27th Annual INCOSE International Symposium (IS 2017)
Adelaide, Australia, July 15-20, 2017

An industrial example of using Enterprise Architecture to speed up systems development

Peter Sjöberg
Volvo Construction Equipment
TCA11, SE-631 85 Eskilstuna
Sweden
+46 73 765 63 87
peter.t.sjoberg@volvo.com

Lars-Olof Kihlström
Syntell AB
P.O. Box 100 22, SE10055 Stockholm, Sweden
+46 706 661978
lars-olof.kihlstrom@syntell.se

Matthew Hause
PTC
Engineering Fellow
Round Rock, Texas, USA
+1 917 514 7581
mhause@ptc.com

Abstract. The development of large, complex, heavy construction equipment can be difficult, time consuming and expensive, even more so if the goal is to design a complete site solution. The example used is taken from an ongoing real project named Electric site. The aim is to electrify a transport stage in a quarry – from excavation to primary crushing and transport to secondary crushing. This will reduce the CO_2 95% and the total cost of operation 25%. This paper describes how a standards-based enterprise architecture model can be used to significantly influence continued system engineering efforts as well as the software architecture for the application development. The enterprise architecture model has been developed specifically to ensure overall management of the site. It is this description, created with an enterprise perspective of the site that is used directly to speed up the development of the systems architecture. The model also details the applications that are required as part of the different systems that will support the overall management of the site.

Introduction

Enterprise architecture models have been seen as something with only a peripheral connection to actual system development. At best, they have been used to influence decision making as to changes in processes or systems that an enterprise makes use of. The development of these changes has then been carried out as separate developments with little or no connection to the enterprise architecture model. The Unified Architecture Framework (UAF) has made it possible for a model to directly influence the systems development. The fact that UAF is based on the Systems Modeling Language (SysML) is an essential enabler. The approach to the creation of the model is also critical. UAF based enterprise architecture modelling allows the patterns established during the enterprise architecture model development to be reused directly as part of the systems development in the SysML model. This directly guides the systems development effort in the areas that the enterprise architecture model has been focused on.

The key benefits that can be derived from this approach are:

- The ability to make use of the enterprise architecture model as a short-cut to detailed systems development, resulting in shorter development time.
- Even if systems development is performed by another party, the existence of the model and the software architecture will enable the customer an unprecedented level of control of the system as it is development.

Electric Site

Electric Site is a research project between Volvo CE (Construction Equipment), Skanska and Swedish Energy Agency with involvement from Mälardalen University and Linköping University. This research project within Volvo CE has the goal: “For 10 weeks, in autumn 2018, we will demonstrate the electric site concept with our key account customer Skanska Sweden at one of their sites in western Sweden. The system is safe, productive, environmentally friendly and commercially viable. It is the solution for the sustainable quarry and aggregate industry.” The aim is to electrify a transport stage in a quarry – from excavation to primary crushing and transport to secondary crushing. This will reduce CO_2 95% and the total cost of operation by 25%. The concept as presented here is based upon “needfinding” (Yang Yang et al, 2016) that has been documented as user focused ConOps. This has provided the main input for the model.

Present Operation of Quarries

The operation of quarries has not changed much during the last century. They look roughly the same all over the world. You transport the blasted rock to the crusher(s) or, as in this case, you have a primary crusher at the blast site and then transport to the secondary crusher. What has changed during the decades are the machines: better fuel efficiency, higher productivity etc. The site of today can be regarded as something between an acknowledged system-of-systems and a collaborative system-of-systems (Jakob Axelsson, 2015). In the present set up at the intended site, Skanska is working two shifts since the production capability is higher for the secondary crusher. In the morning operation [Figure 1] the crushed material is loaded into the rigid dump truck by the wheel loader. The material is taken from the stockpile created during the previous afternoon shift, and from the small stockpile at the primary crusher.

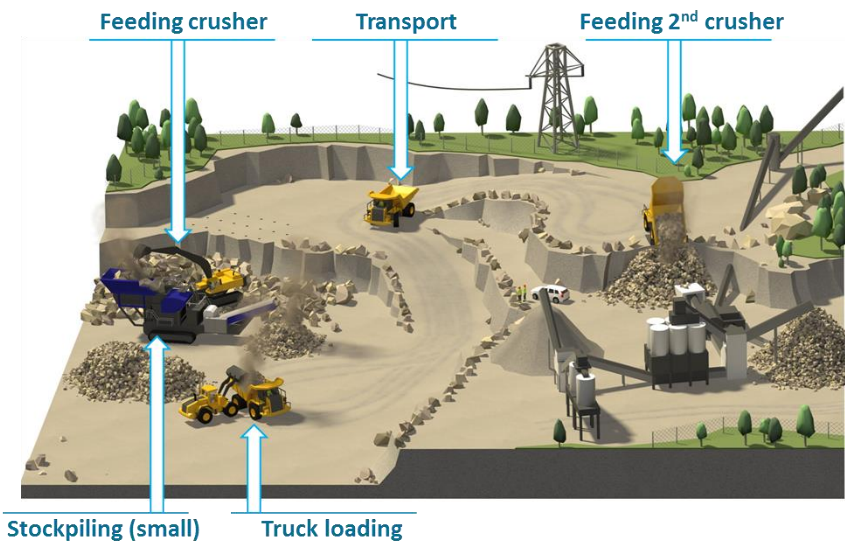

Figure 1. Present, Morning operation

During the afternoon shift [Figure 2] the rigid dump trucks are parked and all material is moved to a larger stockpile close to the primary crusher. This larger stockpile also works as a buffer in the next day's morning operation.

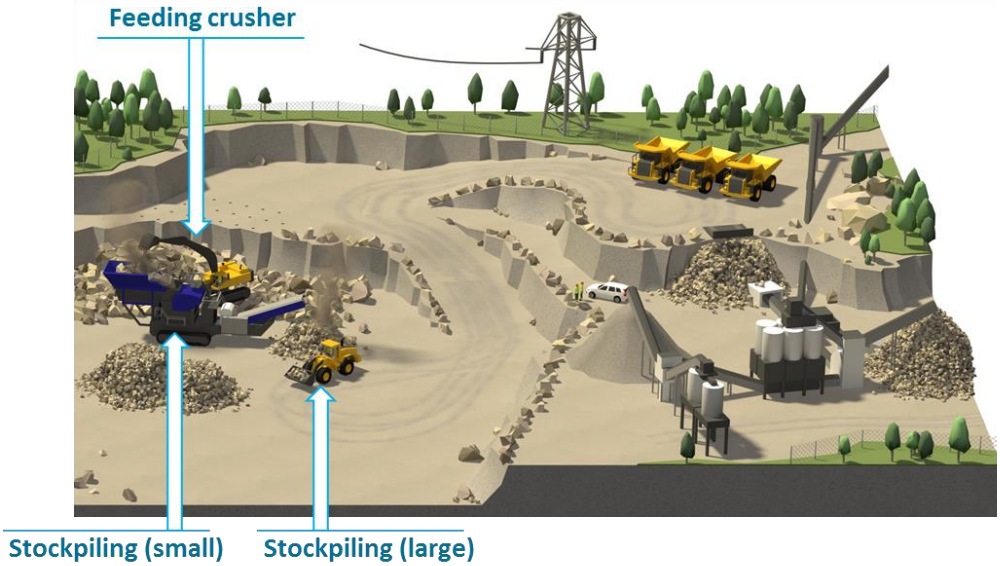

Figure 2. Present set up, Afternoon operation

Electric Demonstrator Operation

Setting up a site from the start makes it easier since one is starting from a blank sheet of paper. Skanska and Volvo decided to take a process approach to the operation set up, moving to a directed System-of-Systems (Jakob Axelsson, 2015). When using an electric energy source, one can divide the machines into two groups: those that can be regarded as more or less stationary during a cycle and those that move material longer distances or need to be versatile. The first group consists of the primary crusher and the excavator. The second is the dump truck and the wheel loader. The first is suitable to be supplied by electric cable connected direct to the grid. The second one requires energy storage since a cable will not be practical.

