Architecture Renovation.

White Paper Resulting from Architecture Forum Meeting

March 15-16, 2010, Stevens Institute of Technology, Hoboken, NJ, USA

Edited by:

Dr. Gerrit Muller, Buskerud University College, Embedded Systems Institute

Mr. Eirik Hole, Stevens Institute of Technology

Input was provided by the following participants in the Architecture Forum:

Name	Organization
Leandre Adifon	OTIS
Robert Cloutier	Stevens Institute of Technology
Petri Haavisto	Nokia
Teun Hendriks	ESI
Eirik Hole	Stevens Institute of Technology
Kees Kooijman	FEI Company
Pierre vd Laar	ESI
Hugo van Leeuwen	FEI Company
Gerrit Muller	Buskerud University College/ESI

Name	Organization
Mike Pennotti	Stevens Institute of Technology
Sølve Raaen	Kongsberg Maritime
Matin Safarez	Stevens Institute of Technology
Rolf Siegers	Raytheon
Martin Simons	Daimler
Andy Turner	Nokia
Dinesh Verma	Stevens Institute of Technology
Jesse Wijntjes	FAA
Ernst Fricke	BMW; remote guest presentation

Published on July 22, 2013

1. Introduction

Two topics that keep popping up during forum meetings are architecture end-of-life and how to preserve the quality of an architecture. This time the forum chose architecture renovation as subject, which links to both topics. The Architecting Forum members explored architecture renovation based on the following questions:

1. What metrics can be used to guide investments in architecture?
2. When to make significant investments in architecture, and what triggers architecture investments?
3. How to start, and how to do, significant architectural change?
4. What is the "right" size of change?

2. Architecture Renovation Experiences

Historic analysis

One forum member did an historic analysis of past renovations. His study covered 22 projects. The projects were classified as 17 renovation and 5 new projects. In many cases (10 clearly, some vague), new requirements or business needs were the reason to change in combination with the recognition that existing technology will be a limiting factor. In four cases, a change in business strategy triggered the renovation. Renovations rarely have been initiated just for improving how existing functionality is implemented.

Usually, the need for a renovation was identified and initiated in time, but most renovation efforts caused delays for the first products produced from the renovated architecture. Product or function delays sometimes gave the competition the possibility to increase their market share. However, more than half of the renovation efforts were ultimately positive for the business over the long term. Success and failure is largely judged on business terms (rather than technical). No renovations were found that had been done too soon.

Architecture investments have been triggered mostly because of very clear new business needs coming from business plans, architects anticipating future needs, or changes in strategy or technology access. Rarely have investments been initiated solely because of limitations of current architecture; this is difficult to sell to decision makers.

Many parameters were collected for this study, such as starting year, duration, age of original architecture, project size, the degree of disruptiveness of the renovation, time of identification and time of initiation, budget overruns, short term impact, strategic, business, and technical impact and success. We analyzed the data to see if any of the parameters correlated to the success:

A short **duration** correlates weakly with successful renovation; Two of the three most successful renovations took two years or less, the third took eight years. A short duration is certainly no guarantee for success; 7 failed renovations had a duration of three years or less.

Size shows marginal correlation with success; the three most successful renovations were between 20 and 500 person-months. However, the two least successful renovations were 200 and 500 person-months.

The **time period** when the renovation was executed shows that projects in the 2000 to 2007 time window had a higher success rate than later projects. No explanation was provided for this finding; it might be internal (e.g. organization) or external (e.g. market changes or technical developments). It is also possible that these data are biased, since the success of later renovations might not yet be visible.

Some positive correlation is visible between success and **disruptiveness**; four of the six most successful projects were disruptive to highly disruptive. Disruptiveness often is related to interfaces and compatibility. Changes with low disruptiveness often maintain existing interfaces; new components are compatible to old components. Disruptiveness is no guarantee for success either; two of the more disruptive renovations were a failure, and four were marginally successful.

A negative correlation exists between the **age** of the original architecture and success; the four most successful projects renovated architectures of two or less years of age. One successful and one marginally successful project renovated architectures with an age of 8 years. The three worst failures were attempts to renovate architectures of 6 to 8 years of age.

