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Software Engineering in Industrial Practice (SEIP)

Dr. Ralf S. Engelschall

: not covered in lectures

: key aspect of lectures

ENGINEERING FUNDAMENTALS

Software Classes

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EF 01.1

Business

Custom Software Development — CSD

Commercial development of **non**-standardised, **fully** individualised, and **non**-reusable **company**-specific software for a **single** customer.

Standard Software Development — STD

Commercial development of standardised, **partially** customisable, and **fully** reusable **domain**-specific software for **many** customers.

Open Source Software Development — OSS

Non-commercial development of standardised, **highly** customisable, and **fully** reusable **generic** software for **many** customers.

Class: Graphics & Media

target audience: **consumers & enterprises**

Graphics Editing Application — GEA

Software for editing and rendering graphics in vector and bitmap format.

Examples: Cinema4D, Maya, Blender, After Effects, Illustrator, Inkscape, Scribus, Photoshop, GIMP, etc.

~~CSD~~ STD OSS

Graphics Animation Engine — GAE

Software for animating the 2D/3D virtual worlds of games and overlays of TV productions.

Examples: Unity, Unreal Engine, CryENGINE, Godot, HUDS, SPX-GC, Holographics, H2R Graphics, etc.

CSD STD ~~OSS~~

Audio/Video-Processing System — AVS

Software for live-processing and post-production of audio/video based multimedia streams.

Examples: vMix, OBS Studio, VLC, Lossless Cut, Handbrake, Adobe Premiere, FFmpeg, Nimble, etc.

~~CSD~~ STD OSS

Class: Business & Data

target audience: **consumers & enterprises**

Office Productivity Application — OPA

Software for productivity in the desktop-based office environment.

Examples: PowerPoint, Excel, Word, Visio, OmniGraffle, LibreOffice, Outlook, XMind, Firefox, Chrome, etc.

~~CSD~~ STD OSS

Business Information System — BIS

Software for driving business processes through interactive information management.

Examples: Vote, CampS, Mission Control, IPW, KEZ-PSC, TimeSheet, SAP ERP, OpenProject, etc.

CSD STD ~~OSS~~

Data Management System — DMS

Software for protocol-based storing and retrieving of persistent data.

Examples: NextCloud, PostgreSQL, CockroachDB, Redis, InfluxDB, Neo4J, Tendermind, Gitea, Vault, etc.

~~CSD~~ STD OSS

Class: Machinery & Network

target audience: **consumers & enterprises**

Technical Control System — TCS

Software for controlling a physical machinery or technical system.

Examples: AquaTherm, AVM! FritzBox Firmware, BirdDog Camera Firmware, etc.

CSD ~~STD~~ ~~OSS~~

Network Communication System — NCS

Software for protocol-based communication of data over a computer network.

Examples: Apache, NGINX, HAProxy, Mosquitto, RabbitMQ, Node-RED, KeyCloak, etc.

~~CSD~~ ~~STD~~ OSS

Operating System Kernel — OSK

Software kernel for low-level operating a physical or virtual device and run programs on it.

Examples: Windows, macOS, iOS, Linux, FreeBSD, QNX, ChibiOS/RT, Kubernetes, Wildfly, etc.

~~CSD~~ STD OSS

Class: Development & Tools

target audience: **vendors & suppliers**

Software Development Kit — SDK

Software libraries and frameworks of reusable functionality for developing software.

Examples: NDI SDK, HAPI, GraphQL-IO, Sequelize, JDK, Spring, Hibernate, etc.

~~CSD~~ ~~STD~~ OSS

Software Development Tools — SDT

Software tools for editing, linting, compiling, packaging, distributing, and installing software.

Examples: Visual Studio Code, Sublime Text, GCC, GNU Binutils, NPM, JDK, Docker, Helm, etc.

~~CSD~~ ~~STD~~ OSS

Operating System Tools — OST

Software tools for high-level operating a physical or virtual computing device.

Examples: Coreutils, Bash, Vim, TMux, FZF, cURL, RSYNC, OpenSSH, etc.

~~CSD~~ ~~STD~~ OSS

audience & deliverable

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Software Development Approaches

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EF 01.2

Development Approaches

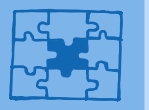
Software Prototyping *mocking* SP

Develop an early sample or model of a software solution by mocking and cheating in order to just once test a concept, idea or process.

Example: Customer Sales Demo

Software Bricolage *integrating* SB

Develop a single instance of a software solution by tinkering, cobbling and integrating partial solutions in order to prove feasibility or just provide a service.



Example: Company-Internal SaaS

Software Craftsmanship *crafting* SC

Develop a production-grade software solution by professional, clean but plain craftsmanship means in order to solve a usually complicated problem.

Example: Open Source Framework

Software Engineering *teaming* SE

Develop a production-grade software solution by a professional, risk-hedged engineering approach in order to solve a usually complex problem.

Example: Business Information System

Continuum & Process

The four development approaches do *not* form a hierarchy, but can be combined in practice: **Prototyping** and **Bricolage** can be earlier stages of **Craftsmanship** or **Engineering**. **Craftsmanship** can be part of **Bricolage** or **Engineering**. Each approach requires a special skill (mocking, integrating, crafting, teaming).

Development Approaches: Characteristics Comparison *

	Effort: Person-Days	Effort: Persons	Process: Risk-Hedge	Process: Traceability	Solution: Target Technology	Solution: Production-Grade	Solution: Sustainability	Solution: Claim	Solution: Life-Time Months	Solution: Lines of Code (k)
Software Prototyping	1-20	1-2	-	-	-	-	-	5%	0-3	0-3
Software Bricolage	5-100	1-2	-	-	X	(X)	-	60%	3-24	1-10
Software Craftsmanship	5-100	1-2	-	-	X	X	X	100%	24-48	5-25
Software Engineering	>150	5-50	X	X	X	X	X	80%	>48	>25

* All figures are just rough orders of magnitude for indication and illustration purposes.

Key Message

All four approaches are equally essential in practice. Which one(s) to choose, entirely depends on the particular requirements.

Development Approaches: Success Patterns

	Software Prototyping	Software Bricolage	Software Craftsmanship	Software Engineering
Performance Responsibility Model	One-Man-Show Single Mental	One-Man-Show Single Mental	One-Man-Show Single Mental/**Documented**	**Team Play Separated Documented**
Decisions Process Optimisation	Implicit **Minimized Time**	Implicit **Partial Efficient**	Implicit/**Explicit Partial Effectiveness**	**Explicit** Complete **Economics**
Risks Stakeholders Mastering	Ignore Ignore **Time-Constraint**	Ignore Ignore Complexity	Ignore Ignore **Complication**	**Mitigate Manage** Complexity
Solutions Standards Efforts	**Use Full** Use **Configuration**	Use Partial Use **Integration**	Use Partial **Potentially Create** Programming	Use Partial Use Programming
Target Sustainability Traceability	**Demo No No**	Solution **Partial No**	**Product** Full **Partial**	**Product** Full Full

goal & approach

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Software Engineering

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EF 01.3

Engineering

Machinery

The collection of physical components of a mechanical apparatus using electrical power to perform a certain task.

specialised by

Hardware

The collection of physical components (machinery) of a computer system.

operated by

Software

The collection of instructions and data that tell a computer system how to work.

created by

Engineering

The systematic application of **scientific and technological knowledge, principles, approaches, practices, methods, and experiences**, to **design, build, operate, and maintain** complex production-grade solutions through a **traceable** process. *

transferred to

taking into account

Engineering Code of Conduct

Commit yourself to the **highest ethical and professional conduct**, accept responsibility in making decisions consistent with the **safety, health, and welfare of the public**, apply the **state of the art in science and technology** of your field, perform services only in areas of your **competence**, and comply with the principles of **sustainable development**. *

statements of ASCE, NSPE, ACM, IEEE, etc.

Wording

Engineering: derived from the *Latin* words **ingeniare** (to create, generate, contrive, devise) and **ingenium** (cleverness).

Software Engineering

created by

Software Engineering (transferred)

The systematic application of scientific and technological knowledge, principles, approaches, practices, methods, and experiences, to design, build, operate, and maintain complex production-grade **software** solutions through a traceable process.

simplified to

Software Engineering (simplified)

The systematic application of **engineering** knowledge, principles, approaches, practices, methods, and experiences to **the development of software.**

also taking into account

profession & ethics

ENGINEERING FUNDAMENTALS

Profession Characteristics

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EF 01.4

diagram.direct/XIRF-NITV

	creative	rational
	involving the use of **strong imagination** and **original ideas**	involving the use of **analytical thinking** and **logical reasoning**
practical: involving the **actual doing** and **real application** of something	**CRAFTSMAN** (Handwerker) Objectives: **solve problems**, **create uniques**, … Software Engineering: **Programming**, **Configuration**, …	**ENGINEER** (Ingenieur) Objectives: **solve problems**, **create solutions**, … Software Engineering: **Estimation**, **Automation**, …
theoretical: involving the **manifested imagination** or **analytical study** of something	**ARTIST** (Künstler) Objectives: **create beauty**, **create uniques**, … Software Engineering: **Visual Design**, **Coding Style**, …	**SCIENTIST** (Wissenschaftler) Objectives: **analyse problems**, **create knowledge**, … Software Engineering: **Methodology**, **User Research**, …

INVENTOR (Erfinder)

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Discipline Claim

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EF 01.6

FA FARSIGHTED weitblickend

Be farsighted in your solution finding.

Sei weitblickend in deiner Lösungsfindung.

AR: Scalable [illegible] Spoke
DV: Plugin [illegible]

TE TENET-ORIENTED grundsatzorientiert

Orientate yourself on fixed tenets in your approach and solution finding.

Orientiere dich an festen Grundsätzen in deinem Vorgehen und deiner Lösungsfindung.

AR: Separation of Concern
DV: Strict Coding-Style

TH THOUGHTFUL wohlüberlegt

Act thoughtful in your approach and solution finding.

Agiere wohlüberlegt in deinem Vorgehen und deiner Lösungsfindung.

AR: Modularization
DV: Algorithmical Control Structure

HO HOLISTICALLY ganzheitlich

Think holistically and in the long-term when finding your solutions.

Denke ganzheitlich und langfristig in deiner Lösungsfindung.

AR: Walking Skeleton Design
DV: Consistent Error Handling

AD ADEQUATE angemessen

Ensure that your approach and solutions are adequate to the boundary conditions.

Sorge dafür, daß dein Vorgehen und deine Lösungen angemessen zu den Rahmenbedingungen sind.

AR: No Cloud-Native Complexity
DV: No Over-Engineered Abstraction

FE FEASIBLE machbar

Ensure that your approach and solutions can be realised at reasonable costs.

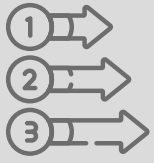
Sorge dafür, daß dein Vorgehen und deine Lösungen mit vernünftigen Kosten realisiert werden können.

AR: Existing Framework Functionality
DV: Realistic Programming Model

IN INCREMENTAL inkrementell

Apply the depth of your discipline incrementally.

Wende die Tiefe deiner Disziplin inkrementell an.



AR: Identified Solution Cruxes
DV: Minimum Viable Product

VA VALUEABLE wertvoll

Provide clearly recognizable added values with your approach and solutions.

Liefere klar ersichtliche Mehrwerte mit deinem Vorgehen und deinen Lösungen.

AR: Technology-Driven Design
DV: User-Story-Driven Functionality

SU SUSTAINABLE nachhaltig

Create sustainable solutions that are well integrated into their environment.

Erschaffe nachhaltige Lösungen, die gut in ihre Umgebung integriert sind.

AR: Interoperable Interfaces
DV: Maintainable Code

ENGINEERING FUNDAMENTALS

Software Engineering Metamodel

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EF 02.1

Craftsmanship Model 4

WHEREBY & HOW

Know how in a profession to operationally perform certain practices with the help of templates and tools.

Profession
A person's occupation, founded upon specialized educational training and formal qualification.

Know-How
Distinct overall knowledge on how to perform certain tasks.

Practice
Distinct steps to perform a certain task with the help of a certain know-how and template.

Template
The initial version of an artifact in order to speed up and/or support crafting the artifact.

Tool
Software application to create an artifact from scratch or from a template and further edit it.

Discipline Model 1

HOW & WHAT

Based on personal inclinations, understand how to act in area-grouped disciplines and create artifacts and their aspects.

Inclination
A person's natural tendency or urge to act or feel in a certain way.

Area
Logical group of strongly related disciplines.

Discipline
Distinct knowledge, responsibility and objectives within Software Engineering.

Artifact
Single representation of an internally used and/or externally delivered result.

Aspect
Smallest result unit of an artifact which can be created separately.

Workflow Model 2

WHAT & WHO

Understand the workflow of separate iterating cycles and work streams, comprised of one or more steps.

Workflow
The five distinct iteration cycles Product Management, Business, Development, Operations and Project Management.

Cycle
Logical iteration cycle of a sequence of strongly related and dependent workflow steps.

Step
Single step in a workflow cycle with a clear logical previous and next step in the logical work flow.

Flow
Logical sequence of interweaved, inter-cycle, optionally skipped, and dependent steps.

Key Message
Mastering Software Engineering means to understanding (in this order) **Discipline**, **Workflow**, **Process** and **Craftsmanship** models. Especially, *never* start with a particular Process model, as it is secondary!

Process Model 3

WHO & WHEN

Map activities onto a project execution schedule, based on horizontal team focus tracks and vertical temporal project periods and phases.

Role
Distinct responsibility and goal of an individual person.

Track
Work stream consisting of a continuously sequence of steps of a workflow cycle.

Activity
Distinct activity in the process to perform a certain task or complete a particular work-package.

Period
Minor time period in the process, to split the project phases into distinct time-, cost-, or scope-based time units.

Phase
Major time period in the process, to split the project into distinct focus periods, separated by major milestones.

suitable for

correlates to

serialized by 1

operationalised by

corresponds to

operationalises 1

derived from

big picture & coherency

ENGINEERING FUNDAMENTALS

Software Engineering Disciplines

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ANALYSIS AN

Software Requirements REQ

Identify Needs: 3 BB
We understand which outcomes of the solution are most valuable to users.

Requirements Engineer / Business Analyst

Domain Modeling DOM

Determine Solution: 2 WB
We model and specify the solution through involved functional and non-functional aspects.

Business Analyst / Business Architect

ARCHITECTURE AR

Software Architecture SWA

Design Software: 1 WB
We design an orthogonal, well-balanced and well-considered solution.

Software Architect

System Architecture SYA

Design Systems: 2 BB
We ensure that the solution fits optimally into its environment.

System Architect / Enterprise Architect

CONFIGURATION CF

Software Versioning VER

Version Artifacts: 1 BB
We place every artifact of the solution under strict version control.

Configuration Manager

Software Assembly ASM

Assemble Artifacts: 1 BB
We build and package the solution through an automated and repeatable mechanism.

Build Manager / Build Engineer

ANALYTICS AC

Software Reviewing REV

Review Code: 4 WB
We regularly and semantically peer-review the source code of the solution.

