more interconnected, interoperability becomes more important. Costs

<table>
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<tr>
<th>Drivers</th>
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<tbody>
<tr>
<td>- Reduce costs by introducing solutions which investments are profitable</td>
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<tr>
<td>- Stay up-to-date in a constantly changing environment</td>
</tr>
<tr>
<td>- Ensure that lock-in is prevented to be able to be flexible</td>
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</tbody>
</table>

involved with a lack of interoperability are very high. For example, studies show that insufficient
interoperability in the supply chain in the US automobile sector increases the operating costs with at least one billion dollar. 86% of this amount can be attributed to problems in data exchange².

Traditionally, an adapter is created to provide interoperability with one tool. Very quickly, this leads to a large number of adapters that becomes impossible to manage. Adopting standards is a common way to ensure interoperability. As the demand for plug-and-play relationships increases, standards become even more important. In order to reduce costs of integration and to facilitate flexibility, solutions based on standards are most promising³.

Also for tool interoperability, the potential of standards is high. In the context of CRYSTAL this is the kind of interoperability that we speak about. The aim of CRYSTAL is to support the development of a solution to make engineering tools interoperable. This solution offers both technical interoperability, and interoperability on the semantic level. The benefits of such a solution are that integrations can be completed faster and at much lower costs.

Mostly, tools are proprietary and heterogeneous and they have a specific view on data which does not correspond with the view other tools have. As this makes it difficult to exchange data between tools, a standard is a good way to go. Although each tool must invest in building an adapter to make sure data from the tool can be exchanged with other tools, this investment has only to be made once. Instead of having to set up bilateral agreements with every tool that the tool itself wants to exchange with, it only has to map its own data to the standard.

Figure 6 Traditional interoperability approach by using 1:1 adapters (colours of arrows indicate dominant language)

Figure 7 Crystal Interoperability approach using n:n adapters and a common IOS language (blue colour arrows)

As the tool landscape is evolving continuously and at a large speed, a standard is a good way to establish interoperability. This interoperability issue could also be solved by using tools from one single vendor only, but in the complex and evolving environment of system engineering this will not offer a full solution.

6.6 Tool vendor perspective

As a software tool vendor, you want to run a healthy business. Therefore, increasing installed base or margin is a natural objective. Your unique tool features and level of integration attract new customers. However, system engineering environments evolve at a rapid pace. Customer requirements to tool integration are getting more stringent because of increasing adoption of model driven system engineering and the need for shorter development cycles. Interoperability becomes a topic for customer satisfaction that cannot be solved with good support alone. Even the most comprehensive vendor will always be confronted with external tools that do not integrate with its toolset. The traditional approach of creating point-to-point integrations for each new tool works to some extent, but does not scale, as each new customer might use a different tool for which adapters need to be developed, tested and supported.

Drivers:
- Increase installed base of my tool
- Handle tool diversity at acceptable cost
- Increase customer satisfaction of users
- Introduce new features efficiently
- Make my tool work with other brand’s tools
- Provide services to users
- Set a de facto standard with my tools
As CRYSTAL shows, many leading vendors have reached the turning point where they adopt a standard for handling interoperability. By opening up their tools and provide key data to other tools, other vendors can create adapters for using that data. The burden for creating adapters is thus spread across tool vendors. In addition, CRYSTAL uses a common neutral standard for interoperability, the IOS. This means that your tool needs only one adapter to publish its data to make it available for all other tools that share the same IOS domain or domains and the same applies for consuming data: only one adapter is required (see Error! Reference source not found.). An IOS domain is a section of IOS that deals with a specific focus, e.g. quality management, requirements management, etc.

![Diagram of Crystal Interoperability approach using n:n adapters and a common IOS language (in blue colour)](image)

Finally, as a tool vendor, you want to be able to offer innovative features, so, reducing the effort need for solving interoperability issues, enables you to focus your investment in providing customer with new and innovative services.