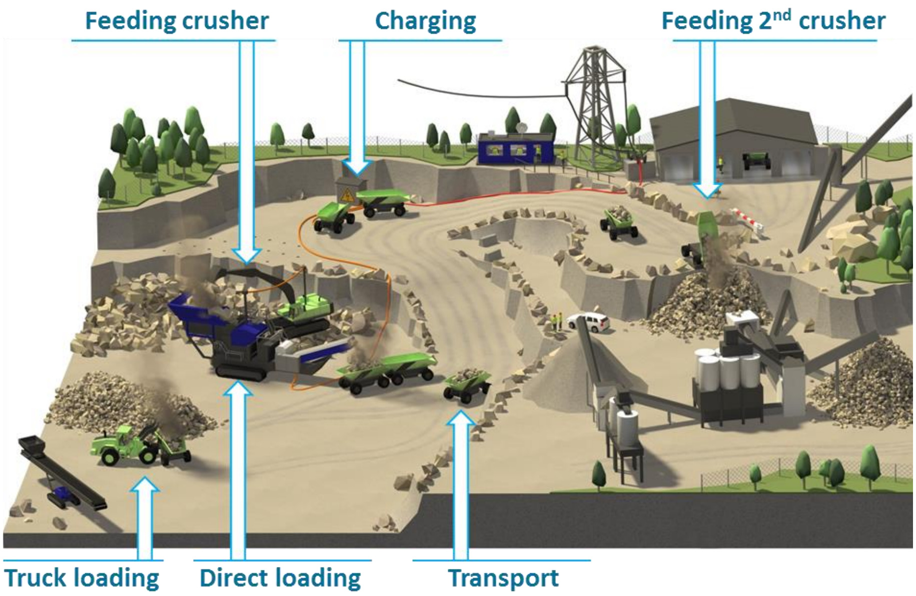

Figure 3. Demonstration set up, Morning operation

To replace diesel engines with electric engines and batteries would require a battery package of 15 tons for a 50-ton truck. Another solution is to make the haulers smaller, (15 tons) and have more machines to reach the productivity target. That solution is more suitable given the battery performance of today and regarding the robustness of the total solution. It also scales better. However, going from 2 to approximately 6 machines increases the workforce cost for the operation unless you make the haulers autonomous. The need for the wheel loader to be able to perform several different tasks that change from shift to shift will not make a pure electric solution suitable. A hybrid, diesel electric solution called LX with a battery and a diesel tank for energy storage will be used. In the morning operation [Figure 3], the autonomous haulers will be directly loaded by the crusher and by the LX that takes materials from the pile created during the previous afternoon shift. In the afternoon shift, there will now be an electrical driven conveyor belt creating the pile. This will free one wheel-operator from this part of the quarry and further reduce the CO_2 emissions [Figure 4].

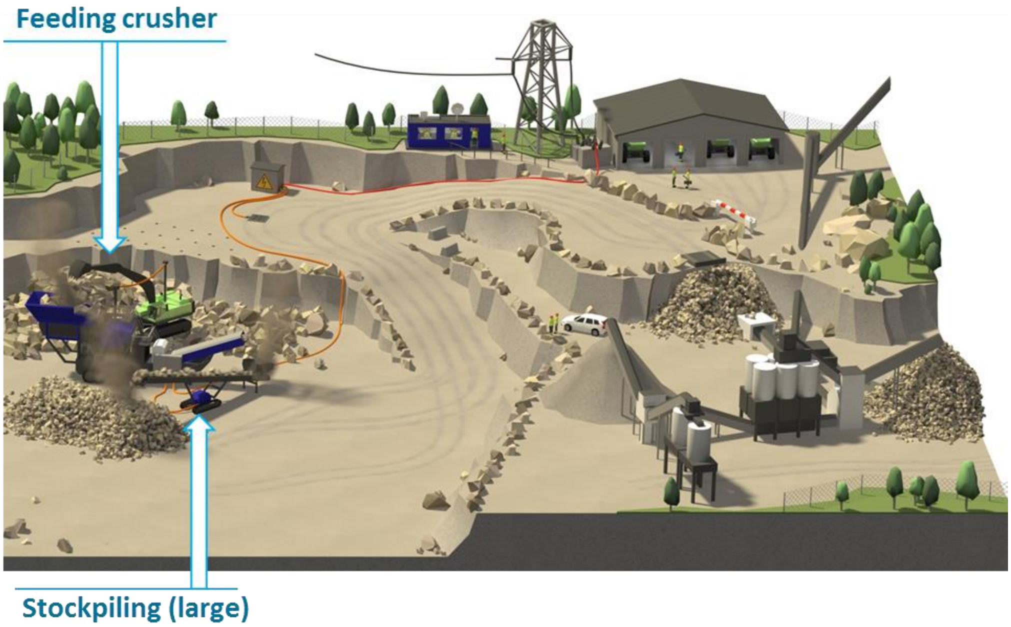

Figure 4. Demonstration set up, Afternoon operation, using an electrical driven conveyor belt instead of a wheel loader to create the large stockpile

Unified Architecture Framework (UAF) 1.0

ISO/IEC/IEEE 42010:2011 defines architecture as the “fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution.” (IEEE, 2011) US Federal Enterprise Architecture Framework (FEAF, 1999) states “Enterprise architecture is a management practice to maximize the contribution of an agency’s resources, IT investments, and system development activities to achieve its performance goals. Architecture describes clear relationships from strategic goals and objectives through investments to measurable performance improvements for the entire enterprise or a portion (or segment) of the enterprise”.

The UAF combines the Department of Defense (DoD) Architecture Framework (DoDAF) and the Ministry of Defence (MOD) Architecture Framework (MODAF). Military Architectural Frameworks such as DoDAF define a standard way to organize an enterprise architecture (EA) or systems architecture into complementary and consistent views. DoDAF originally contained four basic views: the overarching All Views (AV), Operational View (OV), Systems View (SV), and the Technical Standards View (StV/TV). MODAF v1.0 added the Strategic (DoDAF Capability) and Acquisition (DoDAF Project) Viewpoints. In MODAF v1.2, Service views were added to support the development of Service Oriented Architectures (SOA). Although they were originally created for military systems, they are commonly used by the private, public and voluntary sectors around the world, and public services such as the Federal Emergency Management Agency (FEMA). Their goal is to improve planning, organization, procurement and management of these complex organizations.