3. S-curve applied on architectures

Ernst Fricke from BMW gave a guest presentation on the application of S-curves on architectures. S-curves are well-known in literature; see [Rogers 2003]. Gorbea and Fricke [Gorbea 2008] have mapped the historic development of the drive train architecture of the past century; see Figure 1.

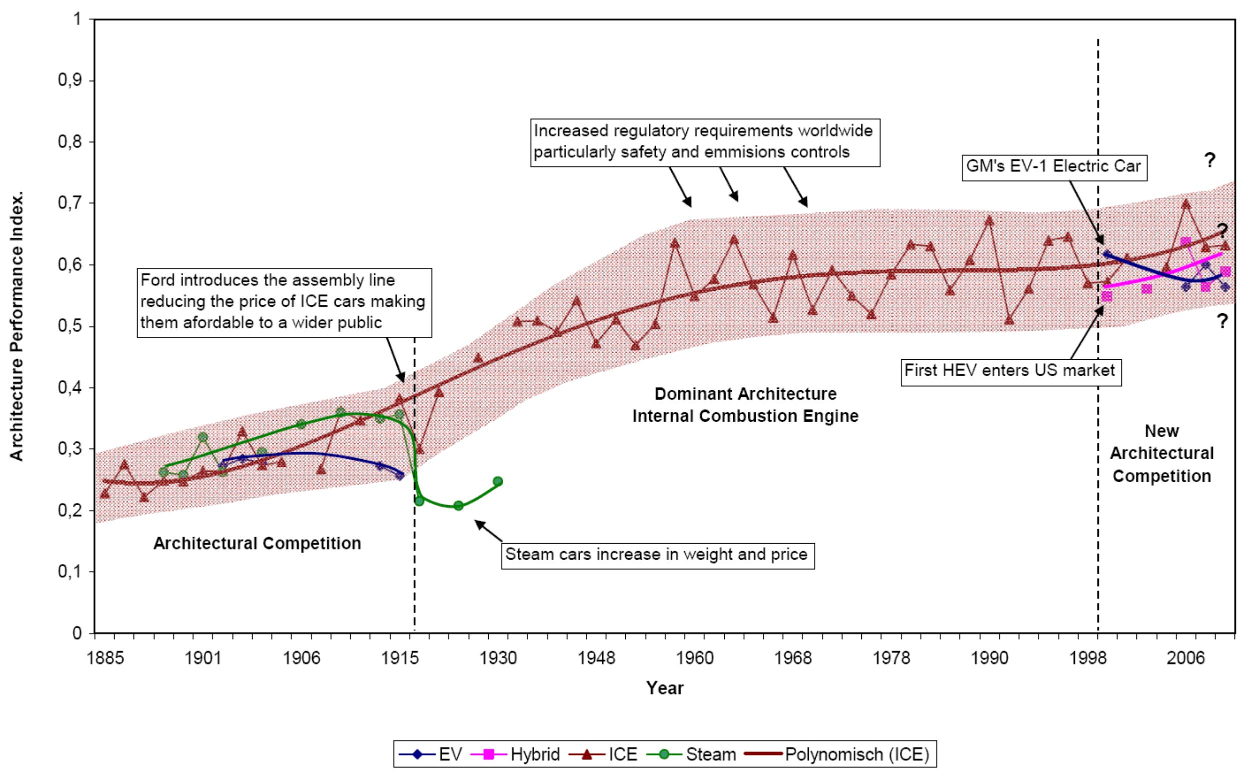


Figure 1. Performance of various automotive architectures from 1885-2008; source [Gorbea 2008].

The idea behind an S-curve is that systems go through different stages of development starting with a slow but increasing growth, followed by a phase with rapid growth, and finally a decreasing growth and even decline. In order to plot any curve a metric is needed for the left hand axis. Gorbea and Fricke use performance for the left hand axis. This performance is the weighted sum of normalized power, weight, maximum velocity, fuel consumption, and price performance.