"Today’s challenges in safety-critical systems engineering cannot be addressed by just one single-vendor tool chain because of the multiple engineering disciplines that are involved in the development process of such complex systems. A truly interoperable tool chain addresses the specific needs in each engineering discipline through best-of-breed capabilities while ensuring seamless integration of the results."

“Our product development strategy at PTC now includes the use of OSLC as open and standardized approach to future-proof tool integrations. Our new OSLC-based interfaces will not only provide better tool interoperability for our customers and partners, but also allow us to shift the energies that we previously spent on tool-specific integrations to the implementation of new innovative functionalities.”

Christoph Bräuchle - PTC, Development Director

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<th>Version</th>
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<td>2016-08-11</td>
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6.7 Standardization body perspective

As a person involved in standardization, you want industrial developments to converge into common practices, definitions and interfaces, eventually solidified in a standard. We all know how much a well-supported standard can help in saving costs and speeding up new product generations.

<table>
<thead>
<tr>
<th>Drivers</th>
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<tbody>
<tr>
<td>OASIS</td>
<td>Promote usage and adoption of OSLC</td>
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<tr>
<td></td>
<td>Expand OSLC</td>
</tr>
<tr>
<td></td>
<td>Identify improvement points for OSLC</td>
</tr>
<tr>
<td>Modelica association</td>
<td>Promote usage and expand FMU</td>
</tr>
<tr>
<td></td>
<td>Embed FMU in system development lifecycle</td>
</tr>
<tr>
<td>CP-SETIS project</td>
<td>Promote usage and sustainability of IOS</td>
</tr>
<tr>
<td></td>
<td>Promote usage of RTP</td>
</tr>
</tbody>
</table>

CRYSTAL promotes interoperability using open standards as this is the only option to define a common language and avoid 1:1 tool interoperability. Using the IOS as a common language, n:n interoperability between tools becomes feasible, even for tools that will arise in the future.

Standardization is therefore essential for the IOS to make the results sustainable beyond the CRYSTAL project. How is CRYSTAL important for the standardization bodies?

OASIS is the standardization body that maintains OSLC. The CRYSTAL project helps to gain critical mass for OSLC in the safety critical systems engineering domains, as important representatives of four domains are involved (automotive, healthcare, aerospace, rail). As the CRYSTAL project lets more and more users and developers experience the advantages of OSLC, the word will go around and OSLC moves towards a well-accepted standard in the system engineering community.

Moreover, CRYSTAL identified new IOS domains and a large range of IOS extensions based on real industry use cases and work flows. Also, real time simulation with FMU was connected to OSLC. Many of these were piloted in implementations. In the process, CRYSTAL identified improvement points for OSLC like link management and query performance. This offers a rich base for the OSLC roadmap in the years to come.

Modelica association is the standardization body that supports FMU as a Modelica association project. The CRYSTAL project made many new companies aware and active in using FMU. It was already successfully adopted in automotive and aerospace and is expanded to rail and healthcare. The CRYSTAL contribution to FMU was to provide the traceability and integration in the engineering workflow and lifecycle, by linking FMUs to requirements, verification and architecture using OSLC. This is standardized in the IOS and the related recommended workflow “Simulation management”.

CP-SETIS is the organization that promotes IOS (interoperability specification) results. For CP-SETIS, CRYSTAL and the related Artemis projects CESAR, MBAT, iFEST, EMC2, DANSE, D3COS, HOLIDES are the main source for the IOS and the proof of industrial viability. CRYSTAL also provided the system engineering community with a library of sample and recommended engineering workflows using the IOS. This helps applying the IOS. CP-SETIS publishes the IOS, the IOS compatible tool catalog and the engineering workflow library.

6.8 Related Artemis RTP projects perspective
If you have been involved in a previous Artemis RTP project, you want your results to be picked up by follow up work like CRYSTAL and brought to a higher level of advancement and adoption. Also, the Artemis Industry Association wants to build a coherent set of solutions across projects that support system development of embedded and cyber-physical systems.

As with any EU collaborative project, the consortium collaboration is temporary. In practice, the projects give rise to much industrial collaboration afterward.