The Evolution of UAF

The Systems Modeling Language (SysML) was used as an underlying mechanism for UAF. SysML includes concepts such as enhanced interface and flow specifications, system concepts, parametrics, integrated requirements and others. UAF inherits these concepts providing additional systems engineering capabilities as well as a mechanism for traceability to SysML implementation models. The final draft of UAF was submitted in June 2016. The model in this paper was created using PTC Integrity Modeler, a standards based modelling tool that supports UAF, SysML, UML and other modelling languages. Simulation of the model is possible, but has not been done at this stage.

The Modeling Approach

For any project that makes use of modelling it is important to provide answers to a set of questions to ensure that the model provides the expected benefit.

- **What is the purpose of the project and the model?**
  The answer to this question varies between projects. If the purpose is a development of a product the answer involves the handling of stakeholder requirements and the need to ensure that the model describes the product in a consistent and coherent manner. In the case of Electric site, rather than individual detailed product development, the intent is a description of a specific system of systems development. The key question here is how the different elements can be controlled and supervised to achieve a safe and productive handling of the quarry. Given the drastic functionality increase that any new product development needs to deal with, even strict product developments will need to consider the context in which the product is to operate (Yang Yang et al 2016).
- **What are the constraints that need to be considered?**
  A constraint may be systems that a product needs to interact with that cannot be influenced by the development. It can also be strategic decisions that have been taken regarding the system development. It is also quite common that product developments have reference architectures or common platform elements that must be used. In the case of electric site, the constraints concern a set of known resources that must be dealt with (the materiel) as well as the use of existing machines and the need to add functionality to achieve the desired site handling.
- **How should the model be structured?**
  A concrete system development project may well be structured based on the use of SysML directly. In the case of electric site, an enterprise based structure is more appropriate and the concepts within UAF 1.0 have been used. UAF distinguishes between operational and resource based parts of the model. This is made use of in the model dealing with electric site to distinguish between a model that deals with the logic of the site handling, i.e. a non-implementation approach and the parts that deal with the actual implementation. This means that while only a single logical description of the site is required, there may be several different approaches to the realization.

Electric site capabilities

In order to tie the model to various strategic decision and stakeholder requirements for electric site a useful approach is to consider the strategic capabilities. Figure 5 shows the capabilities that describe the strategic capabilities of the electric site.

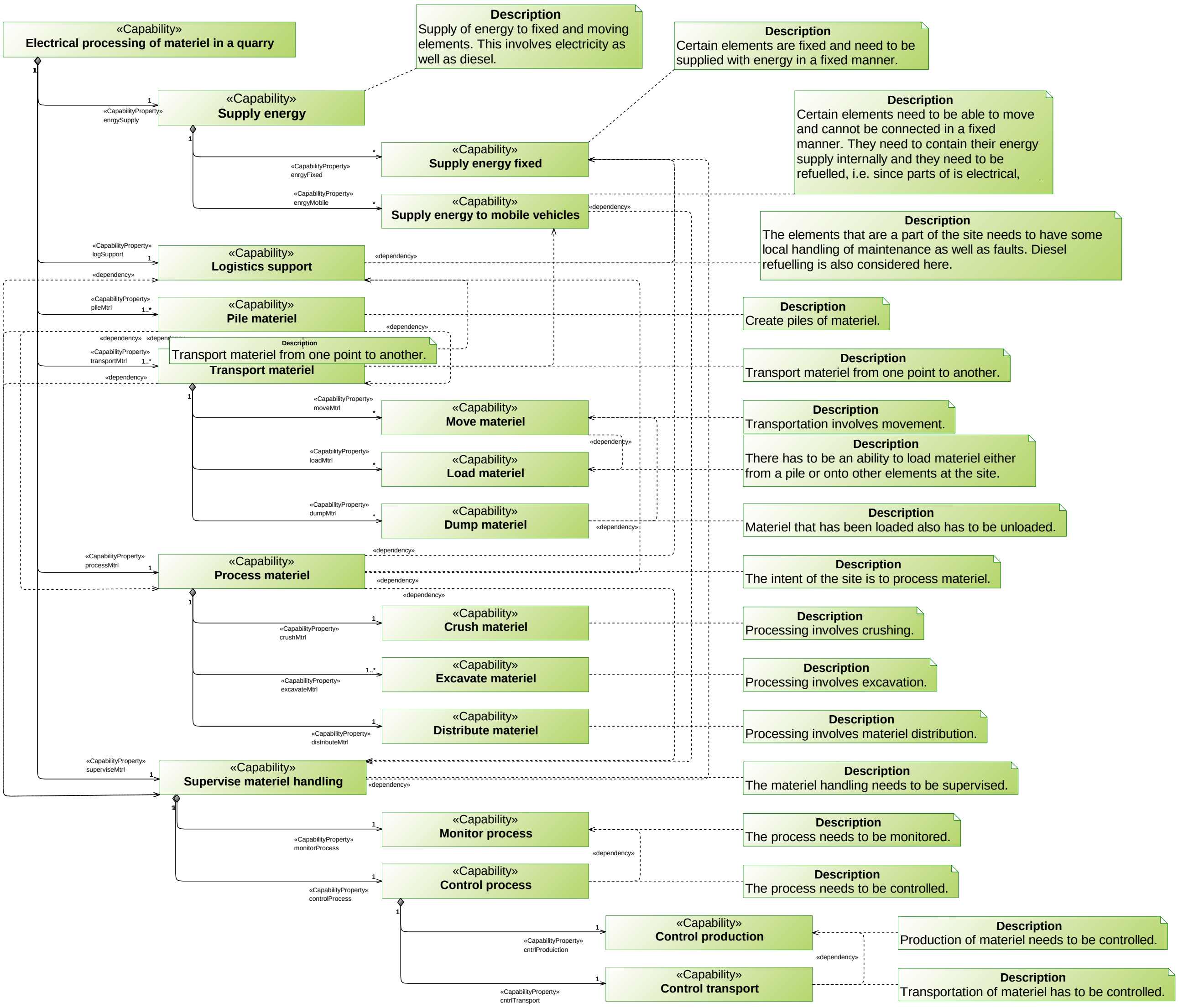

Figure 5: Electric site capabilities

The Electric site logical model

The intent of the logical model is to describe the overall behaviour of the electric site by a set interacting systems and known resources. This describes how all of the systems should work together from a logical point of view by discarding any form of detailed implementation issues. The logical model can be visualized as looking at the site from above to describe the visible behaviour when the site is in operation. The key here is the intent and purpose of the different elements as well as the information structures that determine their behaviour. As described previously, the site elements are essentially determined from the start. The added functionality required to ensure that the site operates as it should, is not. As an example the development of a wheel loader may have a predetermined component in the form of a hydraulic pump. This pump has a logical purpose and is expected to provide a certain capability governed by various parameters. This purpose can be described without any need to consider how it is implemented. (A processor somewhere that contains software that deals with the pump itself). The logical model for the electric site can be seen in Figure 6.