Software Tester

Software Testing TST

Test Solution: 2 BB
We adequately test the functional and non-functional aspects of the solution.

Software Tester

MANAGEMENT MG

Product Management PRD

Push Product: 3 BB
We continuously push the development and release of the solution to the users.

Product Manager / Product Owner

Project Management PRJ

Steer Process: 3 BB
We rigorously balance time, cost and scope to react on changes and reach the goals.

Project Manager

business-oriented & domain-specific | **constructive** & technological | **infrastructural** & technological | **analytical** & domain-specific | **people-oriented** & process-oriented

EXPERIENCE EX

User Experience UXP

Optimize Workflows: 3 BB
We align the solution to the perspective of the target audience.

User Experience Expert

User Interface UID

Design User Interfaces: 2 WB
We design a useful, intuitive, and beautiful user interface for the solution.

User Interface Designer / Graphics Designer

DEVELOPMENT DV

Software Development DEV

Implement Code: 1 WB
We develop the solution outside-in, from coarse to fine aspects.

Software Engineer / Software Developer

Software Refactoring REF

Refactor Code: 4 BB
We regularly and holistically refactor the solution to ensure long-term quality.

Software Engineer / Software Developer

DELIVERY DL

Software Deployment DPL

Deploy Artifacts: 1 BB
We ship and deploy the solution through an automated and repeatable mechanism.

System Engineer

System Operations OPS

Operate Solution: 4 BB
We ensure that our infrastructures and the solution can be operated in a resilient and secure way.

System Administrator / System Operator

COMPREHENSION CP

Usage Documentation DOC

Document Solution: 2 WB
We adequately document the usage and operation of the solution.

Technical Writer

User Training TRN

Train Users: 4 BB
We adequately train the users and operators of the solution.

Product Expert

ADJUSTMENT AD

Project Coaching COA

Support Members: 4 BB
We ensure that project members use state-of-the-art methodology, technology, and tools.

Project Coach / Methodology Master

Change Management CHG

Involve Stakeholders: 3 BB
We ensure that all stakeholders of the solution are suitably involved.

Change Manager

WB white-box view (details before whole) | BB black-box view (whole before details)

X scalability layer (from 4/most to 1/least dispensable)

EF 02.2

inclination & knowledge

ENGINEERING FUNDAMENTALS

Software Engineering Workflow

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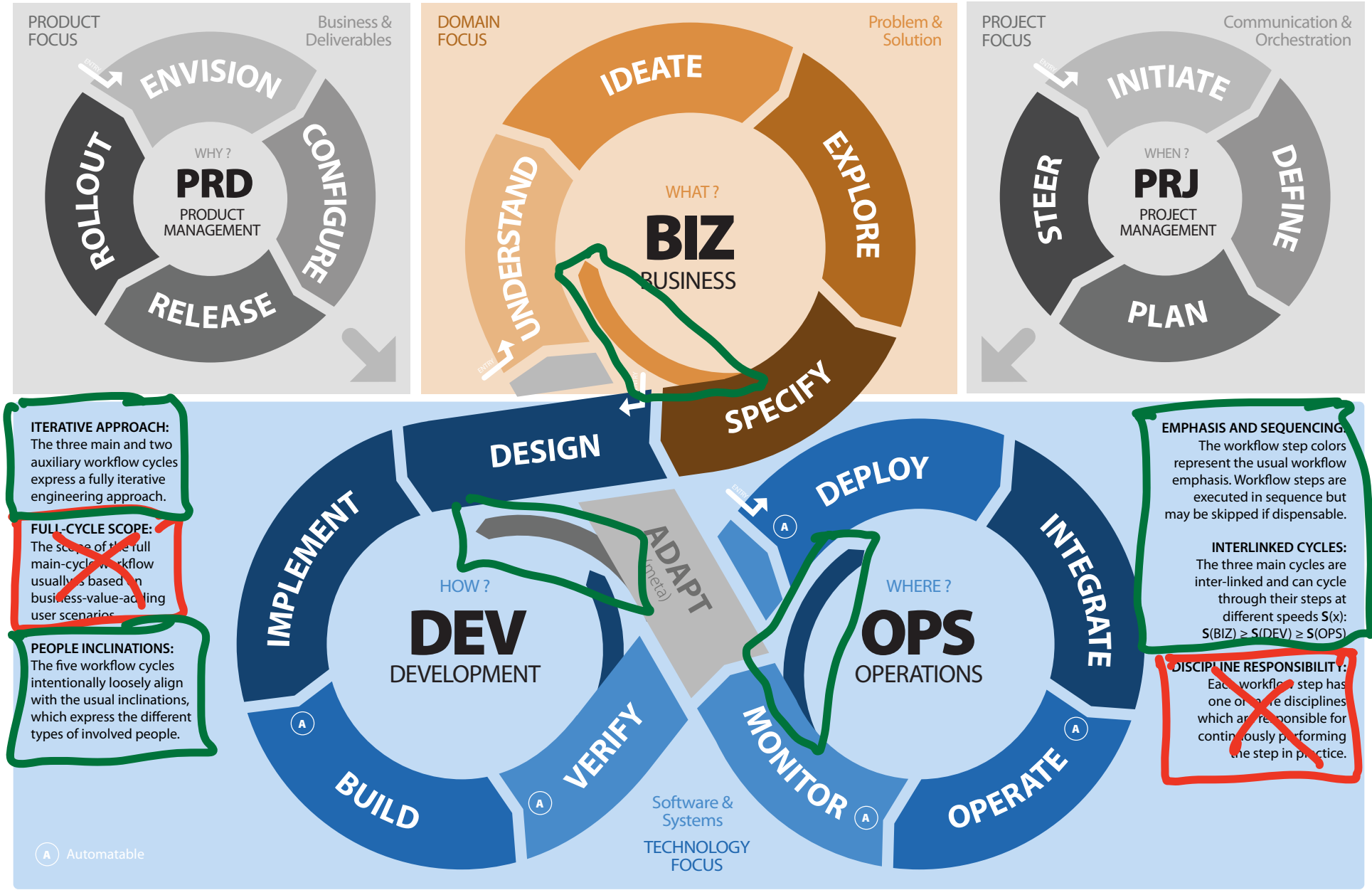

EF 02.3

ENGINEERING FUNDAMENTALS

Software Engineering Steps

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PRODUCT MANAGEMENT (PRD)

ENVISION
Envision Solution: We envision the solution functionality and quality from the business and user perspectives.
PRD, UXP

CONFIGURE
Configure Version: We configure versions of the solution from versioned artifacts and their feature-sets.
PRD, VER

RELEASE
Release Version: We create and release a distinct version of the solution.
PRD, ASM, DOC

ROLLOUT
Rollout Version: We adequately inform, involve and train the users and operators of the solution.
CHG, TRN

BUSINESS EFFORTS (BIZ)

UNDERSTAND
Understand Problem: We empathically understand the problem and requirements of the users.
REQ, UXP, PRD

IDEATE
Ideate Solution: We find an adequate solution for the problem and the requirements of the users.
UXP, REQ

EXPLORE
Explore Ideas: We prototype, explore, and assess ideas, approaches and technologies for the solution.
UXP, UID, SWA, DEV

SPECIFY
Specify Solution: We rigorously and completely specify the functionality and quality of the solution.
DOM, UID

DEVELOPMENT EFFORTS (DEV)

DESIGN
Design Architecture: We design how to implement the solution in an orthogonal, adequate and sustainable way.
SWA, SYA

IMPLEMENT
Implement Solution: We implement the solution outside-in, from coarse to fine aspects.
DEV, DOC, REF, REV

BUILD
Build Artifacts: We build and package the solution from versioned artifacts.
ASM, VER

VERIFY
Verify Solution: We rigorously, but adequately, review and test the functional and non-functional aspects of the solution.
TST, REV

OPERATIONS EFFORTS (OPS)

DEPLOY
Deploy Artifacts: We ship and deploy the solution releases and their updates in an automated and repeatable way.
DPL, OPS, SYA

INTEGRATE
Integrate Environment: We integrate the solution with its target environment.
DPL, OPS, SYA

OPERATE
Operate Solution: We ensure that our infrastructures and the solution can be operated in a resilient and secure manner.
OPS

MONITOR
Monitor Solution: We continuously monitor our infrastructures and the solution under run-time.
OPS, TST

PROJECT MANAGEMENT (PRJ)

INITIATE
Initiate Project: We initially setup the project on the contract and resource level.
PRJ, COA

DEFINE
Define Constraints: We define the constraints of the project on the time, cost, and scope level.
PRJ, PRD

PLAN
Plan Tasks: We continuously plan the next iterations, their steps and their tasks in the project.
PRJ, PRD

STEER
Steer People: We rigorously and continuously balance time, cost and scope to react on changes and still fulfilling the constraints.
PRJ

EF 02.4

steps & goals

ENGINEERING FUNDAMENTALS

Software Engineering Process

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1. WORKFLOW CYCLES
The workflow has five cycles which continuously iterate through their steps. Workflow steps are executed in each cycle in sequence, but may be skipped if dispensable in a particular iteration of the process. The length of an iteration is arbitrary, but can be e.g. about 1/3 of a Scrum sprint.

2. WORKFLOW STEPS:
The workflow steps describe a logical activity which has to be performed. Each step relates to one or more discipline areas and their corresponding disciplines, which express the operative responsibilities for each workflow step. In each discipline individual roles act.

3. WORKFLOW ROLES:
The workflow roles are held by individual persons. Each role is primarily responsible for a particular workflow step. In addition, each role can be secondarily responsible for other workflow steps or at least actively support those steps.

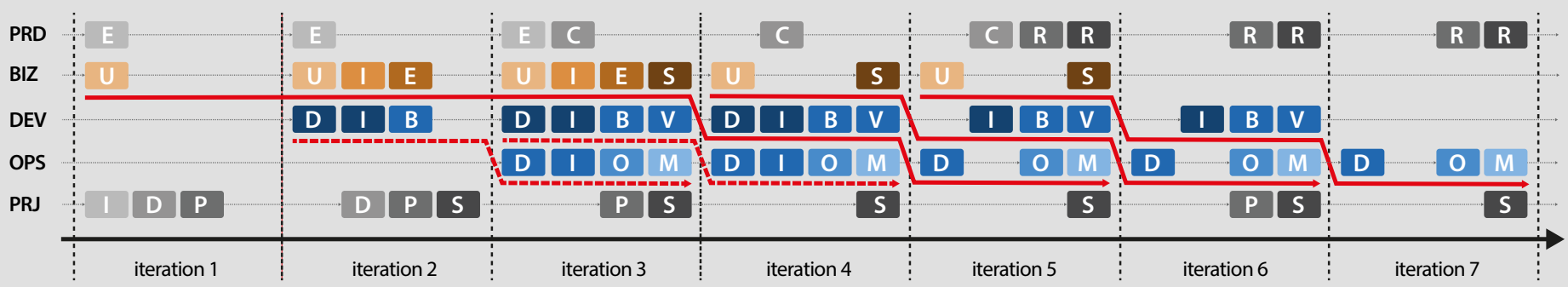
4. PROJECT SCHEDULE:
To create a particular project execution schedule, the five cycles, their iterations and their steps have to be mapped onto a timeline. The cycles are mapped onto (horizontal) timeline tracks, the iterations are mapped onto (vertical) timeline phases, and the steps are mapped onto timeline activities.

5. PROCESS FLOWS (THE CRUX):
The activities across the cycles can (and should) be linked into individual (diagonal) waterfall-like flows, although the execution schedule, from the perspective of the cycles, is fully iterative. There are multiple such flows in parallel and they are usually highly interleaved on the project timeline in order to maximally utilize the team.

6. PROCESS ADAPTION:
In the meta-step ADAPT, the process is adapted by choosing which workflow steps are required for the next iteration. The major input for this decision is the current solution state and the feedback on it by the customer.

		business-oriented & domain-specific				constructive & technological				infrastructural & technological				analytical & domain-specific				people-oriented & process-oriented			
		AN		EX		AR		DV		CF		DL		AC		CP		MG		AD	
		REQ	DOM	UXP	UID	SWA	SYA	DEV	REF	VER	ASM	DPL	OPS	REV	TST	DOC	TRN	PRD	PRJ	COA	CGH
		Requirements Engineer	Business Architect	User Experience Expert	User Interface Designer	Software Architect	System Architect	Software Developer	Software Developer	Configuration Manager	Build Manager	System Engineer	System Administrator	Software Tester	Software Tester	Technical Writer	Product Trainer	Product Owner	Project Manager	Project Coach	Change Manager
PRD	ENVISION	+	+	*														*			
	CONFIGURE	+	+	+						*								*			
	RELEASE									+	*					*	+	*	+		+
	ROLLOUT																*	+	+		*
BIZ	UNDERSTAND	*	*	*														*			
	IDEATE	+	+	*														+			
	EXPLORE	+	+	*	*	*	+	*										+			
	SPECIFY	*	*	+	*	+	+								+	+					
DEV	DESIGN	+	+	+	+	*	*			+	+	+		+	+			+			
	IMPLEMENT				*		+	*	*	+	+			*		*					
	BUILD					+	+	+		*	*	+		+							
	VERIFY	+	+	+	+	+	+	+						*	*			+			
OPS	DEPLOY					+	*	+		+	+	*	*								+
	INTEGRATE					+	*			+	+	*	*								+
	OPERATE											+	*								
	MONITOR	+	+	+		+	+					+	*		*			+			
	ADAPT	+	+	+		+	+											*	*	*	+
PRJ	INITIATE																		*	*	
	DEFINE	+	+			+												*	*		
	PLAN	+	+			+												*	*		
	STEER	+	+			+													*		

* responsible (primarily)
* responsible (secondarily)
\+ supporting



EF 02.5

roles & tasks

ENGINEERING FUNDAMENTALS

Software Engineering Artifacts

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EF 02.6

1 Software **Requirements** Specification — *input / what* — REQ

Requirements: **Customer Journey** — REQ UXP PRD — 2 ENVISION	Domain Model: **Personas** — REQ DOM UXP — 3 UNDERSTAND
Requirements: **Solution Vision** — REQ UXP PRD — 2 ENVISION	Domain Model: **Test Cases** — REQ DOM TST — 3 SPECIFY
Requirements: **Functional Requirements** — PRD UXP REQ — 1 UNDERSTAND	User Interface: **Usage Concept** — UXP UID — 2 SPECIFY
Requirements: **Non-Functional Requirem.** — PRD SWA REQ — 1 UNDERSTAND	User Interface: **Language Conventions** — REQ UXP UID — 3 SPECIFY
Domain Model: **Data Model** — REQ DOM — 1 SPECIFY	User Interface: **Dialog Patterns** — UXP UID — 3 SPECIFY
Domain Model: **Use Cases** — UXP REQ DOM — 1 SPECIFY	User Interface: **Dialog Storyboard** — REQ UXP UID — 1 SPECIFY
Domain Model: **Use Case Scenarios** — UXP REQ DOM — 2 SPECIFY	User Interface: **Visual Design** — PRD UXP UID — 3 SPECIFY

2 Software **Architecture** Specification — *input / how* — ARC

Viewpoint: **Context View** — SYA SWA PRD — 2 ENVISION	Perspective: **Configurability & Extensibili.** — DEV SWA DPL — 3 INTEGRATE
Viewpoint: **Functionality View** — DOM SYA SWA — 1 DESIGN	Perspective: **Performance & Scalability** — OPS DPL SYA SWA — 1 DESIGN
Viewpoint: **Information View** — DOM SWA — 1 DESIGN	Perspective: **Availability & Recoverability** — SYA SWA DPL OPS — 2 OPERATE
Viewpoint: **Concurrency View** — DEV SYA SWA — 2 DESIGN	Perspective: **Reliability & Resilience** — DEV SYA SWA — 2 DESIGN
Viewpoint: **Development View** — ASM VER SWA DEV — 3 IMPLEMENT	Perspective: **Interoperability & Compatib.** — DEV SWA — 3 DESIGN
Viewpoint: **Deployment View** — SYA SWA OPS DPL — 1 DEPLOY	Perspective: **Compliance & Tracability** — PRD TST SWA DEV — 3 IMPLEMENT
Viewpoint: **Operations View** — SYA SWA DPL OPS — 2 OPERATE	Perspective: **Security & Safety** — DEV SWA — 1 DESIGN

3 Software **Implementation** Results — *output / what* — IMP

Source Code: **Application** — REF DEV — 1 IMPLEMENT	Binary Code: **Application** — ASM — 1 BUILD
Source Code: **Build Automation** — DEV VER ASM — 2 BUILD	Source Code: **Deployment Automation** — DEV VER DPL — 3 DEPLOY
Source Code: **Test Automation** — DEV TST — 3 VERIFY	Source Code: **Operation Automation** — DEV OPS — 3 OPERATE

Notice: Artifacts vs. Aspects

The four **Artifact Sets** shown here just cluster the individual **Artifacts** and their contained **Aspects**. The **Artifacts** can be represented in an arbitrary graphical and/or textual form and be provided in an arbitrary format. The **Aspects** just structure an individual Artifact internally.