After the project end, the results run the risk of quickly becoming outdated. For the results of the project to be used in full, the Artemis program stimulates clusters of projects that build on top of related projects. In that sense, CRYSTAL was built on the shoulders of CESAR, MBAT, MODELWARE, iFEST, DANSE, D3COS and SafeCer.

These projects have an interest for their results to be taken up and be expanded. This shows the value and sustainability of the project results and avoids reinventing the wheel. For that reason, CRYSTAL has adopted parts of the MBAT and CESAR IOS and the corresponding approach. As some of the precursor projects had a specialized focus, CRYSTAL expanded this to the full scope of system engineering and the system life cycle. This means that not only the previous results are reused, but also that they are expanded.

The catalog of interoperable tools called the RTP was already started in MBAT and CESAR and is further developed in CRYSTAL and published with the Platform Builder. More and more tools have been adapted in CRYSTAL to expand the interoperable tool library. CESAR already selected OSLC as the key interoperability principle for the Interoperability Specification (IOS) which is elaborated in full in CRYSTAL. The critical mass that CRYSTAL provides helps to turn the IOS into a standard. With OSLC being adopted as a standard by OASIS and the IOS taken up by the CP-SETIS project, it has become clear who takes responsibility for the governance and sustainability of the standards.

### 6.9 Frequently asked questions

As the results of CRYSTAL are based on existing solutions, we would like to refer to external sources for questions about these solutions:

- **OSLC**:
  - [http://open-services.net/resources/](http://open-services.net/resources/)

- **FMI/Modelica**:
  - [https://www.fmi-standard.org/faq](https://www.fmi-standard.org/faq)
These FAQs will give more details about the added value of and issues with the specific CRYSTAL results.

### 6.9.1 Added value

**A. What is the advantage of building an OSLC/IOS adapter for my tool over other solutions to share data across tools?**

Various solutions that try to establish integration between multiple tools from different vendors have relied on each individual tool providing an API. These APIs make it possible for one tool to access data from another tool, however the API is often tied to specific choices in the (programming) technologies that are used. For a one-on-one integration this works fine, but when you strive for a web of tools which are exchangeable and replaceable you end up with a bunch of point-to-point integrations that are hardly manageable.

When using OSLC with IOS as its extension for integrating your tool chain, the data in your tools is linked to data in other tools, just as the internet is linked. After having built an adapter for each tool, no more copying or synchronization of data is necessary to share data. This adapter will not specifically be developed for integration with one specific other tool, but can be used for sharing data with every other tool that has implemented an OSLC/IOS adapter.

OSLC does not depend on any particular programming technology, and other technologies that are chosen are Web based, open and extensible (URLs, HTTP, RESTful protocols, RDF).

**B. What is the advantage of the IOS specifications over the specifications of OSLC?**

OSLC has developed specifications for a number of life cycle domains. Although these specifications offer a generic base, they are written to be minimalistic and to address only the most common scenarios. The semantics they express are quite low profile.

The IOS specifications are a result of consolidation of specifications from different industry domains. This has resulted in semantically richer specifications than those of OSLC, but which are still supported by a large and varied community. IOS also includes FMI, a standard for co-simulation and model exchange.

**C. What are the limitations of OSLC and does IOS solve these limitations?**

The specifications of OSLC are not enough to define complex business processes. They are however a very solid and practical basis for achieving interoperability in an engineering tool chain. Customers facing integration problems do not mind that OSLC is based on modern web based technologies, they just want their problems to be solved. Customers need support in developing a strategy how to establish integration. OSLC provides the technical capabilities to support these kinds of strategies, but it does not give further guidelines what for example the workflow should look like and which tools can help them in creating traceability. To solve some of these issues, CRYSTAL has come up with reference examples and specific examples of interoperable workflows which may help as input for an integration strategy.

### 6.9.2 What should I not expect from the IOS?

- The IOS is not meant for:
  - Real time processes like control systems (this holds for the OSLC parts of IOS. FMI is capable of dealing with real time processes and is also part of IOS).
  - Moving data in bulk like streaming data or exchange of large data sets.
o Defining tool sets or tool work flows. It is meant for enabling interoperability for a tool set defined elsewhere. The Platform Builder can give support in specifying the tool set and mapping this to IOS.