Within an operational model, UAF employs three different concepts:

- Operational architecture:
  The basic container of the operational elements.
- Known resource:
  An element that needs to be present and interacted with but is considered outside of the trade-space.
- Operational performer:
  An element inside the trade-space realizing the goals of the architecture model.

The logical model contains a logical architecture and a set of parts (block properties that are stereotyped as operational roles based on a UAF stereotype). These roles are briefly described below and are subdivided into a set of known resources and a set of operational performers.

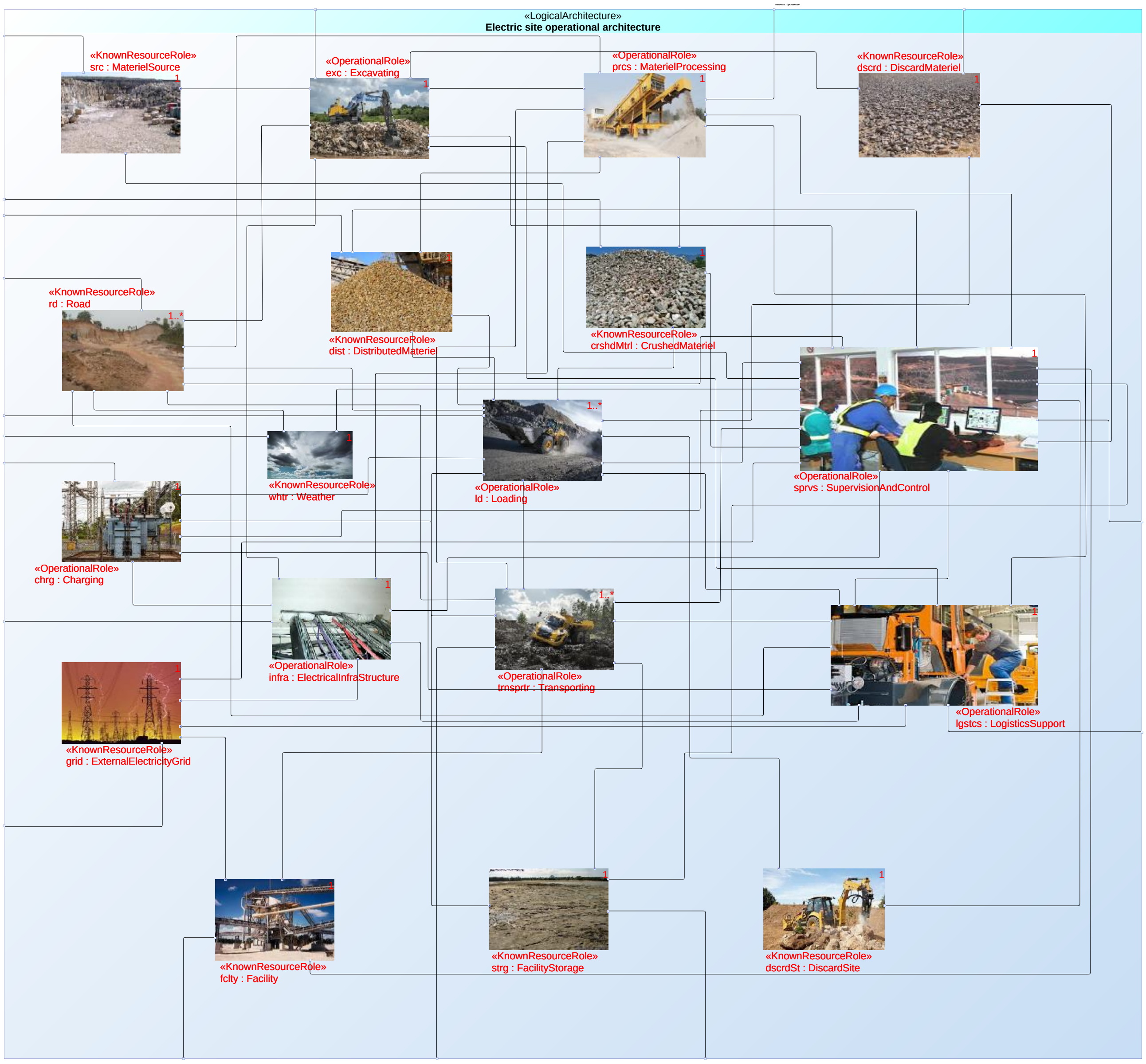

Figure 6. The logical architecture for the Electric site

Electric site elements

Known resources in the logical model:

- Crushed materiel:

The initial processing can happen in either one or two ways. This implies that there is no ability to spread the crushed materiel. Instead the crushed materiel turns up directly associated with the crushing process. This imposes a special limit of the maximum volume that cannot be exceeded without impairing operations.

- Discard materiel:
  The place where materiel unsuitable for crushing is placed.
- Discard site:
  This is where discarded materiel needs to be placed to make it available for further processing. Note that this is not the same as Discard materiel and that materiel placed there needs to be transported to get to this site.
- Distributed materiel:
  There is a possibility that when materiel has been crushed, distribution to a larger area may occur and this implies that the volume limitation is different.
- External electricity grid:
  A connection to an external supplier of electricity is required and this element is a representation of the external grid.
- Facility:
  This element acts as the receiver of the crushed materiel and is essentially a materiel sink. Materiel stored there is consumed at a given rate.
- Facility storage:
  The Facility element has a limited capacity and can be filled up. This element acts as a temporary storage while waiting for facility capacity to become available.
- Materiel source:
  The source of the materiel to be excavated.
- Road:
  The site contains different roads that lead to different facilities. Any form of management of the overall site performance requires handling of roads. It is therefore crucial to determine the kind of information that the overall site needs to have relating to the roads. Also note that the use of roads is dynamic both in the sense of different elements travelling on them and the fact that roads can be blocked by model elements that fail and that roads themselves may fail. An example of a possible road structure can be seen in Figure 7. Note that this is just an example; the information structure needs to be able to deal with any kind of road network throughout the site.