Notice: Internal vs. External

In a Software Engineering project, additional **internal Artifacts** are created by the **Disciplines** in order to perform their work efficiently and effectively. The Artifacts shown here are the **external** ones which value together the Disciplines and which are part of the delivery set.

4 Software **Documentation** Results — *output / how* — DOC

User Guide: **Usage Tutorial** — UXP TRN DOC — 2 SPECIFY	Operation Guide: **Configuration Reference** — TRN DOC DPL DEV — 1 IMPLEMENT
User Guide: **Functionality Reference** — DOM TRN DOC — 1 SPECIFY	Operation Guide: **Deployment Procedure** — TRN DOC OPS DPL — 1 DEPLOY
User Guide: **Release Information** — PRD VER — 3 RELEASE	Operation Guide: **Operation Procedures** — TRN DOC DPL OPS — 2 OPERATE

Notice: Artifact Tagging

Each Artifact is tagged with the primarily and secondarily responsible **Disciplines**, the primary **Step** of the **Workflow** where the Artifact is developed, and the **Scalability Layer** (1 to 3, indicating more to lesser importance).

Notice: Domain vs. Technology

The **Software Requirements Specification** and the **Software Documentation Results** primarily have a **domain-specific** focus. The **Software Architecture Specification** and the **Software Implementation Results** primary have a **technological** focus.

artifacts & deliverables

ENGINEERING FUNDAMENTALS

Software Engineering Efforts

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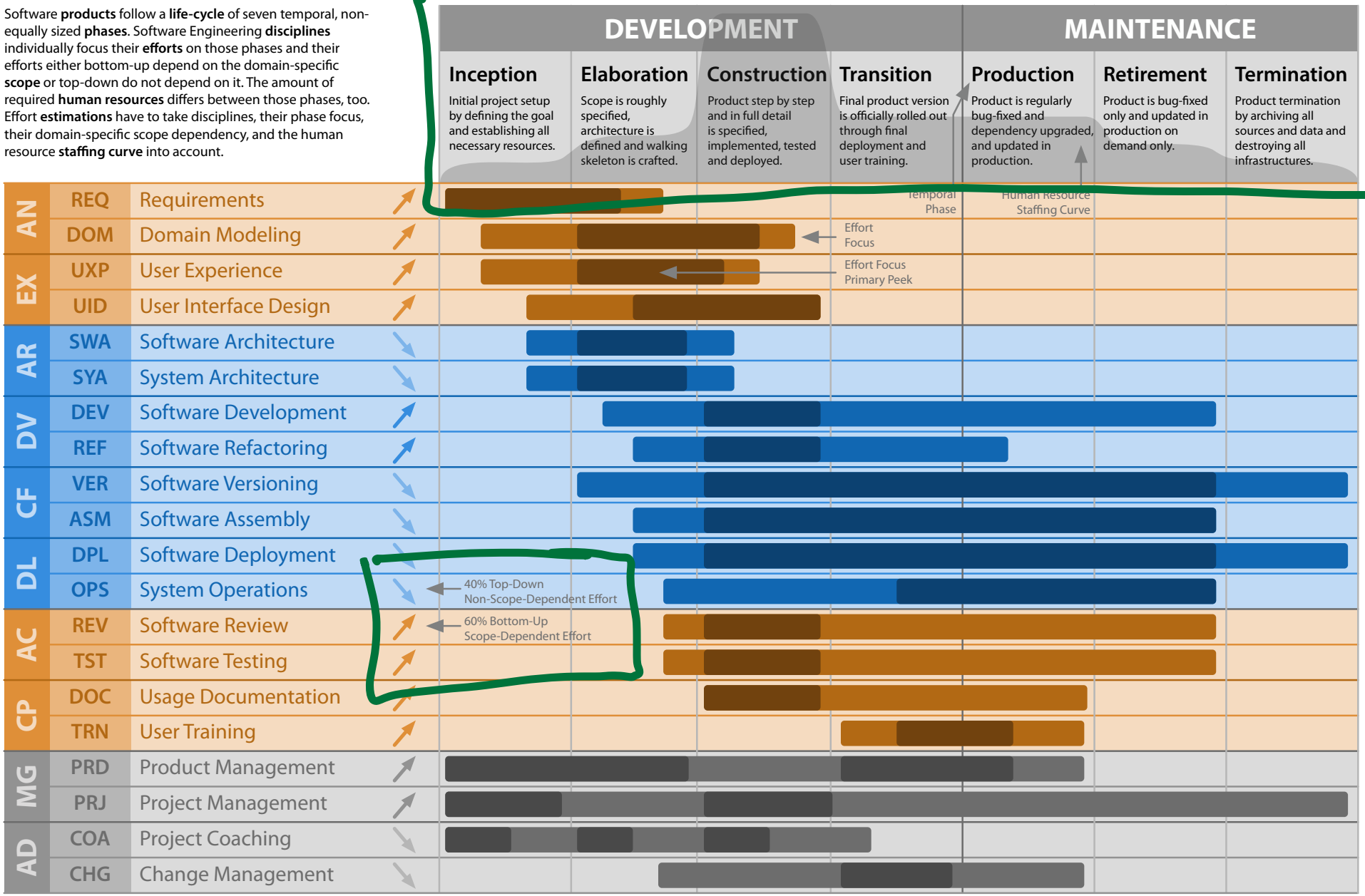
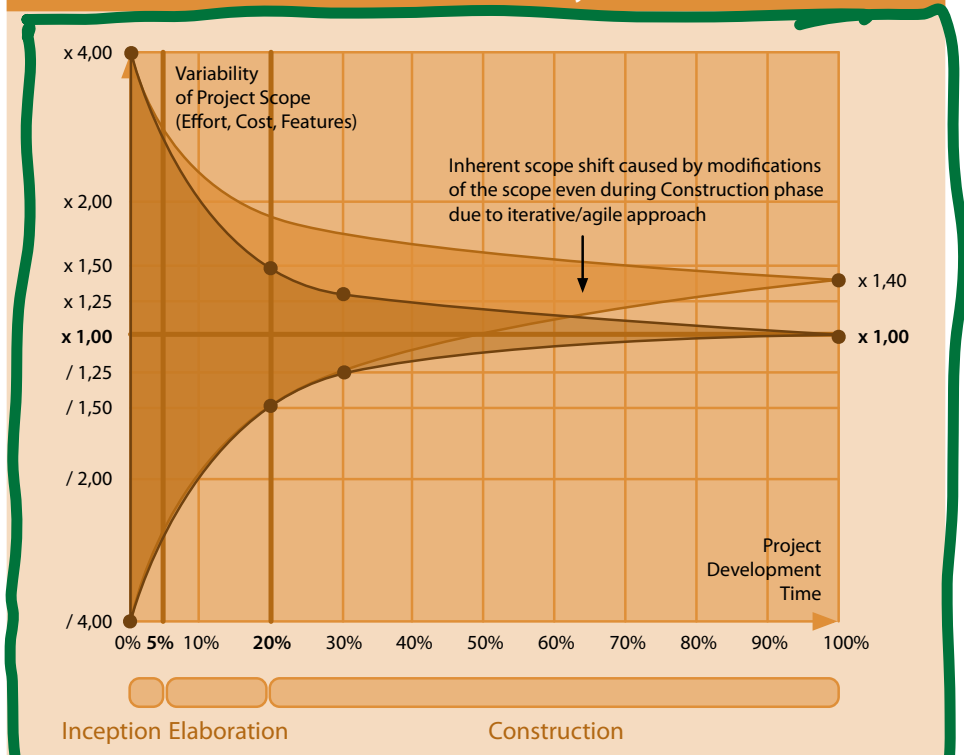
Software **products** follow a **life-cycle** of seven temporal, non-equally sized **phases**. Software Engineering **disciplines** individually focus their **efforts** on those phases and their efforts either bottom-up depend on the domain-specific **scope** or top-down do not depend on it. The amount of required **human resources** differs between those phases, too. Effort **estimations** have to take disciplines, their phase focus, their domain-specific scope dependency, and the human resource **staffing curve** into account.



Uncertainty & Elaboration

Cone of Uncertainty



The ***Cone of Uncertainty*** (*Steve McConnell*, 2006) tells how the variability of the project scope (measured in Effort, Cost or Features) in Software Development changes over time. Initially, it usually is within the range of +/- 400% of the final scope.

The early development phases Inception and Elaboration especially have to ensure that within the first 20% of the project, the variability is reduced noticeably to just +/- 50%. During the initial iterations of the Construction phase within the first 30% of the project, the variability usually can be further reduced to about +/- 25%.

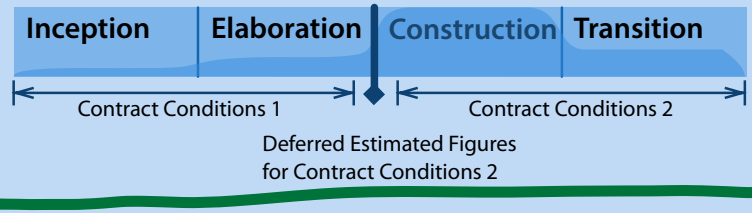
For iterative/agile approaches, experience showed that during the Construction phase inherently the final scope further shifts by about + 40% due to the just step-by-step learned required details of the required solution. This especially has to be taken into account for estimations.

Essential Elaboration Phase

Walking Skeleton:

The ***Walking Skeleton*** (or *Technical Breakthrough*) is the design and implementation of the bare technical foundation of an application, still *without* any domain-specific functionalities. It is made during the Elaboration phase with the primary purpose to establish a stable integration of all technical aspects (libraries, frameworks, build procedures, etc.) onto which the domain-specific functionalities later can be successively put onto.

Agile Fixed-Price Contracts:



The ***Agile Fixed-Price*** is an agile variant of a fixed-price contract, *not* a fixed-price project with an agile development process.

There are two important inherent aspects:

First, the contract contains two types of conditions: one (usually *Time & Material* but fixed duration based) for the Inception and Elaboration phases in order to make experiences and to gather necessary figures, and one (usually Fixed-User-Story and/or Fixed-Price based) for the Construction and Transition phases based on deferred estimated figures, gathered in the Elaboration phase.

Second, the Fixed-Price aspect of the contract is actually based on an amount of User-Stories (resulting in costs by multiplying them with either an average hourly rate of an engineer or individual rates based on engineer job levels), which the customer can 1:1 *exchange* during the project for different deliverables.

The crux of an Agile Fixed-Price contract is: first, during the Inception and Elaboration phases the supplier can shrink the *Cone of Uncertainty* and this way its risks dramatically, and second, during the Construction and Transition phases the customer still remains flexible in scope.

Effort Estimations

Estimation & Variability

Three-Point Estimation and Estimation Variability Classes:

$e = (b + 4 \times m + w) / 6$	expected effort (weighted average)
$s = (w - b) / 6$	standard deviation (effort variation)

b: best-case (optimistic)
m: most-likely (realistic)
w: worst-case (pessimistic)

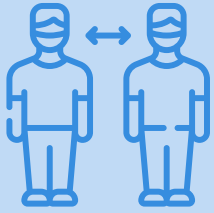
Insane Variability: +/- 10%
Very Good Variability: +/- 15%
Good Variability: +/- 20%
Acceptable Variability: +/- 25%

Conversion & Normalization

1. Ask Estimater:
"How many Person-Days do you need when you can focus on this task?"

2. Convert from Estimator to Performer:
(see also CAP-Model, http://cap-model.com)

Estimator \ Performer (Non-Linear Effort Reduction)	Novice 0%	Practitioner 10%	Master 25%	Expert 45%	Guru 80%
Novice	1,00	0,90	0,75	0,55	0,20
Practitioner	1,11	1,00	0,83	0,61	0,22
Master	1,33	1,20	1,00	0,73	0,27
Expert	1,82	1,64	1,36	1,00	0,36
Guru	5,00	4,50	3,75	2,75	1,00

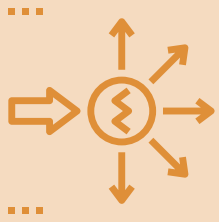


Sizes & Variability

Estimation Sizes and Estimation Variability:

T-Shirt-Size (Logically)	XXS	XS	S	M	L	XL	XXL	XXXL
Fibonacci-Size (PD or SP)	**0,50**	**1**	**2**	**3**	**5**	**8**	**13**	**21**
Size Variability (-)	0,25	0,25	0,50	0,50	1,00	1,50	2,50	4,00
Size Variability (+)	0,25	0,50	0,50	1,00	1,50	2,50	4,00	8,00

Notice: Estimations can be done in *Person-Days (PD)* or *Story-Points (SP)*. In both cases, keep in mind to use something like the *Fibonacci* numbers which increase in a non-linear fashion and express the increasing variability with the increasing total amount of estimated effort.