- Interoperability issues:
  o Tools may partially implement IOS domains. This means that if a tool claims to be compatible with a IOS domain, it is good to verify which artefacts of this domain are actually implemented.
  o Cross-company implementation takes special care. When implementing the IOS, local flavours of IOS are likely to arise. If you want to exchange with other companies on a regular basis, align IOS implementation approaches from the start, not afterwards.

- Issues with persistence:
  o For data retrieval after decades, such as for certification, IOS does not provide a solution for link maintenance, link integrity or accessibility of data after decades within a changing tool environment. Paper work is still the reference here.
  o IOS does not provide solutions for link integrity or longevity: it assumes that links are valid OAIIand available. In your implementation you can add additional measures for data confidence such as extra IDs. This is all custom work.

- Implementation issues:
  o In many implementations, the mapping of tool artefacts to IOS is ‘frozen’ in the compiled adapter. In such implementations, dynamic mapping of internal tool artefacts to IOS is not possible.
  o Queries for analytics are currently not supported by the IOS. Typically, these require complex queries across tools or departments. The OSLC queries do not suffice for this. Authentication and other security mechanisms may block this as well.

### 6.9.3 What tools are available for starting with IOS?

There are several tutorials and tool kits available to help you start with developing solutions with the IOS:

- OSLC offers a lot of materials to support you in starting developing with OSLC. These can also be used to start working with IOS.
  - Tutorials:
    - Primer: [http://open-services.net/resources/tutorials/oslc-primer/](http://open-services.net/resources/tutorials/oslc-primer/)
    - Getting started: [http://oslc.github.io/developing-oslc-applications/](http://oslc.github.io/developing-oslc-applications/)
    - Integrating products with OSLC: [http://open-services.net/resources/tutorials/integrating-products-with-oslc/](http://open-services.net/resources/tutorials/integrating-products-with-oslc/)
  - Toolkits:
    - OSLC4NET: an SDK and sample applications to help the .NET community to adopt OSLC and build OSLC-compliant tools ([http://oslc4net.codeplex.com/](http://oslc4net.codeplex.com/))
  - Sample applications:
    - OSLC offers several sample applications, for example a Bugzilla adapter and a fictional CRM system. ([http://open-services.net/resources/tutorials/integrating-products-with-oslc/](http://open-services.net/resources/tutorials/integrating-products-with-oslc/))
CRYSTAL offers multiple solutions that support you in how to deal with this IOS. The two most important solutions are the Platform builder and the Generalized engineering methods. The details of those two solutions can be found in the Introduction of this document.

### 6.9.4 How much effort does it take to implement the IOS?

A simple SurveyMonkey questionnaire was setup: https://nl.surveymonkey.com/r/LW7GFVP

10 questionnaires were submitted. 80 percent of the respondents built an adapter for the first time.

![Effort to create adapter (weeks)](image.png)

**Figure 9 – Effort required to create an IOS adapter**

#### Effort drivers

The question how much effort is involved in creating an adapter for your tool really depends on the kind of tool you are considering and what you want to achieve with the adapter. The following aspects are important (in rough order of decreasing impact):

- How open is your tool for interoperability? This depends on internal structure of data. The less open for interoperability, the more effort.
- How mature does the adapter need to be? The more mature, the more effort.
- Is this the first time you build an adapter? The less experience, the more effort.
- How fast should the data exchange via the adapter be? The faster, the more effort.
- How many IOS domains must the adapter support? The more IOS domains, the more effort.

Many of the activities that you must execute to implement the IOS are comparable with activities that you need to do to make data exchange with another tool possible. Below the effort that is needed to make a tool interoperable are specified. The ones that are specific for IOS are marked as *extra effort*. Time savings are marked with *effort saved*.