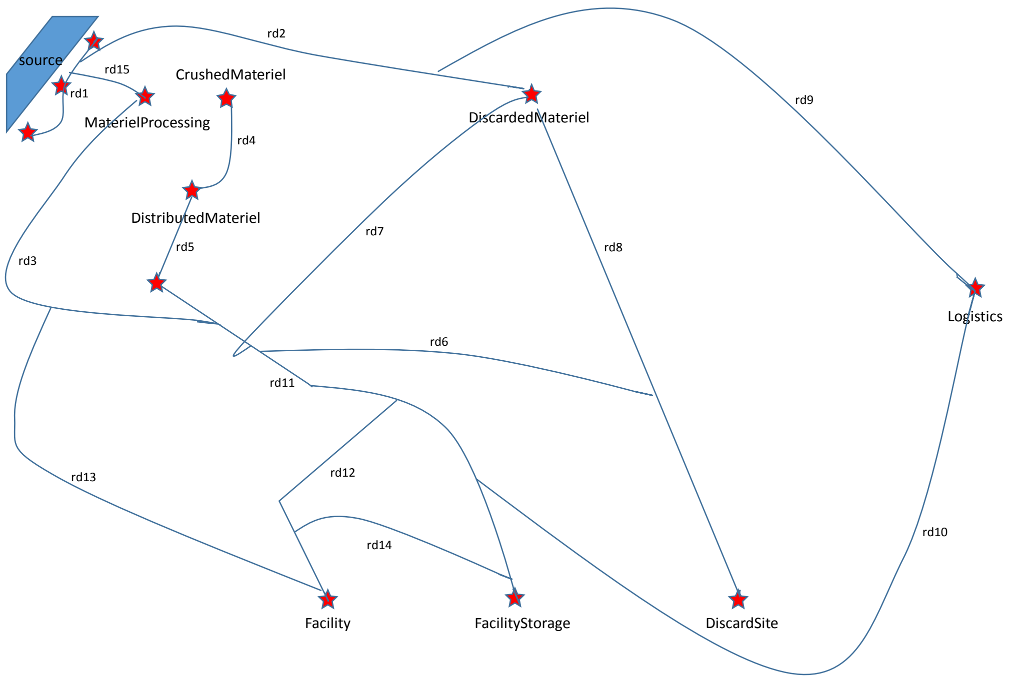

Figure 7. A possible road structure for a site

Operational performers in the logical model:

- Charging:
  The elements that move will require charging to replenish their energy storage. Typical information here is the number of simultaneous charging ports as well as the rate at which charging can be performed.
- Electrical infrastructure:
  There are elements that have a fixed connection. Electricity distribution to these elements needs to be considered. It should be noted that this connection may fail.
- Excavating:
  The element responsible for retrieving source materiel and feeding it to either materiel processing or discard materiel. Information here is concerned with the weight in each load and the time it takes to load and unload materiel.
- Loading:
  Materiel and discard materiel needs to be picked up and unloaded. The information required here is concerned with speed, acceleration, braking, maximum load etc.
- Logistics support:
  Logistics handling is not inside the trade-space but there are still elements from a site control and supervision point of view. This information is concerned with the possible parallel handling, the time it takes to get to and from a remote maintenance location and the amount of time each team needs to spend to perform a task. Logistics support concerns diesel fuel supply and refuelling for elements that require it.
- Materiel processing:
  Materiel processing involves materiel crushing as well as distribution of the crushed materiel. The information needed is concerned with rates of handling as well as timing.
- Supervision and control:
  The site needs to be managed to ensure that the required capabilities are handled.
- Transporting:

Materiel needs to be transported and unloaded. The information here is similar to that of the Loading element. The distinction here is that this element cannot pick up materiel from the ground.

Handling of interfaces. The information flow within the logical model and the information structure within the model is crucial to create a model that can be used for analysis of changes as well as decision making. The model is based on the use of SysML which means that all ports shown for the logical model are defined and typed by the UAF element operational interface (a stereotype based on the use of the SysML element InterfaceBlock). An example of the definition included in the model can be seen in Figure 8. The first of these interfaces deals with the interactions between charging and a transporting element and involves requests, acknowledgements, disconnections as well as queueing. There may be more elements requesting charging than there are available charging locations at Charging. The latter of these interfaces details the interactions between supervision and control and Charging. A crucial interaction here is the response of the element to a status request since it is the status of the elements that supervision and control uses to manage the site.

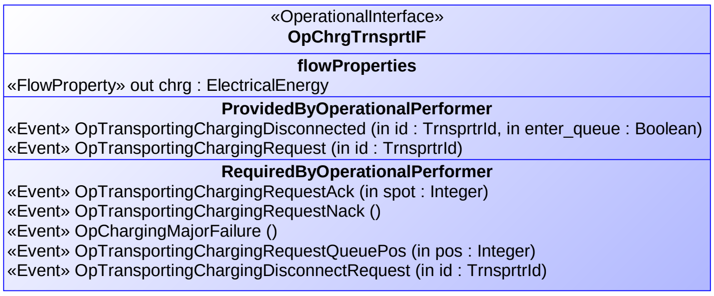

Figure 8. The interface between Transporting and Charging

Handling of information. One of the primary goals of the logical model is to define the information structures that different elements need in order to perform their work. Some information changes dynamically as the element operates. Other information is configuration data that does not change once it has been determined. In order to keep track of each type of information each element has a special interface that originates from the border of the operational architecture. The interfaces defined for these elements list the set of attributes for the element that are essentially static, i.e. where the values do not change as operation of the site progresses. An example of attributes within an element as well as the interface from the operational architecture border can be seen in Figure 9.

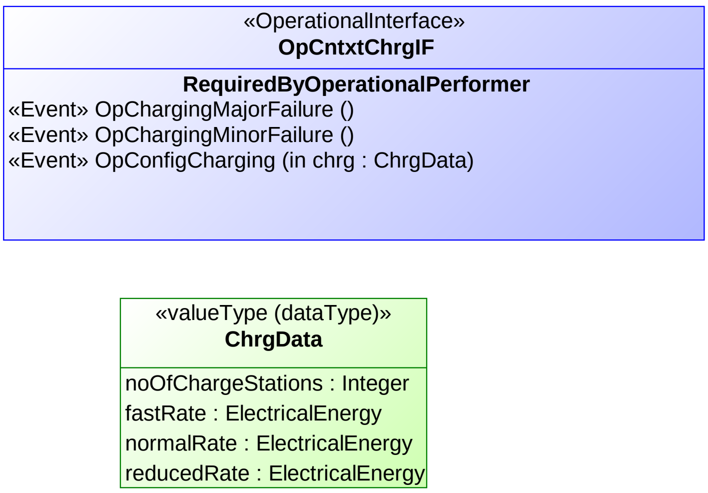

Figure 9. The interface between supervision and control and charging

Events indicate whether a major (no charging possible) or minor error has occurred. This needs to be issued to a logical model from the outside and makes it possible to explore the model how different kinds of errors are to be handled.

Handling of behaviour. In order to reach a level where decisions regarding effects can be made the behaviour of the elements also needs to be considered. In this model this is done by means of state machines. An example of a state machine for an element can be found in Figure 10. The use of state machines for all of the elements in the logical model makes it possible to describe the behaviour of the complete site based on the different flows of information that are communicated in between the elements. The states can be modified based on:

- Triggers defined by events.
- Triggers based on timers.
- Triggers based on changes in attribute values.
- Guards that make it possible to behave differently based on the same trigger if conditions are different.

The bluish text shown below represent behaviour that defines actions to be taken either while remaining in a given state (internal transitions) or with transitions between states. The combination of element attributes, states that describe a specific logical condition of the element and triggers make it possible to be extremely specific about the required behaviour. It also adds clarity and consistency to the model. This is what makes it possible to perform reasoning based on the model. As an example the first version of this model made the assumption that the excavation element had to travel from its excavating position to the place where the discarded materiel should be placed as well as to the materiel processing element. It was determined that this was not always required if the two elements in question were positioned close enough to the excavation position. Dealing with this change and logically describing this consistently within the model required no more than 15 minutes of consideration and model update.