Figure 1 shows this performance for different drive-train concepts, such as steam engines, electric vehicles (EV), internal combustion engines (ICE), and Hybrid drive trains. In the early days, steam engines, electric vehicles and combustion engines competed, until about 1920 when ICE started to dominate and competing architectures did not perform well enough. Since 1998 the competition of architectures has been revived by the introduction of hybrid vehicles and a renewed interest in electric vehicles.

Gorbea and Fricke observe that automotive organizations were entirely focused on the existing dominant architecture that allowed them to innovate at the subsystem level. Organization and competences were built around ICE; now new competencies are needed and attention for the integral architecture instead of the subsystem focus.

BMW worked on extending the ICE architecture by improving its performance, partially by borrowing features from competing architectures. For example, the energy management is approached more integral with features such as *brake energy regeneration* or *auto start stop function*. The combined improvement in CO_2 efficiency is 16 to 20% in 3 years time.

4. Revisiting the Renovation Questions

We started with four questions listed in the introduction. The presentations and the initial discussions resulted in some answers that we discuss in the following subsections.

What metrics can be used to guide investments in architecture?

The following metrics were mentioned in the discussion

- estimated architecting cost

- number of Zachman Framework cells
- number of operational scenarios
- number of Department of Defense Architecture Framework (DoDAF) models
- percent reuse (for ongoing projects and strategic pursuits)
- business results
- non Functional Requirements, for example in the BMW presentation: power, weight, maximum velocity, fuel consumption, and price performance
- R&D Efficiency
- number of defects
- coupling between components, architectural unwanted amount of coupling

One of the architects remarked that most metrics are not clear indicators for architecture.

One company showed the analysis of component coupling. The layered visualization of coupling was used to show the amount of coupling and to identify connections that violate architectural rules. See Appendix A for an example of such coupling visualization.

When to make significant investments in architecture? What triggers architecture investments?

The following reasons for making significant investments were mentioned:

- A program or project that is a system integration job
- Complex command and control systems
- Creating a new product line; Often use the value of risk reduction as an ROI indicator as it relates to an architecture investment
- When a Customer explicitly demands an architecture
- When interoperability with other products/systems is needed

- To make a paradigm shift
- To escape from a tyrannical or dominant subsystem

The general opinion was that a clear business driver or goal must be present to make such investment. It is difficult to sell such investments without it. However, one of the architects in a managerial leadership role remarked “Architects in business decision making positions often drive disaster.” The conclusion from this remark is the following principle:

Principle 10.1: The decision to invest in architecture renovation is collaborative, with both architects and business managers involved.

Some examples of successful architecture improvements were given without explicit external business drivers (functionality, cost, or performance):

- Technology replacement (Defense)
- Maintenance (people skills) (Defense)
- Maintenance, safety (Maritime)

How to start, and how to do, significant architectural change?

Alignment with business plans and understanding of business decision makers’ objectives is a prerequisite to start the renovation; see Principle 10.1. A significant architecture change needs to be sold in business terms and has to bring understandable benefits. Promising better qualities such as maintainability is risky because support from the organization might decrease too much during the project.

Architects should strive for isolation of the changes as far as possible, for example by:

- Replacement behind old interfaces
- First implement old functionality before introducing new functionality.

A fallback plan helps in order to give the business an option if things go wrong. Synchronization of changes across the system helps to avoid too many big bangs.

One of the participating companies uses a refactoring strategy where a monolithic system was gradually rejuvenated. The more generic solution approach was formulated as:

- open up the black box
- understand the internals
- find a partitioning
- take it from there.

Figure 2 shows a generic approach to architecture renovation. The first step is to understand the current situation and to articulate the architectural problem. Next step is to formulate the desired long term situation, based on the company's vision, strategy, and needs. The last step is to come up with a feasible migration path from the current situation toward the desired future situation.