**Interoperability definition TRL 1-2: 2 – 12 weeks**

*The adapter has been specified in terms of IOS services and engineering method supported.*
The need for interoperability is identified and specified, a solution is chosen and a functional mapping from your own tool towards the chosen solution is established. A solution in this case is a particular interoperability implementation approach such as IOS, import/export, sockets, etc.

<table>
<thead>
<tr>
<th>Regular effort</th>
<th>Extra effort</th>
<th>Effort saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to define your local processes that use this tool's data or are affected by it</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding the user's workflow, requirements and business objectives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Need for interoperability for the tool identified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to define data artefacts involved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciding the scope of the interoperability solution</td>
<td>Deciding which IOS domains the solution could cover</td>
<td></td>
</tr>
<tr>
<td>Time to map existing artefacts onto artefacts of the chosen solution.</td>
<td></td>
<td>CRYSTAL offers examples how to do this mapping. It is only necessary to make this mapping once, not for each new tool you want to be interoperable with.</td>
</tr>
<tr>
<td>Getting to know the chosen solution (first time only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mapping engineering steps to functionalities of the chosen solution</td>
<td>Mapping engineering steps to IOS services using examples</td>
<td>CRYSTAL offers examples how to do this mapping. It is only necessary to make this mapping once, not for each new tool you want to be interoperable with.</td>
</tr>
</tbody>
</table>

**Interoperability prototyping TRL 3-5: 3 – 14 weeks**

*The interoperability solution has been prototyped, i.e. the required functionalities are available for evaluation. The solution has been integrated in System Engineering Environment, i.e. it is possible to execute the workflow.*

<table>
<thead>
<tr>
<th>Regular effort</th>
<th>Extra effort</th>
<th>Effort saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to install the development tool for the solution (first time only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Get to know the development tool for the solution (first time only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prototype level coding and testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establish a data provision connection between your tool and the solution</td>
<td>Time to create provider adapters</td>
<td>You now publish your data for all tools that wish to use it. So you have to do this only once for this tool</td>
</tr>
<tr>
<td>Establish a data consumption connection between your tool and the solution</td>
<td>Time to create consumer adapters</td>
<td>You can now read from any tool that publishes this type of data (this IOS-domain). So you have to do most of this only once and</td>
</tr>
</tbody>
</table>
Implementation at client TRL 6-9: 4 – 10 weeks

The interoperability solution has been used with relevant data. The solution has been seamlessly executed as part of the overall workflow applied on relevant data. The solution is distributed as a commercial or open source product.

<table>
<thead>
<tr>
<th>Regular effort</th>
<th>Extra effort</th>
<th>Effort saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapt functionality of the solution based on evaluation</td>
<td>Optional: adapting tool to make it more open for interoperability</td>
<td></td>
</tr>
<tr>
<td>Piloted in project</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration of solution in existing tool chain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User customization of the solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization implemented (client &amp; server side)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to switch to new solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final documentation of the solution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Most of this work you only have to do once for a tool. On changing requests for exchanging data, you may have to update this work.
7 Annex II – The CP-SETIS Project

In order to set up a sustainable organizational structure as a platform joining all stakeholders and to coordinate all IOS-related activities, especially the formal standardization and further extensions of the IOS, several CRYSTAL partners, including the coordinator, submitted together with stakeholders from other projects a proposal for an innovation action in the H2020-ICT-2014-1 call, called CP-SETIS (Towards Cyber-Physical Systems Engineering Tools Interoperability Standards). The CP-SETIS proposal is coordinated by SafeTrans, and the initiative has been driven by MBAT and CRYSTAL partners. This chapter gives an overview of the proposed Innovation Action.

The CP-SETIS project was accepted for funding and successfully started in March 2015. The CP-SETIS project is result of CRYSTAL (please note that also other project contributed to CP-SETIS) and is a substantial part of the CRYSTAL sustainability model.

7.1.1 Background & Motivation

Besides CRYSTAL, past and on-going EU research projects have initiated a momentum around a common vision for the Establishment of Recognized International Open Standards of Lifecycle Tool & Data Integration Platforms for CPS Engineering.