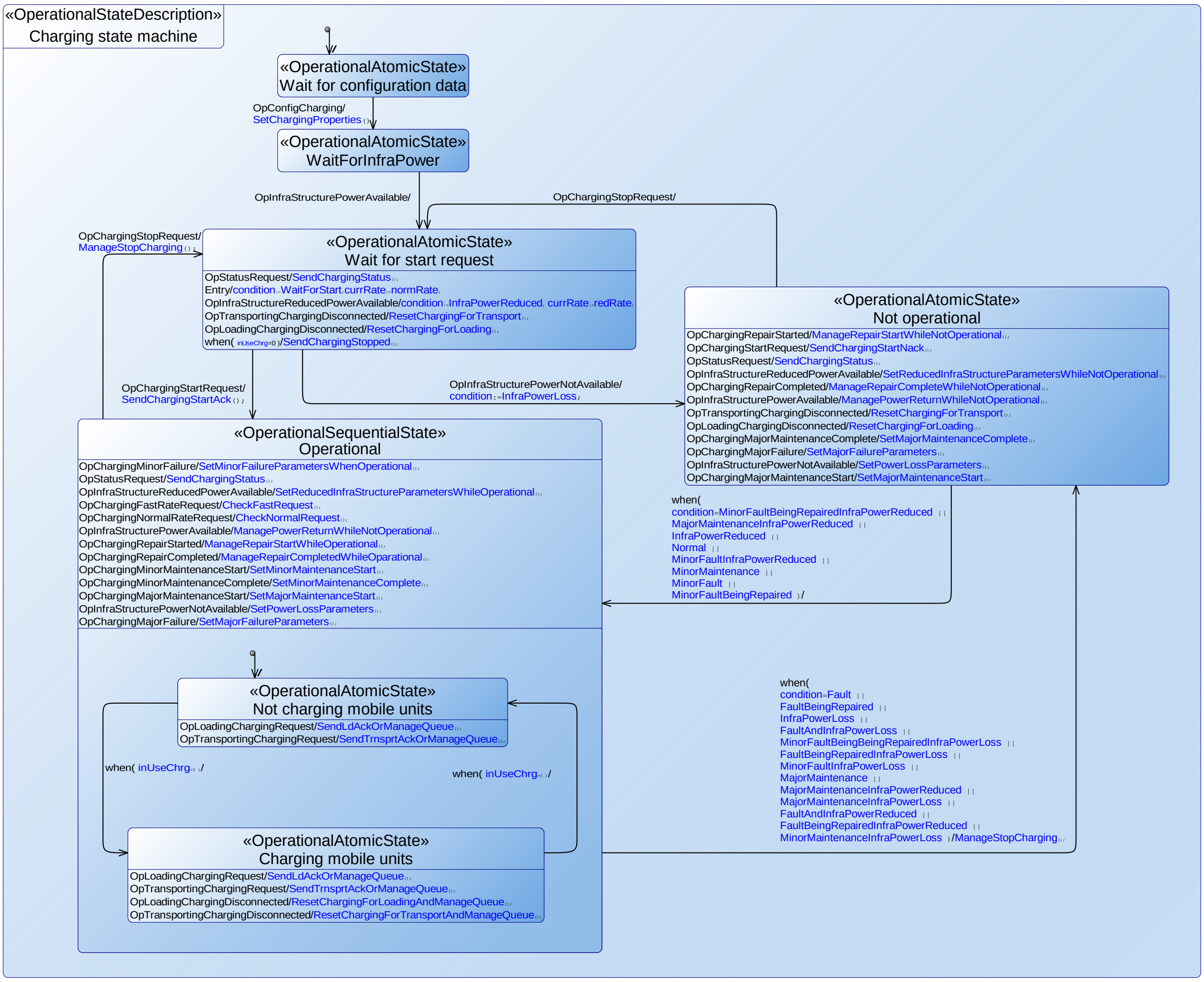

Figure 10. A state machine example

Fundamentally, the selection of viewpoint within the logical model is fundamental to being able to look at the complete enterprise logically. The model is an abstraction at an appropriate level for managing the quarry enterprise by always keeping in mind that the modeler is outside looking in. This enables the modeler to avoid missing the forest due to all the trees that are blocking the view (old Swedish expression).

The Electric site systems architecture

The systems architecture is a representation of the implemented quarry. This is not a logical model any longer but an attempt at a concrete representation of actual machines operating in a quarry. The representation of this model can be seen in Figure 11.