Risk Mitigation & Upscaling

3. Adjust for Reality:
Estimator Optimism: +30%
Performer Meetings: +20%

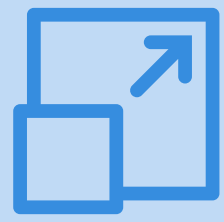
4. Adjust for Uncertainty:

Domain	Inception	Elaboration	Construction
unknown	30%	40%	20%
partially known	15%	20%	10%
fully known	0%	0%	0%

Technology	Inception	Elaboration	Construction
unknown	20%	60%	10%
partially known	10%	30%	5%
fully known	0%	0%	0%

Process	Inception	Elaboration	Construction
unknown	60%	40%	10%
partially known	30%	20%	5%
fully known	0%	0%	0%

People	Inception	Elaboration	Construction
unknown	60%	40%	0%
partially known	30%	20%	0%
fully known	0%	0%	0%



ARCHITECTURE FUNDAMENTALS

Requirements Basics

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Requirements Specification

A binding document that specifies the requirements for a solution, by focusing on the WHAT and WHY of the solution — and *not* giving instructions for the HOW.

The documented set of requirements has to be: correct, unambiguous, complete, consistent, ranked, verifiable, modifiable, and traceable.

Requirement Classes

FR Functional (Shall Do)

A condition or capability that a solution must have to provide its service in terms of its behaviour and information. Think: Functionality.

NFR Non-Functional (Shall Be)

A condition, property or quality that a solution must have to satisfy a contract, standard, or other formally imposed obligation. Think: Constraints and "*-ilities".

Requirement Interdependencies

POS Positive (Backing)

One requirement supports the other (e.g. for NFRs: Maintainability and Comprehensibility usually support Adaptability, Portability, Modifiability, etc., and Scalability usually supports Availability, etc.)

NEG Negative (Trade-Off)

One requirement interferes with the other (e.g. for NFRs: Security usually interferes with Efficiency, Usability, Performance, etc., and Orthogonality can interfere with Usability)

Requirement Characteristics

S Specific

The requirement is precise, unambiguous, and clear on what should be done.

M Measurable

The requirement can be verified when it has been achieved by use of a particular test.

A Achievable

The requirement is achievable given existing circumstances and feasible and viable solutions.

R Relevant

The requirement is relevant to the goals of the context.

T Time-Bound

The requirement can be achieved within a reasonable time frame.

Requirement Life-Time

E Enduring

The requirement lasts forever, as it is derived from core activities and organisational structure.

V Volatile

The requirement can be temporary, as it might change over time.

Requirement Expression

[<req-id>] <req-name>:
<subject/actor>
SHALL
<result/action/condition>
BECAUSE
<rationale>

ARCHITECTURE FUNDAMENTALS

Non-Functional Requirements

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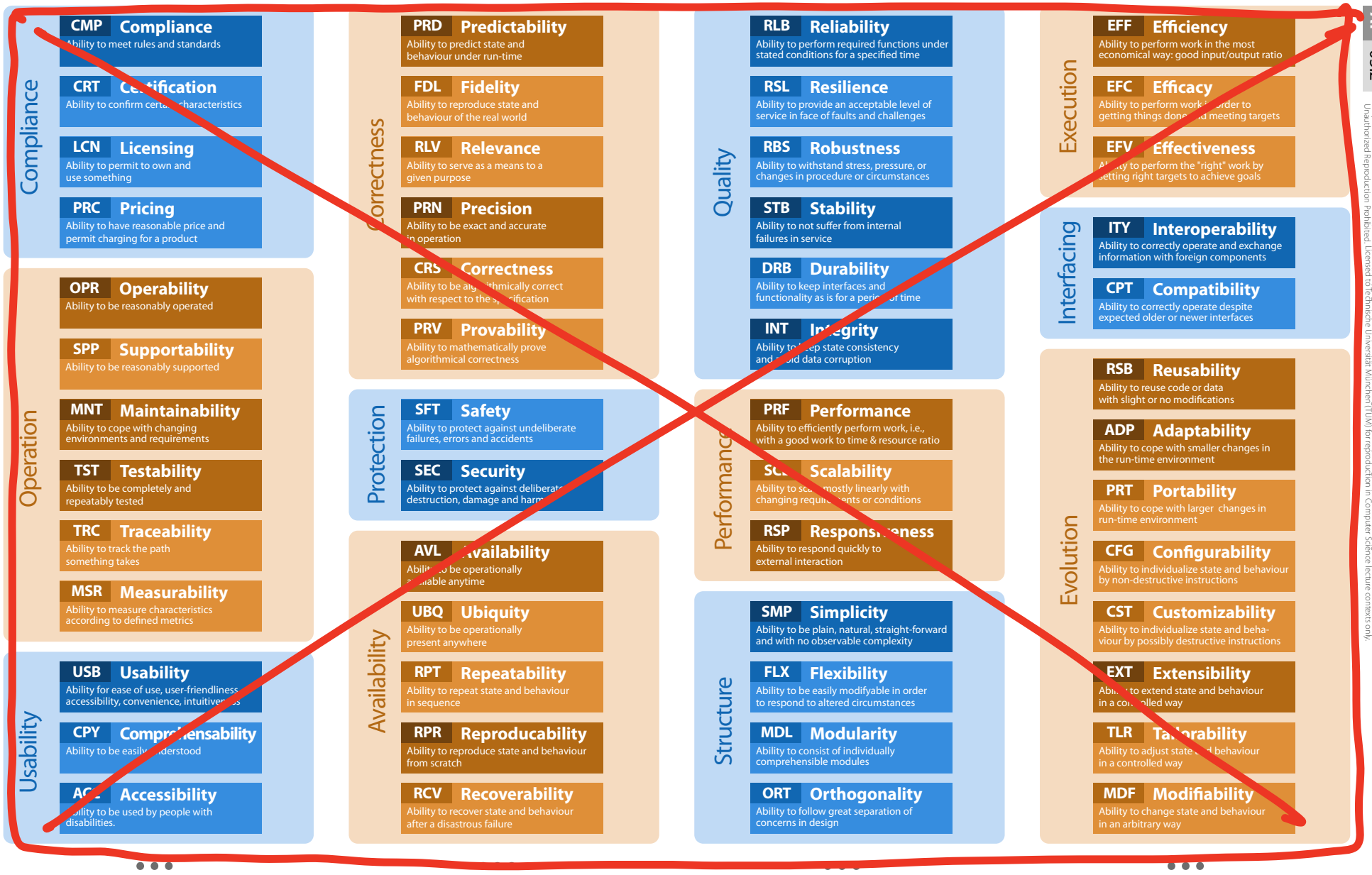

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ARCHITECTURE FUNDAMENTALS

Architecture Stargate

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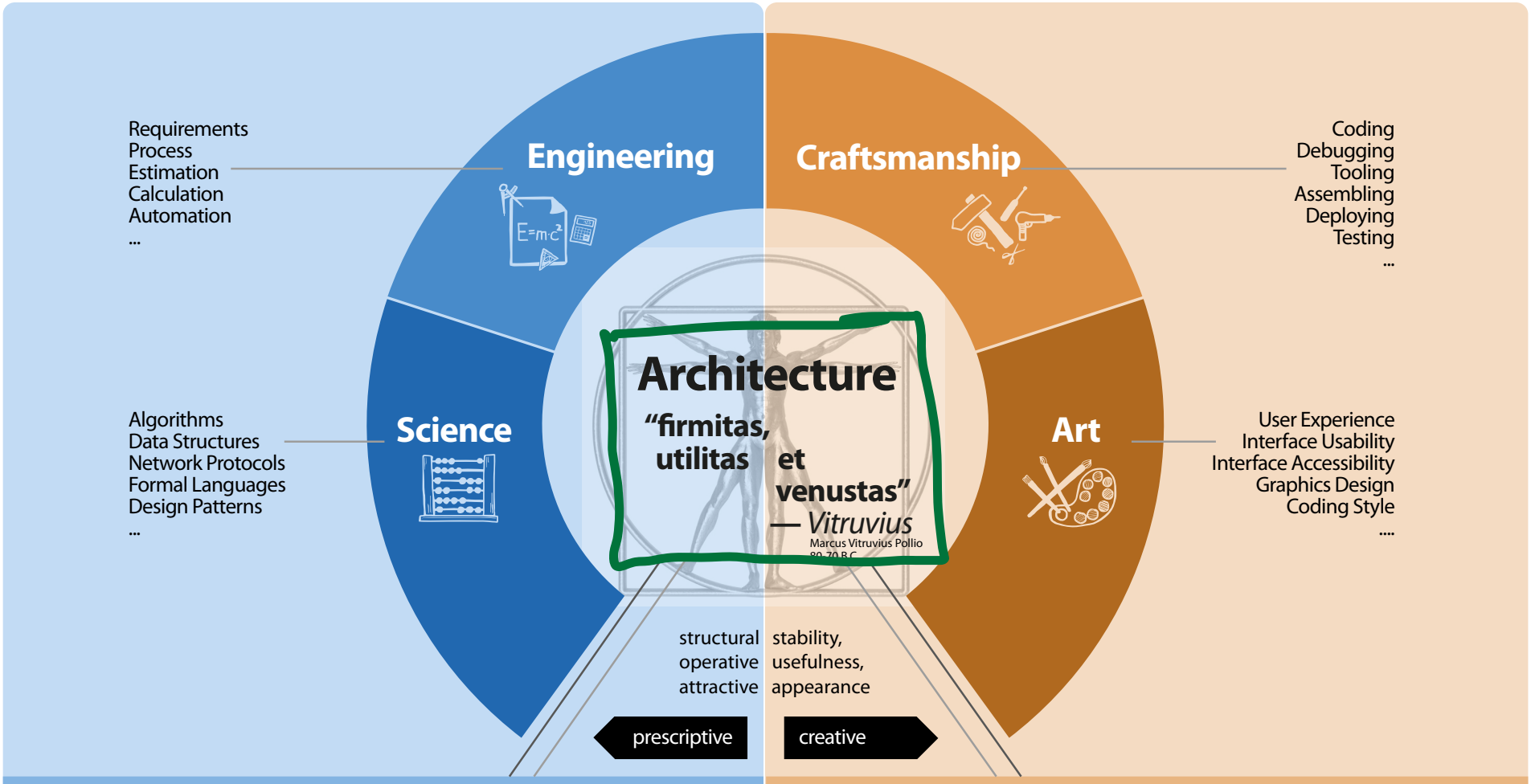


Structural Scientific Definition of Architecture:
Architecture of a system is the set of fundamental **concepts** and **properties** of the system in its environment, embodied in its **elements**[, **interfaces**], **relationships**[and **behaviours**] and the principles of its **design** and **evolution**.
(based on industry standard *ISO/IEC 42010*)

Holistic Artistic Definition of Architecture:
Great architecture is achieved **harmony** and **accord** of all **parts**, where you no longer can add, modify or remove anything without impairing the **whole**.
(based on a quote by *Leon Battista Alberti* on beauty)

Adequacy and Beauty

ADEQUACY

1. **Measure**, how **suitable**
2. something,
3. in its environment,
1. fulfills
4. its imposed functional and qualitative requirements (fitness for purpose),
5. from the **individual** and **subjective** perspective of a person.

Beauty does imply **Adequacy**

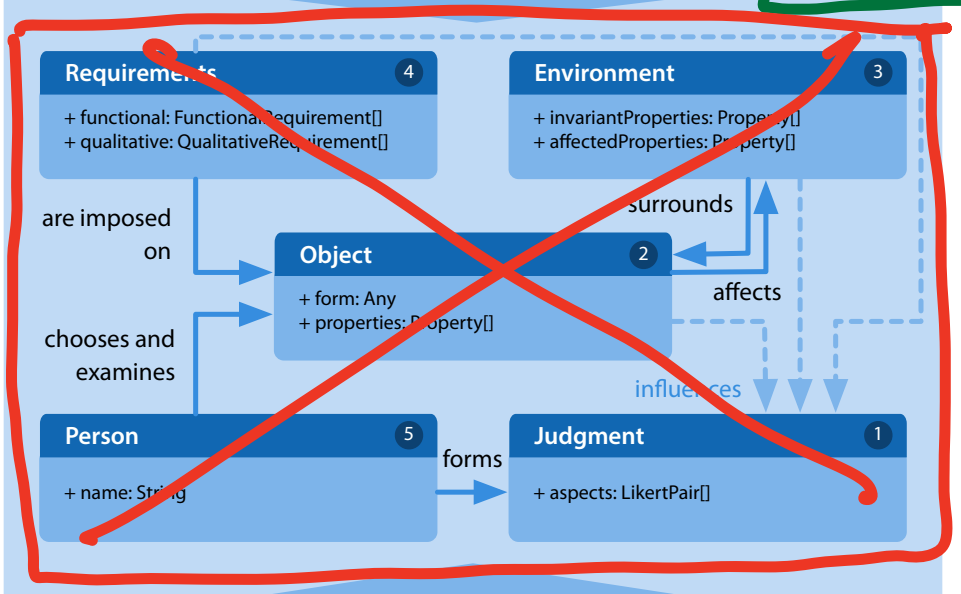
No Beauty does *not* imply No Adequacy

No Adequacy does imply **No Beauty**

Adequacy does *not* imply Beauty

BEAUTY

Perception, how **simple, elegant, natural, securing and evident** (SENSE) something is, from the **evolutionary** and **cultural** perspective of a person.



Simple S

free from *unnecessary* complexity, easy *enough* to comprehend.

Elegant E

broadly applicable, allows combinatorial use-cases.

Natural N

consistent, symmetric, free of anomalies.

Securing S

allows *feeling* safe by captured experiences or omnipresence.

Evident E

obvious, clear and traceable representation.

Adequacy is a **relative** and highly **subjective measure** that defies scientific objectification. Nevertheless, it is an essential concept, as the **three influencing aspects** allow persons in practice to at least better **structure** their **perception and judgment** and **measure** the **differences** over time.

Beauty is a **relative** and highly **subjective perception** that defies scientific objectification. Nevertheless, it is an essential concept, as the **SENSE aspects** *seem* to be universal across persons and allow them to **communicate** their **perception and judgment** and **observe** the **differences** over time.

ARCHITECTURE FUNDAMENTALS

King Discipline Architecture

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Domain

Many specific Domains

N

Domain
Analytics
Business

domain-specific
usage-oriented
specific

Architecture

One (or few) generic Architectures

1

Architecture
Design
Construction

conceptual
constructional
generic

Technology

Many specific Technologies

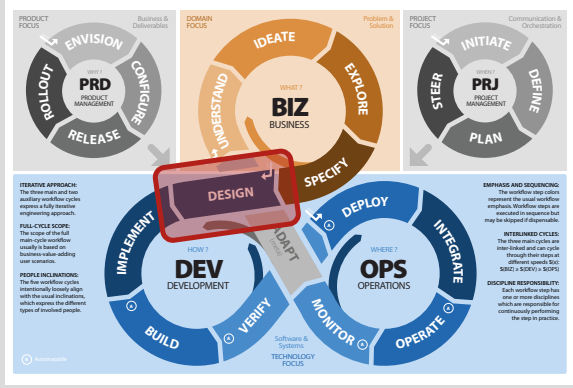
M

Technology
Development
Realisation

technological
programmatic
specific

Software Engineering Disciplines

Software Engineering Workflow



Manifesto for IT Architecture

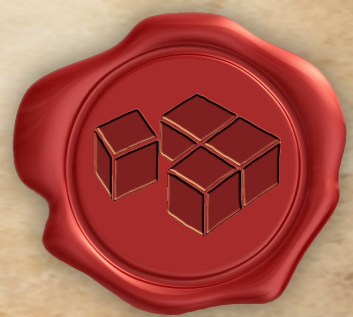
Continuously Raising the Bar

Mission As IT Architects we guide the design, implementation and evolution of IT solutions.