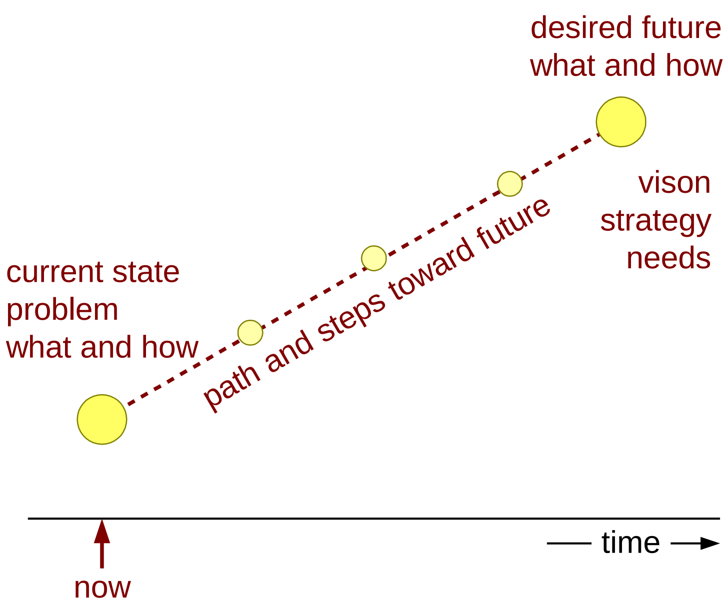


Figure 2. Generic approach to architecture renovation.

What is the "right" size of change?

The historic analysis in Section 2 indicated some relation between size and success. It seems reasonable to expect that small projects will earn quicker return on investment; larger projects take longer to complete. Do larger projects expect larger positive impact?

Many companies struggle with the concurrent existence of old and new architectures. Maintenance of multiple paths should be avoided. One way to achieve this is by adding new functionality only to new architectures. However, old architectures may need some new functionality for business reasons.

Software and hardware have very different characteristics, resulting in different considerations when renovating software or hardware.

5. Snippets from the Discussions

During the discussion several interesting statements popped-up. For example, “Good Downhill Skiers Don't Fall much.” The metaphor is used to explain that learning is often related to making mistakes. However, in some cases making mistakes is immediately fatal and a different learning paradigm is needed. Architectural renovation is seen as high risk area where mistakes might be fatal for a company.

“Renovations are often triggered by problems while losing sight of strength of existing system.” When renovating, the focus might be so much on improving weaknesses that the product’s or system’s strengths are lost. In the solution approach, visualized in Figure 2, understanding of the current state strengths and weaknesses is important.

“Stacking many pragmatic decisions results in a big mess.” Programs and product lines that have been running for a long-time often suffer from this feeling; every individual pragmatic decision made sense but the accumulation of all these decisions has created a large problem. The statement “Architects are Safe Guards for long running product lines” articulates what role we see for architects. This is also captured in the statement “Craftsmanship of architects is to anticipate needs and prepare architectures within pragmatic constraints of costs and risks." We reformulate these statements in the following principle:

Principle 10.2: Architects are Safe Guards for long running product lines. They anticipate needs and prepare architectures within pragmatic constraints of costs and risks. In this way, architects must prevent the stacking of many pragmatic decisions, which could results in a big mess.

In the discussion, multiple classes of architecture problems were identified:

- paradigm shift is needed to stay competitive
- monolithic layer in the existing architecture hampers further expansion and change of products
- tyrannical subsystem hampers further expansion and change of products

"Architects hide renovations that are short term unsalable but this is not preferred behavior." Architects sometimes see the need for technical or infrastructural renovations where the immediate business benefit is not obvious. In these instances, the change is difficult to sell and gain support to realize such change is necessary. The way around the problem is to hide such change; to implement the change without explicit permission or budget allocation. In large organizations, sometimes the behavior "ask forgiveness afterwards" is more beneficial than asking permission up-front. For smaller renovations, we might defend such behavior as part of architect's craftsmanship. Some large organizations have been saved by such behavior in the gray zone of acceptance. Nevertheless, the need to hide is seen as symptom of lacking maturity in the organization.

The need to hide might be overcome by the strategy where "Renovations ride piggyback on function, feature, or performance increases." In this way the architecture renovation is coupled to business related benefits.

Another approach that is suggested is a depreciation model where an explicit budget for architecture renovation is allocated to maintain the value of the architecture asset. This model is derived from other capital investments such as buildings where it is an accepted practice to regularly spend money to maintain the building. The question in this model is how architecture governance is organized: who takes decisions for renovations, architect or business manager?