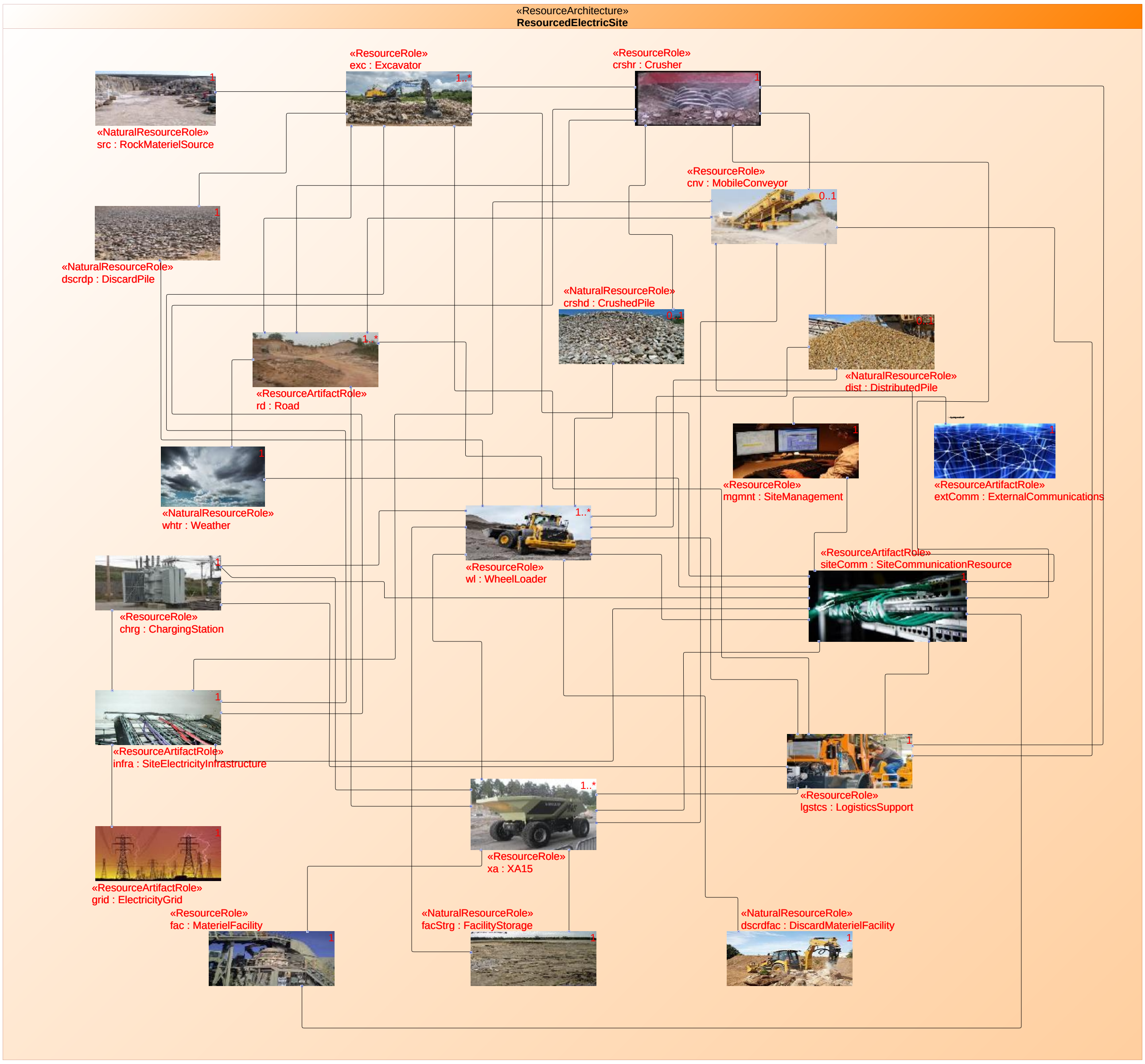

Figure 11. Systems architecture overview

This model looks almost completely the same as the logical one. There are differences however and these are discussed below. In the resources part of the model UAF uses a number of concepts that need a quick explanation prior to discussing these differences. Some of the basic concepts from the UAF realization model are:

- Resource architecture:
  A container element for a set of different interacting resources that can be further specialised, for example Capability configuration and System.
- Natural resource:
  An element type intended to describe natural resources such as a field of grass or a hill.
- Resource artefact:
  An element type used to describe artefacts that are manufactured. Artefacts can contain other artefacts but not organisational resources. If an element needs to contain an organisational resource it becomes a system or a capability configuration. It can be further specialised as technology or Software.
- *Organisational resource*:
  This is an abstract element that can be further specialised as an Organisation, Post, Person or Responsibility.

Differences between the system architecture and the logical architecture

As stated, the system architecture looks similar to the logical architecture. This should however not be a complete surprise, since the use of the different kinds of elements was a requirement from the start. When starting to scratch the surface of the system architecture the differences will start to appear. The following differences are directly visible.

- There are no connectors tying the internal elements to the system architecture border. Attributes that are constant throughout the operation is of less importance here.
- A closer look at the interfaces shows that there are no events inside the interfaces. The interfaces use flow properties that act as place holders for the implementation of communication within the site. The elements that are equivalents of the formerly known resources interact based on physical characteristics rather than by means of events. (Clearly, a road sends no information cannot be queried for status unless complemented with sensors, traffic lights etc. An implementation model could be built where this is done. In this case this has not been assumed).
- Indeed, some elements that had no counterpart in the logical model have appeared. All communications now rely on the site communications resource as an example. Materiel processing has been split into the Crusher and the Mobile conveyor.
- While all of the elements could be further broken down into minute details it needs to be remembered that the key question that needs to be answered deals with the overall management of the site. This means that the intent of the model is not to describe the details of the implementation of say the wheel loader. Instead the intent is to describe the design of functionality within the wheel loader that is needed in order to ensure that the site as a whole can be handled. The element that will be dealt with to a very high degree is the supervision and control element that turns up inside the system architecture as the Site management element.

Scratching the surface further. Based on the key question that needs to be answered a more detailed architecture can be defined. Examples of this architecture can be seen in Figure 12.

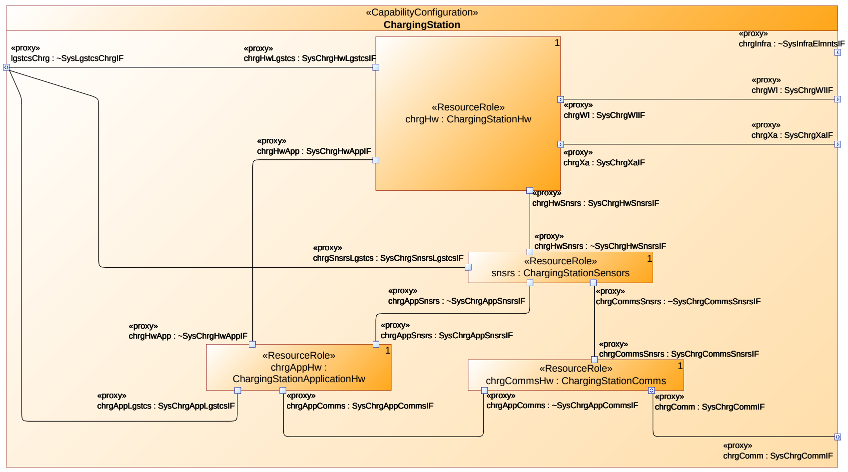

Figure 12. An example of the internal parts of the charging station

The system architecture for the charging station is shown in Figure 12. It has been qualified by the key question that the architecture is interested in answering. The approach taken here is applicable to many elements in the realization model. Three of the parts above are therefore considered as black boxes, only of interest as far as their interfaces are concerned (Charging Station Hw, Charging Station Sensors, Charging Station Comms). One part needs to be considered in more detail, namely the ChargingStationApplicationHw. The architecture has been defined such that this is where the functionality resides that deals with the element and its behaviour from a site perspective. The interfaces between this element and the sensors part, the communications part and the charging station are of crucial importance. The interface from logistics is, as far as the application part is concerned, assumed to deal with lower level handling such as software upgrades etc. and has for now (in spite of its importance) been ignored. From an overall perspective it could be argued that the element should have a local HMI as well as a means of monitoring the operation locally. This has not been added at this point.

Application software architecture

When taking a look at the required architecture for the site based software application within the ChargingStationApplicationHw and the SiteManagementHw, a few conclusions can be drawn. The connection between the logical model element (Figure 6) and the software architecture in Figure 13 for the same example element may not be clear. A more detailed look will reveal that most of the elements contained in the software architecture are representations of the same element and all the elements that the equivalent logical element connects to in the logical model. There are a few additional elements in the form of adaptors that deal with input from communications, sensors as well as hardware. The connection goes further however. The site based behaviour (the purpose of this part of the software) can reuse quite a bit of the logic contained in the logical model. Furthermore, the state machines made use of in the logical model acts as patterns for similar handling of behaviour within this application. The logic is similar, but the implementation is quite different.