Entitlement We continuously strive to raise the bar of professional IT architecture by practicing it and helping others to learn our craft.
We achieve maximum value for our clients through our work.

Values Through this work we have come to value aspects of our craft.
While we acknowledge the beneficial values in the items on the right, we appreciate the stronger values in the items on the left even more.

Sustainable Concepts	over	**Latest Technologies**
Pragmatic Making	over	**Theoretical Consideration**
Constructive Craftsmanship	over	**Analytical Engineering**
Accredited Creativity	over	**Achieved Industrialization**
Proactive Improvement	over	**Reactive Correction**
Inherent Quality	over	**Tested Robustness**
Operational Delight	over	**Useful Functionality**



ARCHITECTURE FUNDAMENTALS

Complex vs. Complicated

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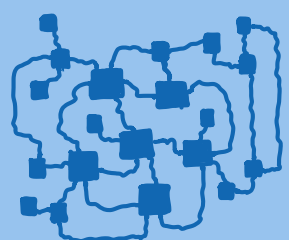
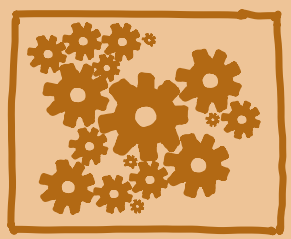
AF 01.5

	complex	complicated
FOCUS	refers to the **extrinsic** and **higher**- or **macro**-level difficulty of a system,	refers to the **intrinsic** and **lower**- or **micro**-level difficulty of a system,
RATIONALE	because the system involves many different and **connected** parts	because the system involves many different and **difficult** aspects
CHALLENGE	which take time to **comprehend** and **master** in **total**,	which take time to **understand** and **learn** in **detail**,
INSIGHT	and which nevertheless are **easy** to explain.	and which usually are **hard** to explain.





NOTICE	NOTICE
Simple (non-complicated) systems can be **complex**.	**Clear** (non-complex) systems can be **complicated**.

RECOGNIZE	RECOGNIZE
Architecture primarily has to master the **complex** aspects of a system.	**Development** primarily has to master the **complicated** aspects of a system.

ARCHITECTURE FUNDAMENTALS

Architecture Space

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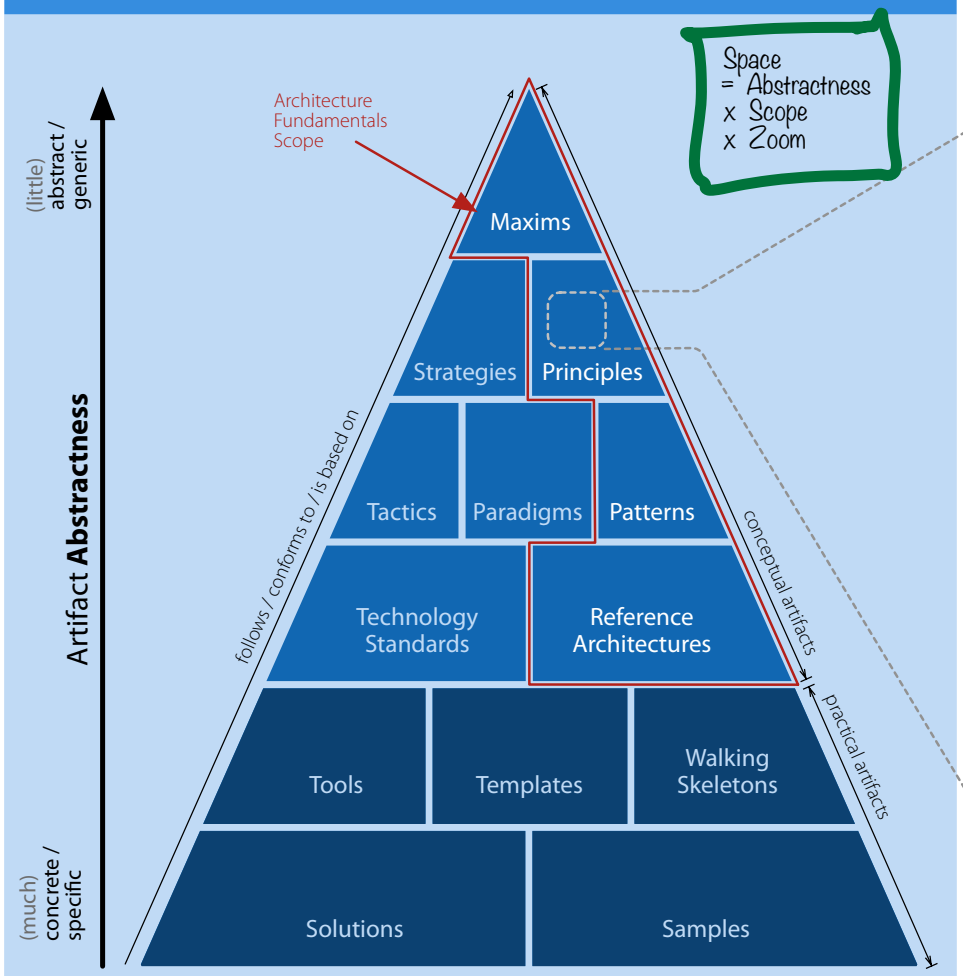
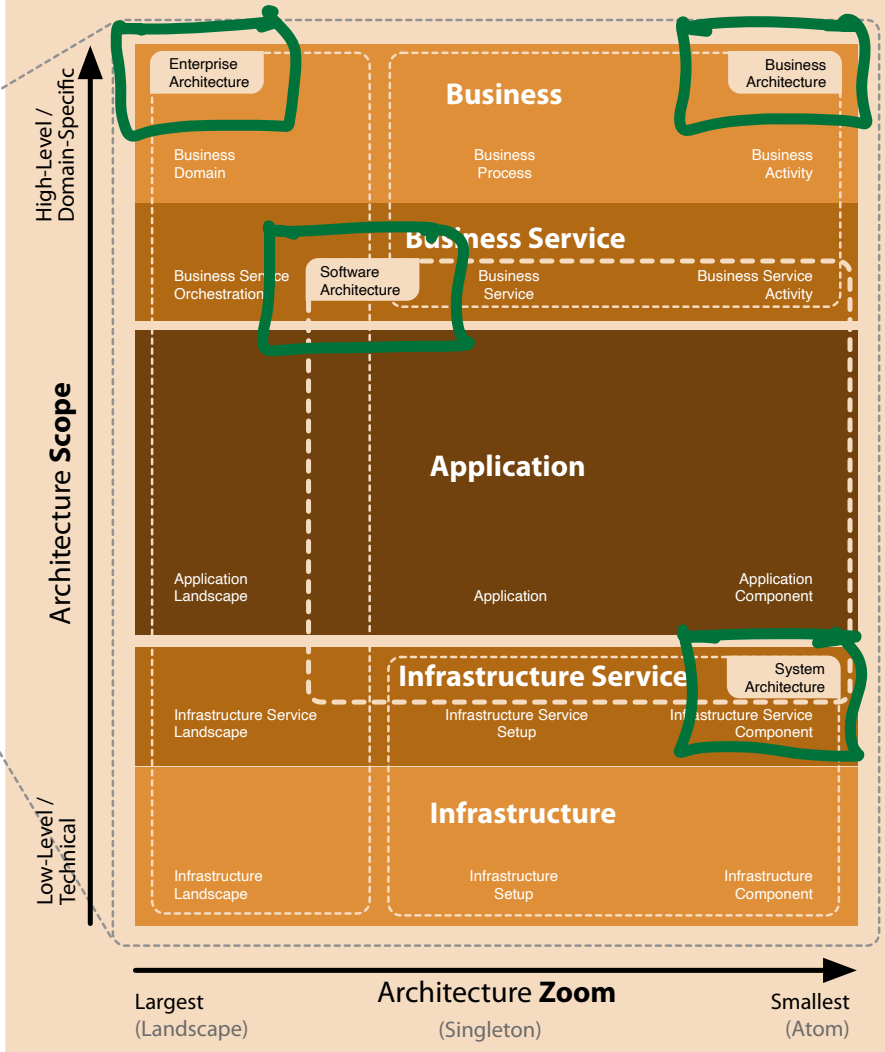
Artifact Abstractness



Architecture Scope & Zoom



ARCHITECTURE FUNDAMENTALS

Architecture Ontology

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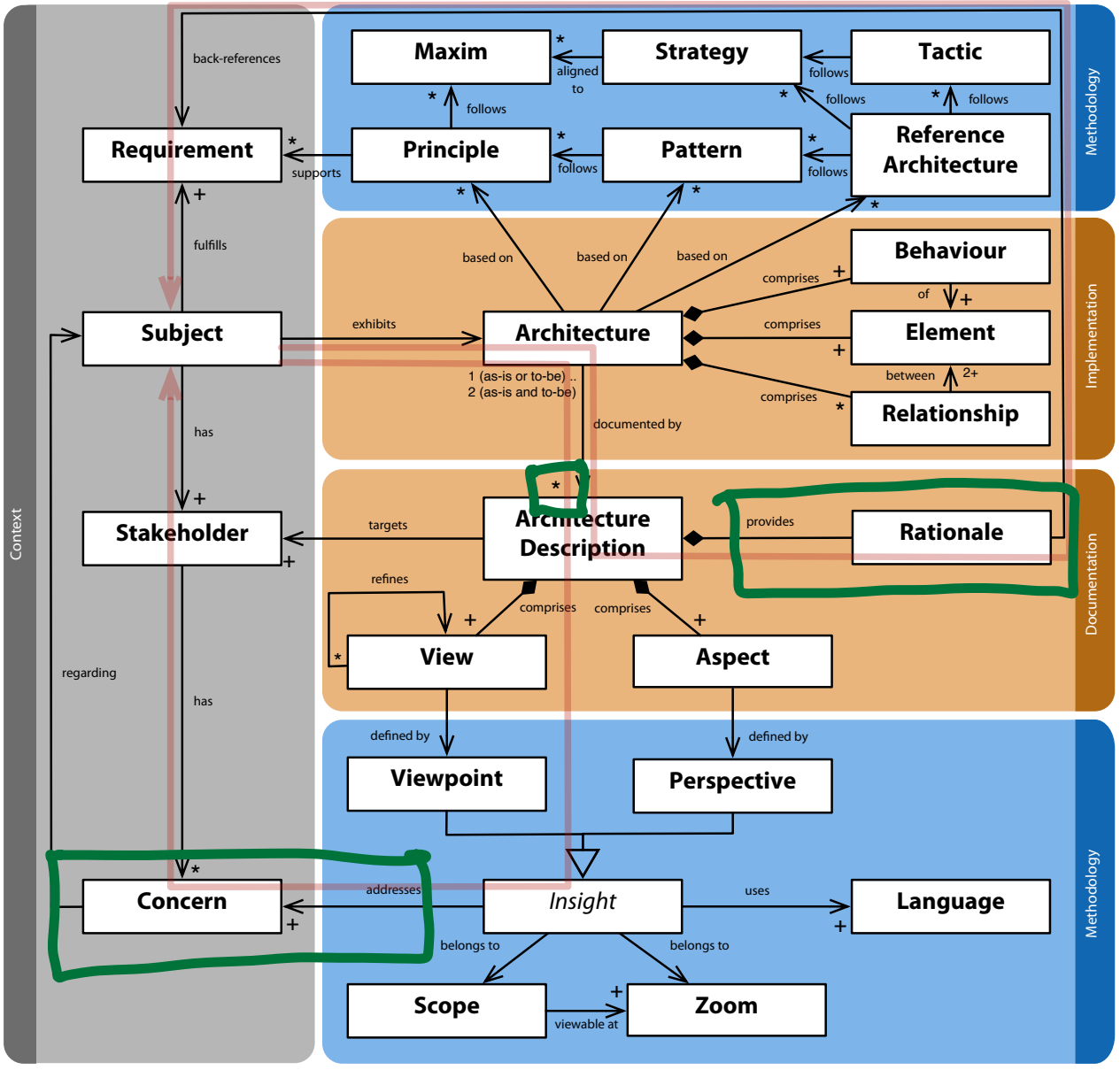

Requirement: A functional or non-functional demand or imposed obligation on the Subject.

Architecture: Inherent static and dynamic structure of a Subject which comprise Elements, the visible Behaviour of Elements and Relationships between Elements.

Maxim: Fundamental, generally valid set of values and rules to guide the architecture discipline (think: law).

Subject: Any type of business process, business service, software application, infrastructure service or infrastructure setup.

Element: Fundamental part from which a Subject can be considered to be constructed.

Strategy: Long-term situation-independent plan of approaches to achieve a particular goal (think: war). Aligned and not in conflict with any Maxims.

Stakeholder: Person, group or entity with an interest in or Concerns about the Architecture.

Behaviour: Run-time characteristic of Architecture Elements of the Subject.

Tactic: Short-term situation-dependent plan of actions to achieve a particular goal (think: battle). Following and supporting a Strategy.

Concern: Requirement, objective, intention, or aspiration a Stakeholder has on an Architecture.

Relationship: Static or dynamic relationship between Elements of an Architecture of the Subject.

Principle: Fundamental truth, rule, tenet or policy an Architecture follows.

Architecture Description: Set of artifacts that document an Architecture in a way Stakeholders can understand and ensures their Concerns are met.

Rationale: Fundamental reasons for a particular chosen Architecture, usually strongly based on non-functional Requirements.

Pattern: Proven recurring theme, structure, approach or behavior an Architecture and its Elements can follow.

Viewpoint: Collection of templates and conventions for constructing one type of View. It addresses Concerns and contains guidelines for constructing a View.

View: Representation of one or more structural aspects of an Architecture that illustrates how the Architecture addresses one or more Concerns.

Reference Architecture: Reusable proven Architecture template, based on a set of Patterns and following one or more Tactics and Strategies.

Perspective: Collection of decisions, guidelines and rules that ensure a Subject exhibits a set of non-functional Requirements, considered across a number of Views.

Aspect: Representation of one or more non-functional aspects of an Architecture that illustrate how the Architecture addresses one or more Concerns.

Scope: Primary area of the Architecture space an Insight addresses: either Business, Business Service, Application, Infrastructure Service or Infrastructure.

Insight: Superordinate abstract concept to address particular Concerns through Viewpoints and Perspectives.

Language: Formal, semi-formal or even prose language to describe an Insight, so it optimally addresses the Concerns of Stakeholders.

Zoom: Level of view distance to the Architecture an Insight has. Also known as the Insight detail level, ranging from smallest atoms, over singletons to the largest landscape.