"Yawnoc's Law: Make the organization mirror structure of the system." Yawnoc's law is the reverse of Conway's law that states that architectures reflect the organization; see [Weiss 2004] and [van Ommering 2005]. The consequence of these laws is that changing architecture is hard; organizational changes are also needed. Here we see again the need of teamwork between architects and managers.

Figure 3 visualizes another statement about the tension between different stakeholders. The perception of architects is that most domain experts tend to be conservative (this is the way we always did this, why change something that is proven?) while technical experts can be naïve (lets introduce this new technology). Similarly, there is a tension between decision makers who are focused on product value and short-term benefits, and hence operate pragmatic, and architects with a long term interest and striving for elegance.

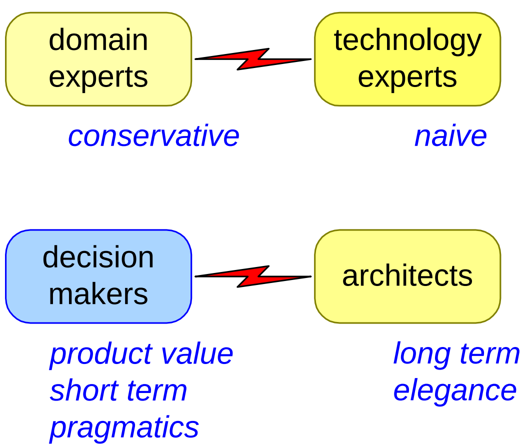


Figure 3. Architecture renovation stakeholders and concerns

Validation is a critical success factor. Timely validation of business value is required; does the renovation fulfill the business driver? The architectural improvements are often based on the architect's hunch and need timely validation. An incremental approach with multiple iterations and early feedback facilitates such validation. A challenge for the architects is to find a migration path that allows early validation.

"Primary renovation causes secondary (non-business) renovation; propagation of changes." This is a common problem when architects are planning a renovation, the spaghetti effect, where one change induces the next change. Earlier we discussed the need to isolate or confine renovations. In practice, the propagation of secondary changes threatens this confinement. Architects need to ensure that architecture renovations stay confined, by addressing any violating propagated change individually.

6. Understanding Architecture Regression

A recurring discussion in architecture renovation is how we got in the bad position that renovation is needed. The perception is that architectures are regressing unless actively maintained. That is the idea behind the depreciation model in last section. During the forum meeting we zoomed in on the questions:

- How to prevent regression?
- How to act pro-actively?

In preparation of this discussion all participants were challenged with the following question: "Can you asses one of your architectures on a quality scale from 0 (=dead) to 10 (=excellent) in the past and now?" The outcome of this question is visualized in Figure 4. For every system architecture a begin value and end value is shown with a straight line connecting the values.

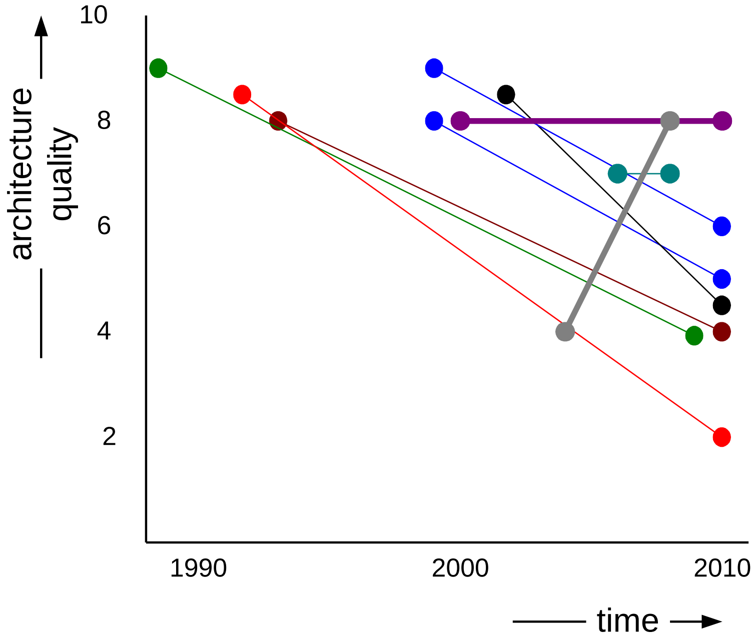


Figure 4. Assessment of the quality of architectures by forum participants.