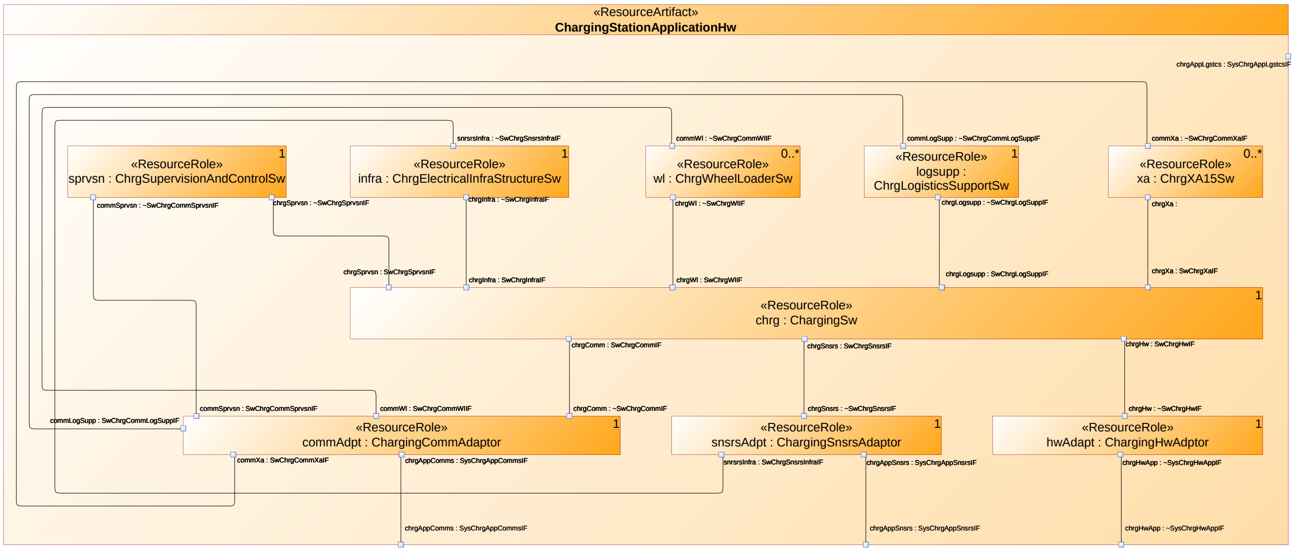

Figure 13. An example of the software architecture for an element

The site management software architecture would show the reuse of patterns to an even greater extent. The components of this software are essentially a replica of the logical model of the site. The additional elements are a couple of adaptors that deal with translation of incoming/outgoing data from either the supervisor, the HMI or the communications adaptor. Their responsibility is to translate between the implementation oriented handling and the internal handling of the site management. This needs to be able to perform much the same handling and store much the same information as the logical model. The information structures defined in the logical model as well as the interactions between the elements can be largely making it possible to develop the software application much faster than would have been possible without the benefit of the logical model.

Conclusions and ways forward

Based on the above, a couple of conclusions can be reached:

- Significant insights that form part of the detailed development can be reached based on a developed architecture dealing with a defined logical scenario.
- A significantly increased knowledge of the actual behaviour that has to be managed for the scenario is made available through the separation of logical and realization models.
- The development effort required for the software required to deal with the scenario management at a real site can be speeded up given that several patterns from the logical model can be made use of as part of the software implementation. This is especially true about the information that needs to flow between the software components and the defined information structures.
- It should however be noted that the pattern reuse has its limitations and there will be additional behaviour as well as information that needs to be added to a real software implementation.
- While the site management software is hardwired to the scenario a future possibility would be to separate individual parts as services in order to create a shielding layer from the logical operations to the technical implementation.
- To achieve the above, UAF 1.0 is a logical choice since the framework is designed to act as a bridge between Enterprise Architecture and concrete systems engineering and development.

References

Yang-Yang Zhao, Peter Sjöberg, Larry J. Leifer, Sara Dersten, Reinventing the ConOps for Innovative Systems Development, 26th Annual INCOSE International Symposium (IS 2016), Edinburgh, Scotland, UK

Jakob Axelsson; Systems-of-systems for border-crossing innovation in the digitized society; A strategic research and innovation agenda for Sweden; Kista, July, 1 2015, SICS Technical Report T2015:07

DoD CIO, 2012, DoD Architecture Framework Version 2.02, DoD Deputy Chief Information Officer, Available online at http://dodcio.defense.gov/dodaf20/dodaf20_pes.aspx, accessed Nov, 2012.

FEAF, Federal Enterprise Architecture Framework (FEAF), Version 1.1, September 1999, Available online at http://www.enterprise-architecture.info/Images/Documents/Federal%20EA%20Framework.pdf, Accessed Nov, 2013

Friedenthal, S., Moore, A., Steiner, R. Practical Guide to SysML: The Systems Modeling Language, Morgan Kaufman September 2008

IDEAS http://www.ideasgroup.org

IEEE, 2011, 42010-2011 - ISO/IEC/IEEE Systems and software engineering -- Architecture description, available at http://ieeexplore.ieee.org/document/6129467/MOD Architectural Framework, Version 1.2, 23 June 2008, Office of Public Sector Information, http://www.modaf.org.uk/

NAF, 2016, NATO Architecture Framework v4.0 Documentation (draft) Available at http://nafdocs.org/viewpoints/ Accessed March 2016

Object Management Group (OMG), 2007b, OMG Systems Modeling Language (OMG SysML™), V1.0, OMG Document Number: formal/2007-09-01, URL: http://www.omg.org/spec/SysML/1.0/PDF , Accessed November, 2007

Object Management Group (OMG), 2009a, Unified Profile for the Department of Defense Architecture Framework (DoDAF) and the Ministry of Defence Architecture Framework (MODAF), available at http://www.omg.org/spec/UPDM/

Object Management Group (OMG), 2009c, Unified Profile for DoDAF/MODAF (UPDM) 2.0 Request For Proposal), available at http://www.omg.org/cgi-bin/doc?c4i/2009-09-02

Biography

Peter Sjöberg:

Peter Sjöberg has had a leading Systems Engineering role within Volvo Construction Equipment since he joined the company 2007. Since 2014 he has been working within the Emerging Technologies organization where he is bringing Systems Thinking and Systems Engineering, incl. Model Based, into a couple of programs and projects. The work to introduce MBSE at Volvo CE, using SysML and UAF, is done in collaboration with the Electric and Electronics (incl. Software) department. In the autumn of 2010 Peter made Volvo CE to take the step to become a CAB member of INCOSE and has since the start been the active CAB representative of Volvo CE.

Lars-Olof Kihlström:

Lars-Olof Kihlström is a principal consultant at Syntell AB and has been dealing with Model based system engineering since 1984. He has developed systems for telecommunications, automotive, aerospace, data collection systems, various industrial applications and on one occasion for the financial sector. He has been active in defining enterprise architecture frameworks since 2003 and was a member of the NRS (NAF revision syndicate) that developed the NATO Architecture Framework (NAF 3.0). He was tasked with the upgrade to NAF 3.1 and has participated in the development of MODAF. He is a member of the UPDM group in OMG and has actively participated in the development of the various versions of UPDM (Unified Profile for DoDAF and MODAF) and the latest version renamed to UAF 1.0 (Unified Architecture Framework)

Matthew Hause:

Matthew Hause is a PTC Engineering Fellow, the co-chair of the UPDM group a member of the OMG Architecture Board, and a member of the OMG SysML specification team. He has been developing multi-national complex systems for almost 40 years. He started out working in the power systems industry then transitioned to command and control systems, process control, communications, SCADA, distributed control, and many other areas of technical and real-time systems. His role at PTC includes mentoring, sales presentations, standards development, presentations at conferences, specification of the UPDM profile and developing and presenting training courses.