AF 02.2

ARCHITECTURE FUNDAMENTALS

Architecture Maxims

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AF 04.1

Business Drives (BD)

Trigger and support the business with technological feasibilities, but always understand the business domain and its demands and align your architecture accordingly.

Component Orientation (CO)

Master complexity in your architecture through stringent bottom-up use of components on all scopes and zoom-levels, loose coupling between and strong cohesion within components.

Separation of Business and Technology (BT)

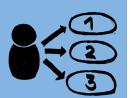
Strictly separate the business, i.e., domain-specific, aspects from the technological, i.e., infrastructural, aspects. Furthermore, ensure the explicit visibility of domain concepts.

Adequate Description (AD)

Provide as much stakeholder-directed architecture description as necessary, and as little as possible.

Use-Case Driven Design (UC)

Design is how it works and runs, so support your customers in their daily work by directly designing your architecture along their domain-specific use-cases.

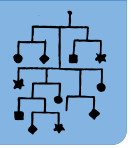


Analytical and Creative Act (AC)

Recognize that every good architecture is based on both analytical engineering (structure) and creative artistic (beauty) aspects.

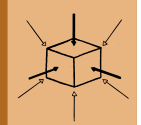
Balance Principles Against Requirements (PR)

By weighing them against one another, find a reasonable balance between fundamental architecture principles and your particular non-functional requirements.



Insights through Views & Aspects (VA)

Give insights into your architecture through carefully selected stakeholder-directed separate views and aspects. Express each with the most suitable graphical or textual language.



Proven Basis (PB)

Never start an architecture from scratch. Instead start from proven reference architectures, patterns and templates. Even if, after some iterations, no initial content is left.

Don't Be Too Clever (TC)

Don't be too clever or tricky, both in your higher-level architecture and lower-level design aspects.

Design for Failure Case (DF)

Murphy was an architect: everything which can fail will sometime ultimatively fail. Hence, already design for the failure case (think: "pessimistic").

Continuous Compliance (CC)

Continuously check through qualitative inspections and quantitative measurements whether your architecture and the non-functional requirements are followed and do not drift apart.

No Silver Bullet (SB)

There is no "one-size-fits-all" architecture, so accept that although you should reuse proven architecture aspects as much as possible, you will always need to individualize your designs.

Simplicity Trumps (ST)

Create solution parts as simple as possible and only as complex as necessary. And remember: simplicity before generality, use before reuse!

Design to Change (DC)

Time changes everything, so your solution is already legacy at the first day of release. Hence, already design for its change (think: "agile").

Integration-Figure Architect (IF)

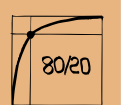
Recognize that you, the architect, are the central integrating figure, having to bridge between the business and technology spheres of people.

Stepwise Refinement (SR)

Start with the "big picture" and perform a stepwise top-down refinement of your architecture by going from coarse to fine aspects.

Perfect is the Enemy of Good Enough (GE)

Beware of the perfection pitfall and design your architecture only as good as necessary and not as good as ultimately possible.



Explicit Decisions (ED)

Record your major architecture decisions and rationales by taking into account and back-referencing the non-functional requirements.

Eat Your Own Dog-Food (OF)

Theory and practice usually differ. Hence it is vital that every architect has good hands-on experience and must both be able to craft the solution and is willing to hypothetically intensively use it himself.

ARCHITECTURE FUNDAMENTALS

Architecture Principles

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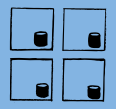
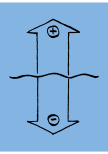
FL Factual Locality
Resources are as spatially and temporarily local-scoped to solution components as possible

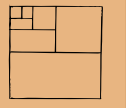


ES Exclusive Sovereignty
Exclusive resource sovereignty by the enclosing component

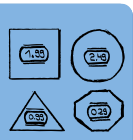
CA Contextual Adequacy
Neither insufficient nor exaggerated solutions for each context



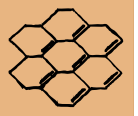
SP Solution-oriented Proportionality
Good expected proportionality in each solution context



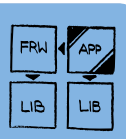
HC Holistic Consistency
Full consistency across all aspects of a solution



SH Structural Homogeneity
Maximum homogeneity in the structure of a solution



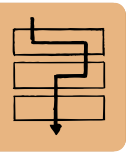
CR Constructional Reusability
High reuse of proven structural components and partial solutions



FS Fulfilled Standards
Compliancy to standards as much as possible, as long as the benefits predominate the drawbacks

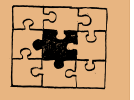
FA Functional Abstraction
Suitable level of abstraction across all functional aspects of a solution

FT Functional Traceability
Suitable traceability across all functional aspects of a solution



CI Communicative Interoperability
Maximum interoperability in communication between solutions

EH Environmental Harmony
Maximum harmony in the integration of the solution with its environment



AR Avoided Redundancy
Minimum total number of copies of a single resource

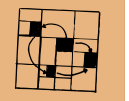
MS Minimum Special-Cases
Minimum total number of special-cases in a solution

LS Logical Separation
Separation of concerns between the components of a solution

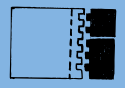
SM Structural Modularity
Splitting of a solution into manageable structural components

LC Loose Coupling
Loose coupling in communication and referencing between solution components

SC Strong Cohesion
Strong relationship between functionalities within a single solution component



OE Open Extensibility
Solution components can be extended by third-parties at fixed interfaces



CC Closed Changeability
Solution components are protected against direct change by third-parties

UI Unique Identification
Unique identification of all components of a solution

UA Uniform Addressing
Uniform addressing of all components of a solution

OS Overall Simplicity
All design aspects of a solution are as simple as possible and only as complicated as necessary

EC Encapsulated Complexity
Complex related aspects of a solution are encapsulated into a single responsible component

LA Least Astonishment
All design aspects of a solution are as little astonishing as possible and only as esoteric as necessary

SD Self Documentation
All design aspects of a solution are preferably self-documenting

OD Operational Delight
The solution provides users true delight even on long-term operation

AA Artistic Aesthetics
The solution has holistic aesthetics and artistic love in details

ARCHITECTURE FUNDAMENTALS

Component Design

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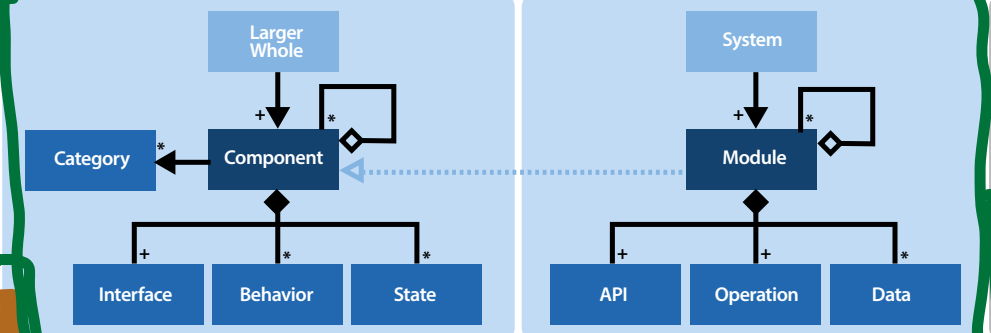
AF 05.1

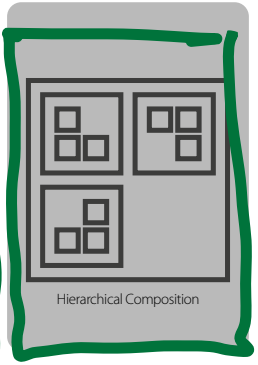
Definition of a Component (of a Larger Whole):
a **know-how encapsulating**, potentially **reusable** and **substitutable** **unit of hierarchical composition** with **explicit context dependencies**, which **hides the complexity** of its optional **behavior** and **state** realization behind **small contractually specified interfaces**, defines its **added value** in terms of **provided** and **consumed** interfaces and optionally belongs to zero or more **categories** of similar units.

Definition of a Module (of a System):
a know-how encapsulating, potentially reusable and substitutable source code unit of hierarchical composition with explicit context dependencies which hides the complexity of its **operation** and **data implementation** behind small contractually specified **Application Programming Interfaces (API)**, defines its added value in terms of provided and consumed **APIs** and optionally belongs to zero or more categories of similar units.

Example Categories of Components:
- Namespace
- Directory, File
- Configuration, Section, Directive
- Host, Virtual Machine, Container
- Process Group, Process, Thread
- Application, Microservice, Program
- Package, Class, Function
- Database, Schema, Table, Record
- Datamodel, Entity Group, Entity
- User Interface, Dialog, Widget

Any group of anything!





How to find Components (or Modules)?

DCA Domain Concept Abstraction
Model domain concepts as entity components and then group at higher levels.

SOC Separation of Concerns
Build components for clearly distinct concerns.

USE Reusability Potential
Decide on components based on their reusability potential.

UCC Use-Case Clustering
Build domain components for each use-case or each logical use-case cluster.

SRP Single Responsibility Principle
Build components for clearly distinct responsibilities.

DCC Divide & Conquer Complexity
Master overall complexity by splitting larger things into smaller things.

DDD Domain-Driven Design
Model domain "Bounded Contexts" through DDD and derive components from them.

CNC Coupling and Cohesion
Decide on components based on their loose coupling and strong cohesion.

CCC Cross-Cutting Concerns
Build common cross-cutting concerns as cross-cutting components.

OOD Object-Oriented Design
Model Object-Oriented Design entities (and/or OOP constructs) as components.

DEP Dependency Encapsulation
Decide on components based on their encapsulation of dependencies.

PAT Architecture Patterns
Build inner components to comply to outer structure, slicing and clustering architectures.

ARCHITECTURE FUNDAMENTALS

Interface Design

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AF 05.2

Definition of an Interface:

well-defined shielding and abstracting **boundary** of a passive, providing **component**, consisting of one or more distinguished, **outside-in** designed, **interaction endpoints**, each accessed and controlled by active, consuming components through the **exchange** of **input/output information** and operating under a certain **syntactical** and **semantical contract.**

Endpoint: Name, Directive, Command, Function, Method, Procedure, Address, Port, URL, Dialog, ...

Exchange: Option, Argument, Return Value, Result, Request/Response Message, Error/Exception, Interruption, ...

Contract: Syntax, Pre-Condition, Invariant, Post-Condition, Side-Effect, Idempotence, Determinism, Functionality, ...

Types of Software Interfaces

API Application Programming Interface

Example: `foo("bar", 42)`
(call and use)

SPI Service Provider Interface

Example: `register("foo", (x,k) => ...)`
(extend and implement)

SCI Startup Configuration Interface

Examples: INI, Java Properties, TOML, YAML, JSON, XML, etc.

BPI Batch Processing Interface

Examples: Unix at(1), Unix ts(1), GNU Batch, Spring Batch, Java Batch, SAP LO-BM, etc.

CLI Command-Line Interface

Example: `foo -x --bar=baz quux`

GUI Graphical User Interface

Examples: Windows/WPF, macOS/Cocoa, KDE/Qt, GNOME/GTK

RNI Remote Network Interface

Examples: GraphQL-IO, HTTP/REST, SOAP, RMI, WebSockets, AMQP, MQTT, etc.

Characteristics of Good Interfaces

AP Appropriate & Proportional

Appropriate to consumer requirements, proportional to provider functionality.

SA Shielding & Abstracting

Shields from direct access, abstracts and hides implementation details.

IE Inviting & Expressive

Invites through "outside – in" design, powerful in expressiveness.

IF Intuitive & Foolproof

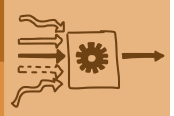
Intuitive to grasp and use, hard to misuse.

OC Orthogonal & Concise

Supports combinatorial use-cases, causes minimum boilerplate.

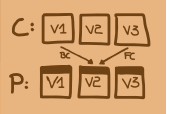
TP Tolerant & Predictable

Tolerant on input, predictable on output.



EC Extensible & Compatible

Easy to extend for providers, backward/forward-compatible for consumers.



Selected Interface Design Patterns

IVF Interface Version & Features

Provide version and feature information for algebraic comparison and feature detection.

2LF Leaky Two-Layer Facade

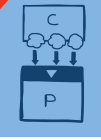
Provide higher-level convenient use-case and lower-level orthogonal feature interface.

EVE Event Emitter

Emit events to previously registered, interested consumers.

CTX Multi-Context

Use contexts to distinguish between different usage scenarios and to carry common info.



CEF Configure-Execute Flow

Spread use-cases onto a flow of configuration exchanges and a final executional exchange.

IOC Inversion Of Control

Invert control on asynchronous operations via callbacks, promises or async. mechanisms.

HMR Human/Machine Responses

Support humans and machines in outputs through both description and parsing-free info.

ARCHITECTURE FUNDAMENTALS

Component Hierarchy

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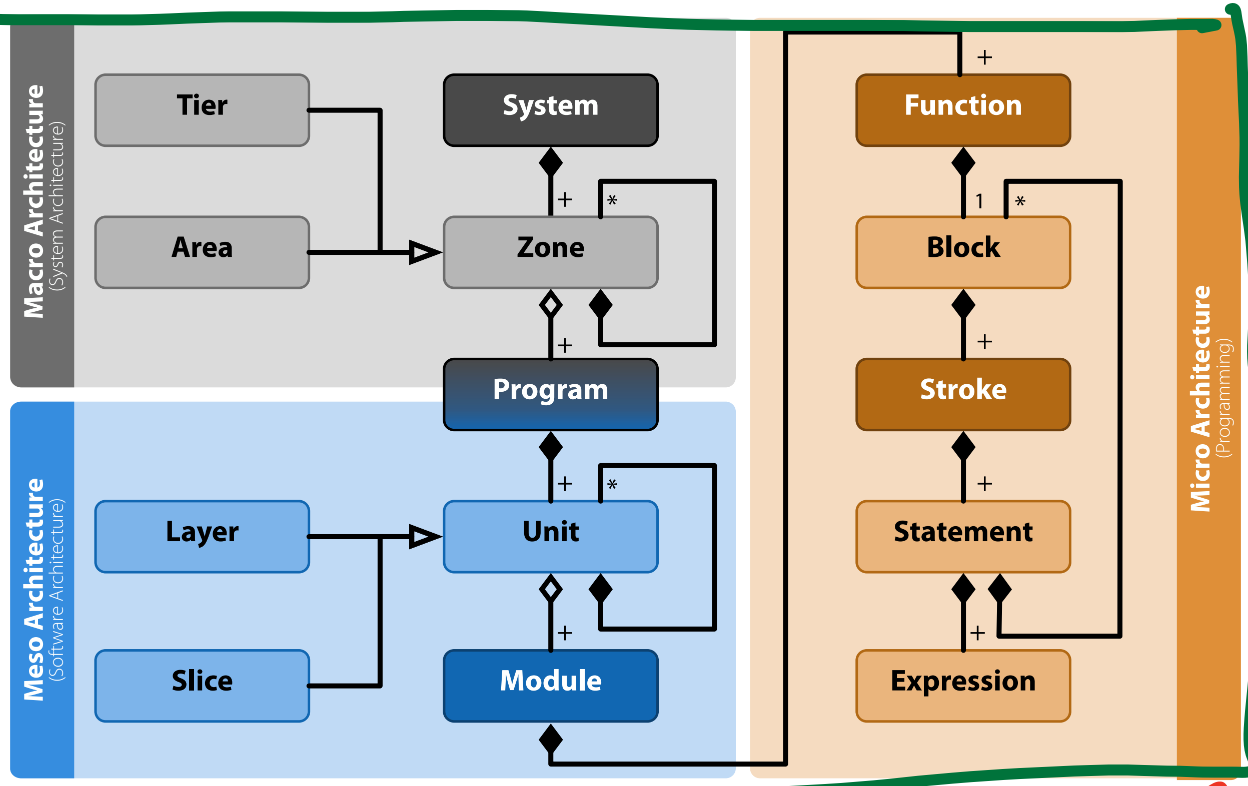