Many participants of the forum are Europeans. The European assessments are visualized with a thin line; the US assessments are visualized with a thick line. The perception of the participants is clear: the quality of architectures decreases over time. At the same time, this analysis (based on a small sample) might suffer from a cultural difference in assessments: Europeans tend to be critical, to see the imperfections; Americans tend to be positive, to celebrate the strengths.

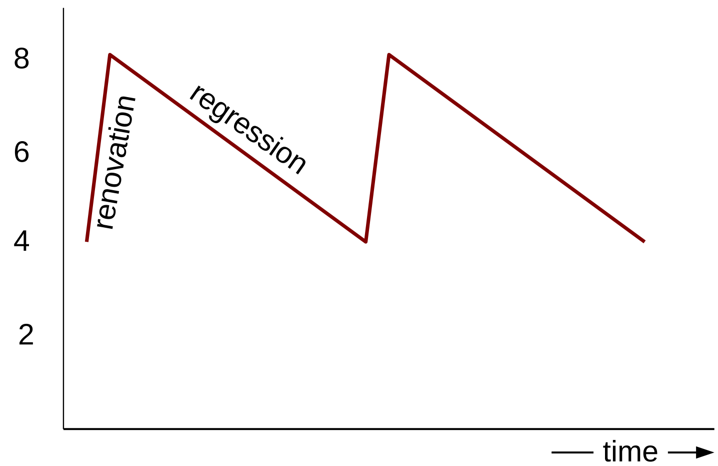


Figure 5. Alternating regression and renovation?

One of the participants proposed a model where regular renovations undo the regression that takes place; see Figure 5.

Long term accumulation of regression results in systems with legacy. A question that relates to regression and prevention is: can we get rid of legacy. One of the suggestions that was raised is to (stepwise) retire legacy. No successful examples of such strategy were provided.

7. Summary and Conclusions

Architecture renovation is a hot topic. The tendency of architectures to degrade in quality over time triggers architects to come up with strategies to maintain architecture quality. We discussed architecture renovation by using 4 questions, with the following summarized answers:

1. What metrics can be used to guide investments in architecture?

   Most metrics that were mentioned are business oriented (cost, risk, business results). Non-functional requirements or qualities are mentioned, and one example was given where coupling was measured.

2. When to make significant investments in architecture, what triggers architecture investments?

The common opinion is that architecture renovation has to be driven by business drivers and needs. Technical or architectural improvements need to be coupled to business benefits. Architecture renovation requires teamwork between architects and managers.

3. How to start, and how to do, significant architectural change?

Make sure that the current situation is well understood, including current strengths and shortcomings. Determine the future situation and plot a migration path toward the desired future situation.

4. What is the "right" size of change?

No clear guidelines for the size were found. Smaller steps seem to be more successful. However, the renovation needs to be significant. Renovations with a disruptive nature were more successful.

The discussion made it clear that we see it as architects' responsibility to ensure architecture quality. However, the perception is that the quality of most architectures degrades over time. Apparently, most of us struggle to fulfill this part of the architect's job.

Acknowledgements

Ernst Fricke provided a remote guest presentation about architecture S-curves.