Related EU research projects in the past include:

- CESAR (59 partners) - Cost-efficient methods and processes for safety relevant embedded systems, an Artemis project,
- iFEST (21 partners) - industrial Framework for Embedded Systems Tools, an Artemis project,
- Sprint – Simplifying the Design of Complex Engineering Systems, an FP7 ICT project,
- MBAT (39 partners) – Combined Model-based Analysis and Testing of Embedded Systems, an Artemis project, and

Related EU research projects which are currently running include besides CRYSTAL:

- EMC2 (98 partners) - Embedded multi-core systems for mixed criticality applications in dynamic and changeable real-time environments, an Artemis project,
- EIT ICTLabs CPS IIE (5 partners) – Integrated Information Engineering

The current situation with respect to IOS (pre-) standardization is characterized by a wide variety of activities, which are only partly coordinated:

- There is a wide variety of projects running, which build upon and extend the IOS (MBAT, EMC2, DANSE, D3COS, HOLIDES). These projects are run by different consortia and have different objectives. Many of them are already doing or at least aiming at pre-standardization activities for the IOS. Although there are some initiatives from these projects, to establish bilateral harmonization of IOS pre-standardization activities in areas of overlap, these initiatives only cover part of the IOS and only few projects.

- New projects emerge that aim at interoperability solutions for development tools, where the consortia are not always aware of the existing IOS and its applicability for their project objectives.

- First attempts of formally standardizing parts of the IOS (for Lifecycle Interoperability, OSLC based) within OASIS have been started, but cover only part of the IOS.

- The commitment of major stakeholders to IOS activities is strong at project level, but not always on an inter-project or even company-wide level.

- Different groups, organizations, clusters and networks (like for example the ARTEMIS Working Groups on Standardization and on Tool Platforms, the ARTEMIS Center of Innovation Excellence EICOSE) have a high interest in and support both, activities for Interoperability of Development Tools as well as Standardization Activities, but still more commitment is required from all key stakeholders involved in IOS Activities.
On an inter-project level, this lack of coordination leads to ungovernable structures, un-coordinated and therefore potentially diverging activities, thus jeopardizing the huge investment in and the innovation potential of the IOS by endangering the chance of establishing a major standard in Cyber-Physical Systems engineering.

The CRYSTAL project partners are collaborating with other projects to overcome these deficiencies.

### 7.1.2 Challenges, Goals and Objectives

The two main challenges to be addressed by the CP-SETIS Innovation Action can be summarized as follows:

- **Challenge 1 (Organizational & Strategical):** A common vision and mission, shared by all major stakeholders, for supporting lifecycle data and tool interoperability for CPS Engineering has to be established urgently and acted upon. It is necessary to better align the only partial coordinated European IOS-related activities and paving the way for establishing the IOS as a major standard in CPS Engineering.

- **Challenge 2 (Technical):** A clear bridge has to be defined between the on-going definition of the IOS and other wide spread Interoperability and Engineering Standards commonly used by European developing organizations (e.g., ASAM⁴, FMI⁵, AUTOSAR⁶, STEP⁷, OMG ReqIF⁸, etc.) for supporting CPS Engineering activities.

In order to tackle these issues, CP-SETIS is articulated by the following goals and objectives:

- **Goal 1:** The alignment of all IOS-related forces within Europe to support a common IOS Standardization Strategy, aiming at a formal standardization process of the IOS.

- **Goal 2:** The definition and implementation of sustainable IOS Standardization Activities supporting both, formal standardization of ‘stable’ IOS versions as well as extensions of IOS, if possible within existing structures that survive the lifespan of single projects.

From these goals, the following objectives were derived:

- **Objective 1:** To build-up a consensus across key stakeholders (i.e., end-users organizations, tool providers, research organizations) and projects on a common IOS Standardization Strategy.

- **Objective 2:** To define a concrete model for sustainable IOS Standardization Activities (activities, processes, roles, responsibilities, interactions with projects, end-users, tool providers and relevant standardization bodies).