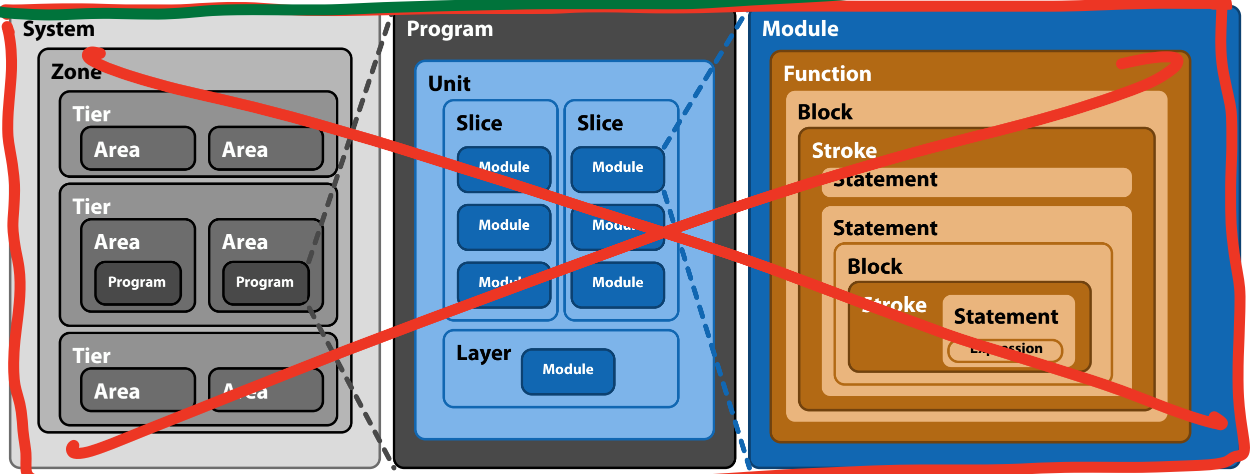

Zone:
Structuring **Tier** or **Area** within a **System** (or within an outer **Zone**).

Unit:
Structuring **Layer** or **Slice** within a **Program** (or within an outer **Unit**).

Tier:
Special kind of ranked **Zone** for horizontally grouping (logically or spatially distinct and network-linked) **Programs** or other **Tiers** and **Areas**.

Layer:
Special kind of ranked **Unit** for horizontally grouping (logically distinct and memory-linked) **Modules** or other **Slices** and **Layers**.

Area:
Special kind of unranked **Zone** for vertically grouping (logically or spatially distinct and network-linked) **Programs** or other **Tiers** and **Areas**.

Slice:
Special kind of unranked **Unit** for vertically grouping (logically distinct and memory-linked) **Modules** or other **Slices** and **Layers**.

System:
One or more network-linked **Programs**, forming a solution as a whole and the primary unit of thinking at the level of Macro Architecture.

Module:
Know-how encapsulating, potentially reusable group of **Functions** and primary unit of thinking at the level of Meso Architecture.

Program:
Stand-alone, self-contained executable piece of software and primary unit of thinking at the level of both Macro and Meso Architecture.

Function:
Operation of a **Module**, with a well-defined interface, and one of the two primary units of thinking at the level of Micro Architecture.

Statement:
Execution of a single action, specified through one or more **Expressions** and zero or more inner **Blocks**.

Stroke:
Logical sequence of **Statements** in a **Block** and one of the two primary units of thinking at the level of Micro Architecture.

Block:
Sequence of one or more **Strokes** within a **Function** or an outer **Statement** and scope for variables of inner **Statements**.

Expression:
Simple or complex representation of a single data value.

ARCHITECTURE FUNDAMENTALS

Application Composition

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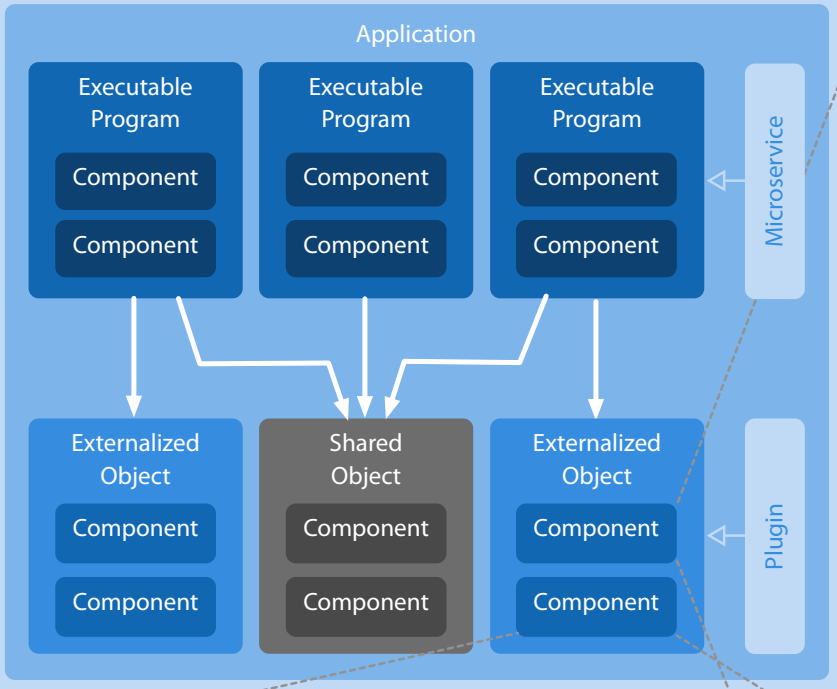
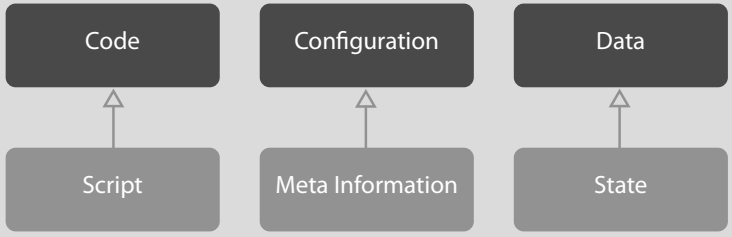
AF 11.3

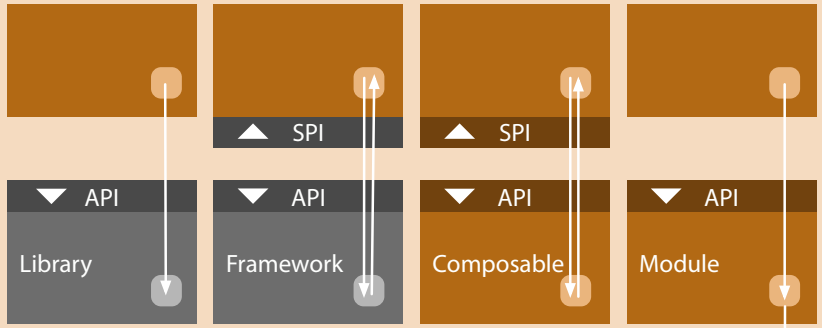
Application Structure



Component Assets



Component Types



Legend:

Applications are composed out of one or more *Executable Programs*.

An *Executable Program* in turn can leverage zero or more (dedicated) *Externalised Objects* and/or (reusable) *Shared Objects*. Both *Executable Programs*, *Externalised Objects* and *Shared Objects* are composed through one or more *Components*.

Components are comprised of the assets *Code*, *Configuration* and *Data* and are of four distinct types: *Library*, *Framework*, *Composable* and *Module*, which are distinguished by their particular combination of characterizing aspects.

	data persistence	own life-cycle	requires integration	self-contained	invasive	passive	active	technical	domain-specific	reusable
Library				X		X		X		X
Framework		X	X	X	X	X	X	X		X
Composable	X	X	X	X			X		X	X
Module	X						X		X	

Architecture Patterns

Pattern Definition

Pattern: unique, catchy, and associative **Name** and concise, precise, and normative **Description** of a contextual, regularly occurring, and practically relevant **Problem** and a general, highly reusable, and best practice **Solution** for it.

Pattern Structure

Pattern

- **Name**
  - unique
  - catchy
  - associative
- **Description**
  - concise
  - precise
  - normative
- **Problem**
  - contextual
  - regularly occurring
  - practically relevant
- **Solution**
  - general
  - highly reusable
  - best practice

Pattern Rationale

- has to be unambiguously distinguished
- has to be recognized and memorized
- has to be intuitively associated to the solution
- has to be reasonably remembered
- has to be clear and unambiguous
- has to be foundational and stringent in expressiveness
- has to be described in a given context
- has to be motivated by enough situations
- has to be motivated by enough practice
- has to be general enough to be sufficiently reusable
- has to be applicable also in variants of the context
- has to be considered a best or at least good practice

ARCHITECTURE FUNDAMENTALS

Layer Architectures

(Patterns)

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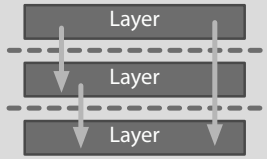
AF 06.2

Layering Principle

Horizontally split code or data into two or more logically, optionally also spatially, clearly distinct, isolating, named, and ranked layers.

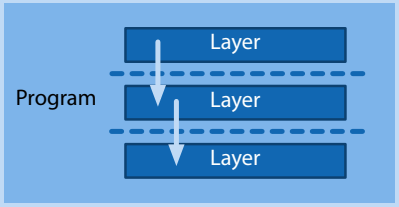
A Layer is not allowed to have relationships to or knowledge about any upper Layers. Additionally for *Closed Layering*, each Layer is allowed to have relationships to and knowledge about *directly* lower Layer only. In contrast to *Open Layering* or *Leaky Abstraction*, where each Layer is allowed to have relationships to and knowledge about *any* lower Layer.



LR Layer

Split related code or data of a Program into two or more logically distinct domain- or technology-induced Layers.

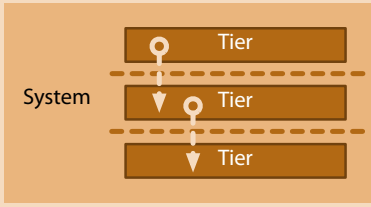
Rationale: Separation of Concern, Single Responsibility Principle, Mastering Complexity, Change Isolation, Functional Abstraction.



TR Tier

Split related code or data of a System into two, three or more logically and spatially distinct, network-connected, domain- or technology-induced Tiers.

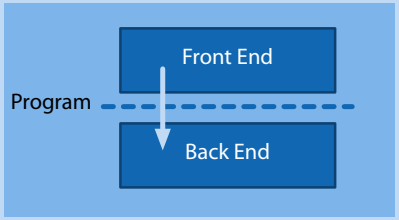
Rationale: Separation of Concern, Single Responsibility Principle, Mastering Complexity, Change Isolation, Functional Abstraction, Deployment Partitioning.



FB Front End / Back End

Split the code of a Program into exactly two logical Layers: a user-facing Front End and a data-facing Back End.

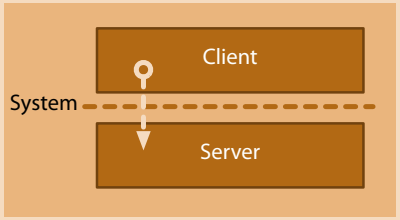
Rationale: Separation of Concern, Single Responsibility Principle, Mastering Complexity, Change Isolation, Functional Abstraction, Organisational Alignment.



CS Client / Server

Split the code of a System into two spatially distinct, network-connected Layers, each forming a stand-alone Program: a user-facing and multi-instantiated (Rich) Client and a data-facing (and logically) single-instantiated (Thin) Server. Both contain a Front/Back End.

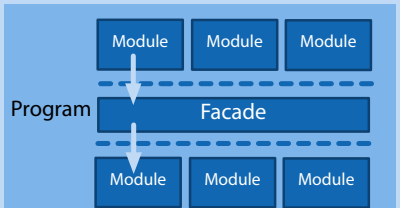
Rationale: Multi-User, User Computing Resource Leverage, Distributed Computing.



FD Facade

Splice a domain-specific Facade Layer into two Layers of two or more Modules. The extra Facade Layer acts as a broker between the Modules.

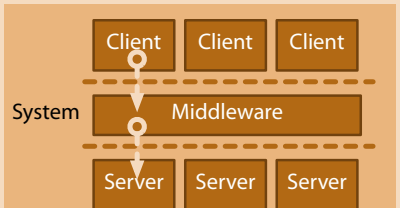
Rationale: Information Hiding, Cross-Cutting Concern Centralization, Functionality Orchestration, Authorization, Validation, Conversion.



MW Middleware

Splice a domain-unspecific Middleware Layer into a Client/Server communication. The extra Layer is a stand-alone Program Tier and acts as a broker between Client and Server.

Rationale: Communication Peer Discovery Simplification, Transport Protocol Conversions, Network Topology Flexibility.



ARCHITECTURE FUNDAMENTALS

Slice Architectures

(Patterns)

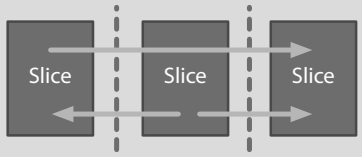
TECHNISCHE UNIVERSITÄT MÜNCHEN

AF 06.3

Slicing Principle

Vertically split code or data into two or more logically, optionally also spatially, clearly distinct, named, and unranked slices.

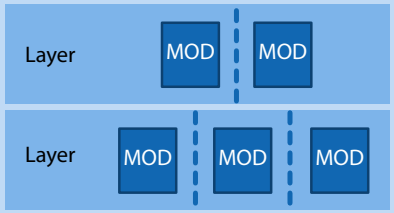
The particular slicing should minimize the total amount of individual relationships between the resulting slices. Per type of relationship, there should be no cycle in the transitive relationships.



MOD Concerned Module

Split related code or data (usually across a single Layer) into two or more logically distinct domain- or technology-induced Modules.

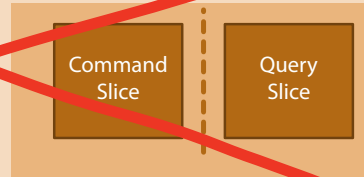
Rationale: Separation of Concern, Single Responsibility Principle, Mastering Complexity.