Literature

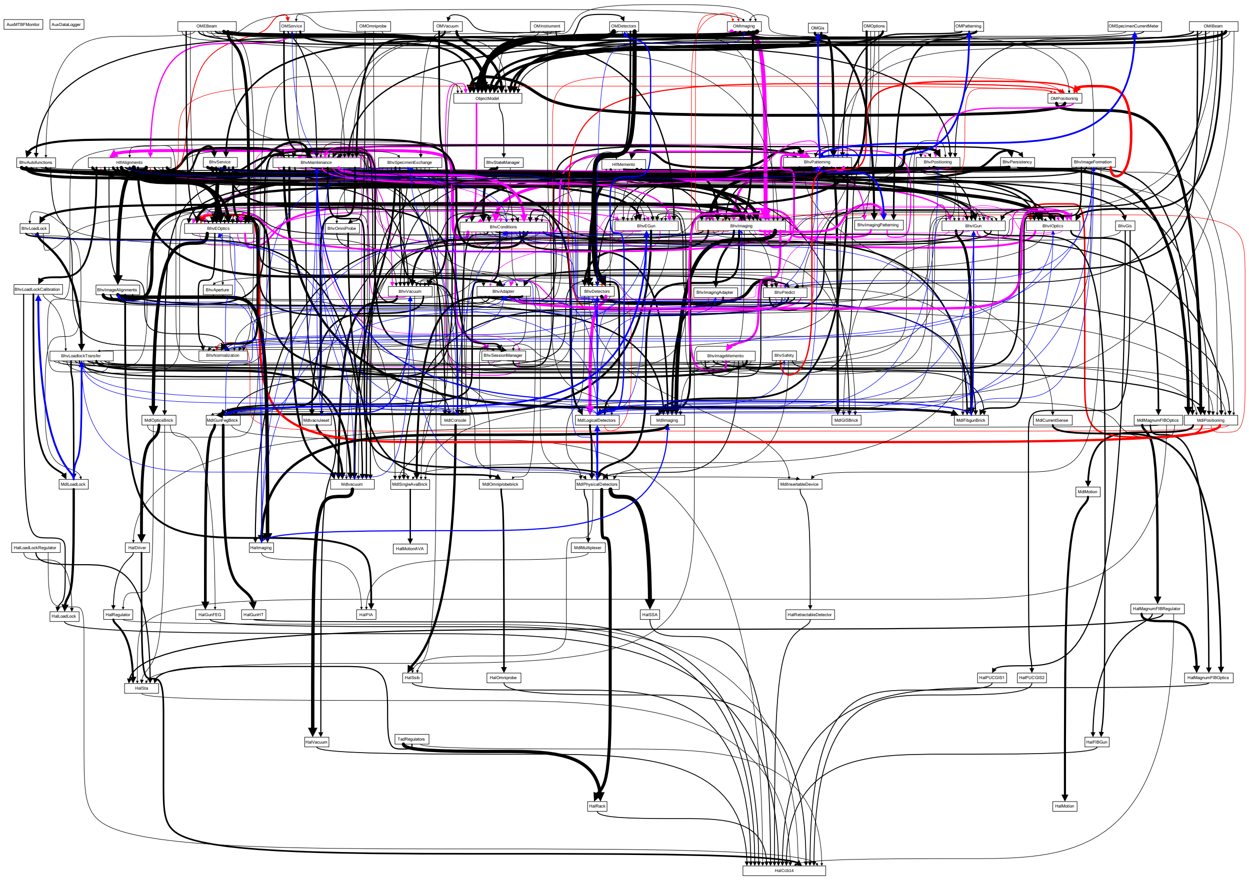
[Gorbea 2008] Carlos Gorbea, Ernst Fricke, and Udo Lindemann, *The Design of Future Cars in a New Age of Architectural Competition*, Proceedings of the ASME 2008 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2008 August 3-6, 2008, Brooklyn, New York, USA

[Rogers 2003] Rogers, E., "Diffusion of Innovations", Fifth Edition. New York, NY: Free Press. 2003

[Weiss 2003]D. Weiss, *Product-Line Engineering as the Basis for Reuse*, Proceedings Eighth International Conference Software Reuse, July 2004.

[van Ommering 2005] R. van Ommering, *Software Reuse in Product Populations*, IEEE Transactions on Software Engineering, vol. 31, no. 7, July 2005, p537-550

Appendix A. Coupling diagram



Coupling analysis of one component in a system. This amount of coupling is not desired because it complicates changes and new developments. The meaning of the colors is

Black lines: Method calls on interfaces from lower level modules

Blue lines: Events

Violet lines: Method calls on interfaces with circular dependencies

Red lines: Method calls on interfaces from higher level modules