- **Objective 3:** To support implementation of sustainable IOS Standardization Activities within sustainable structures having a far longer lifespan than a single project (for example: existing ARTEMIS-IA structures¹⁰, i.e., the Tool Platform Working Group, the Standardization Working Group, the EICOSE Center of Innovation Excellence, etc.).

- **Objective 4:** To get commitment from key stakeholders for supporting common IOS Standardization Strategy and its implementation (firstly from key end-users and projects, ARTEMIS-IA, secondly from key tool & technology providers).

- **Objective 5:** To generalize findings of IOS Standardization Activities to update then ARTEMIS/PROSE Strategic Agenda for Standardization and to support further Standardization Activities within ARTEMIS/ECSEL.

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⁴ Association for Standardisation of Automation and Measuring Systems, [http://asam.net](http://asam.net)

⁵ Functional Mockup Interface for model exchange and tool coupling, [https://www.fmi-standard.org](https://www.fmi-standard.org)

⁶ AUTomotive Open System Architecture, [http://autosar.org](http://autosar.org)

⁷ STEP – standing for “Standard for the Exchange of Product model data” is the informal name used for the ISO 10303 standard for the computer-interpretable representation and exchange of product manufacturing information.

7.1.3 Overall approach and methodology

CP-SETIS is set in two phases: During the first year, a first phase for shaping and implementing a concrete model (in terms of activities, processes, roles, responsibilities, interactions with projects, end users, tool providers and relevant standardization bodies) for Sustainable IOS Standardization activities on the existing ARTEMIS-IA structures will be defined and harmonized between all stakeholders. In the second year, this concrete model will be deployed (‘implemented’), using existing sustainable structures, if possible, particularly taking into account ARTEMIS structures. In addition, the second year is used to expand the numbers of participants beyond our core/associate partners, to get a broad commitment from all stakeholders involved in sustainable IOS activities.

CP-SETIS consists of the following work packages:

- WP1 sets out to define a concrete model for sustainable IOS Standardization Activities and support its implementation (Objectives O2, O3)
- WP2 will be the link to the R&D projects. It will identify the key issues to be addressed for supporting IOS Sustainability (input to WP1) and serve as interface to IOS-related projects for providing them support and collect IOS Success Stories to be disseminated at a large scale for promoting our shared IOS Vision & Mission (WP6). WP2 will thus fulfil Objective O2.
- WP3 will be the link to the key stakeholders in the IOS. It will identify these key stakeholders and get their commitments regarding sustainable open interoperability specification (Objective O4). As such, it also will provide input to the model definition in WP1, as well as being the interface to these key stakeholders when assessing the potential hosts for the implementation of the model.
- WP4 serves as the interface to the Standardization Bodies. Its overall goal is to define a roadmap for establishing the IOS as a formal standard, thus contributing to Objective O1 and O5. The roadmap will contain identified IOS pre-standards and it is again an input to the model definition in WP1. It also serves as the basis for the concrete actions that have to be undergone for the standardization of the IOS by the main stakeholders, coordinated by the hosting structure(s) identified in WP1 as a host for the coordination model.
- As mentioned above, formal standardization of the IOS could serve as an excellent role model for further standardization activities within Europe. Thus, lessons learned from this undertaking should be collected and influence current Standardization Roadmaps. This is the objective of WP5, which will in particular create a CPS Standardization Strategic Research Agenda (SRA) based upon previous Standardization SRAs and incorporating the lessons learned from the definition and implementation of the IOS model for sustainable standardization activities. These activities will contribute to Objective O5. WP5 will support WP1 and WP4 and vice versa. The SRA will be printed finally by WP 6.
- WP6, finally, deals with communication, dissemination and exploitation of project results. It will elaborate a Communication, Dissemination and Exploitation Strategy and Policy and implement it, linking both, to standardization bodies such as ASAM, OASIS and others, to ensure proper communication between them and all partners and linking with the international scientific community.
CP-SETIS: Structure and Work Packages (A proposal for an Innovation Action which was submitted by several CRYSTAL partners together with stakeholders from other related research projects)