CQRS Command-Query Responsibility Segregation

Split code and data of a Program (across all Layers) or a Tier into exactly two slices to segregate operations that read data (queries) from the operations that update data (commands).

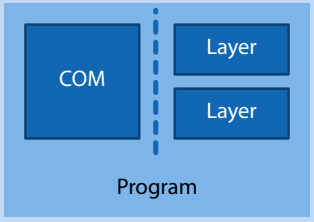
Rationale: Separated Scalability, Separated Data Access Patterns, Event Sourcing Approach.



COM Common Slice

Factor out common or cross concern code or data of a Program (across all Layers) into a single spatially distinct, separate slice.

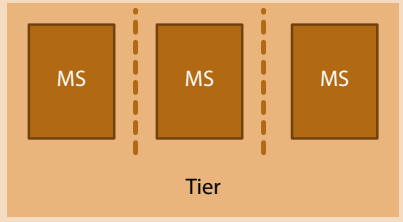
Rationale: Lack of Redundancy, Single Point of Truth, Reusability.



MS Microservice

Split code and data of a Tier (across all Layers) into two or more distinct, loosely-coupled, domain-enclosed, functional services, each forming a stand-alone Program.

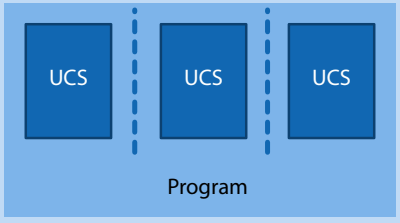
Rationale: Heterogeneity, Long-Term Large-Scale Maintenance, Replaceability, Resilience, (Scalability), (Easy Deployment), (Organizational Alignment), (Composability), (Reusability).



UCS Use-Case Slice

Split the code and data of a Program (across all Layers) into two or more purely logical slices, one for each distinct, domain-specific Use-Case.

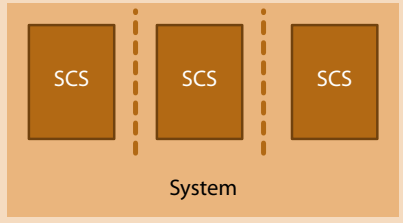
Rationale: Comprehensibility, Domain Alignment, Mastering Complexity.



SCS Self-Contained System

Split code and data of a System (across all Layers and Tiers) into two or more distinct, loosely-coupled, domain-enclosed, functional systems, each forming a stand-alone sub-System.

Rationale: Mastering Complexity, Heterogeneity, Resilience, Scalability, Easy Deployment, Organizational Alignment, Reusability, Replaceability.



ARCHITECTURE FUNDAMENTALS

Flow Architectures

(Patterns)

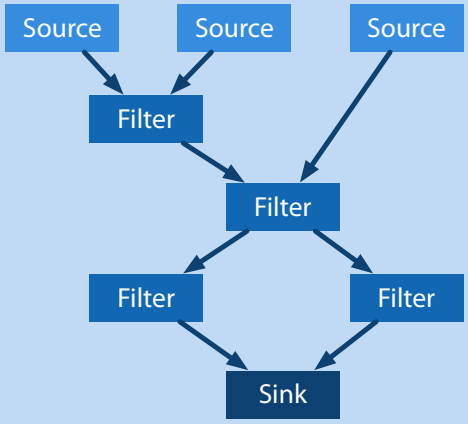
TECHNISCHE UNIVERSITÄT MÜNCHEN

AF 07.1

Pipes & Filters

Pass data through a directed graph of **Components** and connecting **Pipes**. The components can be **Sources**, where data is produced, **Filters**, where data is processed, or **Sinks**, where data is captured. Source and Filter components can have one or more output Pipes. Filter and Sink components can have one or more input Pipes. Components are independent processing units and operate fully asynchronously.

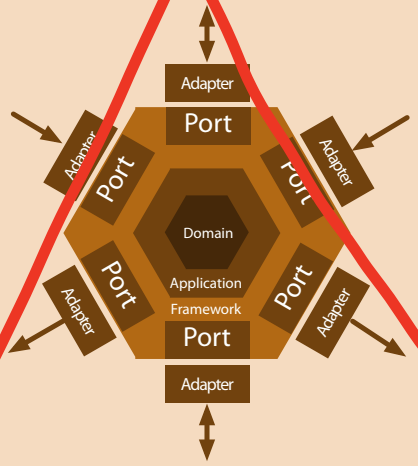
Examples: Unix commands with stdin/stdout/stderr and the Unix shell connecting them with pipes; Apache Spark or Apache Camel data stream processing pipelines.



Ports & Adapters (Hexagonal)

Perform communication in a Hub & Spoke fashion by structuring a solution into the three "Layers" **Domain**, **Application** and **Framework** and use the Framework layer to connect with the outside through **Ports** (general Interfaces) and **Adapters** (particular Implementations). Often some Ports & Adapters are user-facing sources and some are data-facing sinks, although the motivation for the Ports & Adapters architecture is to remove this distinction between user and data sides of a solution.

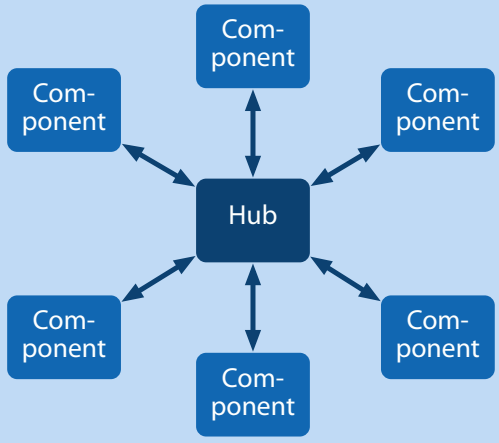
Examples: Message Queue, Enterprise Service Bus or Media Streaming Service internal realization.



Hub & Spoke

Perform communication (the **Spoke**) between multiple Components through a central **Hub** Component. Instead of having to communicate with N x (N-1) / 2 bi-directional interconnects between N Components, use the intermediate Hub to communicate with just N interconnects only. Sometimes one distinguishes between K (0 < K < N) source and N - K target Components and then K x (N - K) uni-directional interconnects are reduced to just N interconnects, too.

Examples: Message Queue, Enterprise Service Bus, Module Group Facade, GNU Compiler Collection, ImageMagick, etc.



ARCHITECTURE FUNDAMENTALS

Process Architectures

(Patterns)

TECHNISCHE UNIVERSITÄT MÜNCHEN

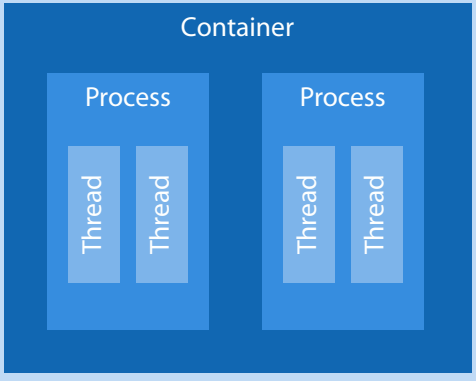
AF 07.2

Container, Process, Thread

The Operating System manages and orchestrates the run-time execution of applications in **Containers**, programs in **Processes** and control flows in **Threads**.

Containers are the ultimate enclosures, separating and controlling both the computing resources processor, memory, storage and network. Processes are the primary enclosures, still separating and controlling at least the computing resources processor and memory. Threads are the light-weight enclosures, just separating and controlling the computing resource processor. Containers can contain one or more Processes, and Processes can contain one or more Threads.

Examples: Docker Container, Unix Processes, POSIX Threads.

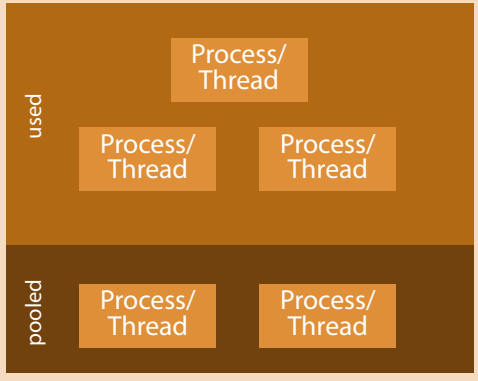


Process/Thread Pool

Instead of creating a Process/Thread for handling each incoming I/O request, pick a pre-created Process/Thread out of a resource **Pool** in order to increase performance and decouple I/O traffic (leading to threads of execution) from the actual computing resource usage and utilization.

The Process/Thread Pool usually has a lower and upper bound of processes/threads. The lower bound keeps the system "hot" between I/O requests. The upper bound limits the computing resource usage and avoids over-utilization.

Examples: Apache HTTP Daemon

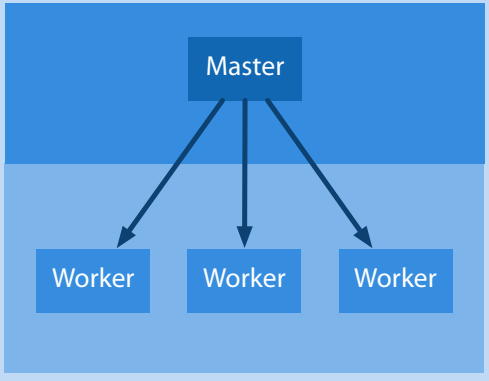


Master-Worker

The system has a single permanent **Master** container/process/thread and a Pool of many ephemeral **Worker** containers/processes/threads. The Master starts, restarts, pauses, resumes and stops the Workers and usually also delegates incoming I/O requests to them. The Workers process the I/O requests and deliver the responses.

Starting the Master usually implicitly starts an initial set of Workers (the initial Pool), stopping the Master implicitly stops all still pending Workers.

Examples: Unix init(8) daemon, Apache HTTP Daemon, SupervisorD, Node.js Cluster module



Cluster Architectures

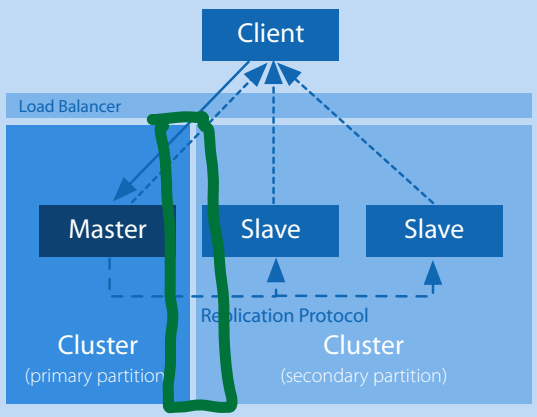
(Patterns)

Master-Slave (Static Replication)

Cluster of a single **Master** and multiple **Slave** nodes, where data is continuously copied from the Master to the Slave nodes in order to support high-availability (where a Slave will take over the Master role) in case of a Master outage and increased read performance (where regular read requests are also served by the Slaves).

In this static replication scenario the Master is usually assigned statically and in case of outages has to be reassigned usually semi-manually. Especially, the full reestablishment of the original Master assignment after a Master recovery usually is a manual process.

Examples: OpenLDAP Replication, PostgreSQL WAL Replication.

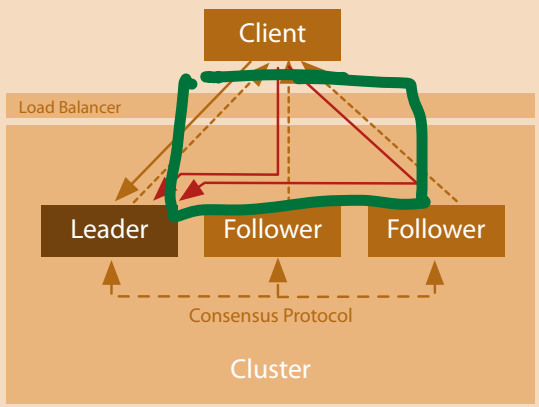


Leader-Follower (Dynamic Replication)

Cluster of a single **Leader** and multiple **Follower** nodes, where data is written on the current Leader node and data read on both the current Leader and all Follower nodes. For writing data to the cluster, the Leader node performs a consensus protocol (e.g. RAFT, Paxos or at least Two-Phase-Commit) with the Followers and this way automatically and consistently replicates the data to the Followers.

In this dynamic replication scenario the Leader is usually automatically assigned by the cluster nodes through an election protocol and in case of outages is automatically re-assigned. There is usually no re-establishment of the original Leader assignment.

Examples: Apache Zookeeper, Consul, EtcD, CockroachDB, InfluxDB.

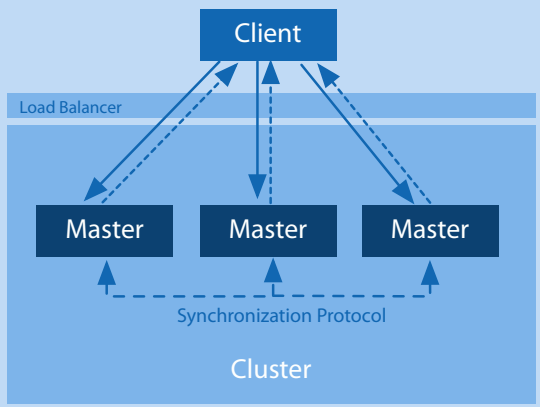


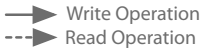
Master-Master (Synchronization)

Cluster of multiple **Master** nodes, where data is read and written on any Master node concurrently. The Master nodes either use Strict Consistency through writing to a mutual-exclusion-locked shared storage concurrently or use Eventual Consistency in a Shared Nothing storage scenario where they continuously synchronize their local data state to all other nodes with the help of a synchronization protocol.

The synchronization protocol usually is based on either Conflict-Free Replicated Data Types (CRDT) or at least Operational Transformation (OT). In any scenario, data update conflicts are explicitly avoided.

Examples: ORACLE RAC, MySQL/MariaDB Galera Cluster, Riak, Automerge/Hypermerge.





ARCHITECTURE FUNDAMENTALS

Networking Architectures

(Patterns)

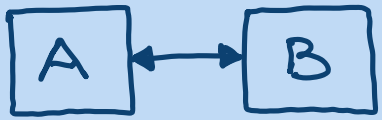
TECHNISCHE UNIVERSITÄT MÜNCHEN

AF 08.1

PTP Point-to-Point

Communicate between two network nodes in a point-to-point fashion, usually through a direct link.

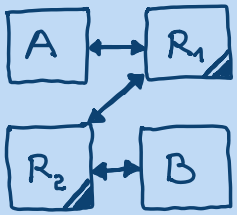
Rationale: simple communication where both nodes know about each other and can directly reach each other.



RTG Routing

Communicate between two network nodes in a point-to-point fashion, but by routing the network packets over intermediate forwarding nodes (routers).

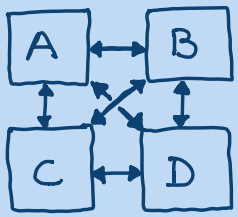
Rationale: simple communication where both nodes know about each other, but cannot directly reach each other.



P2P Peer-to-Peer

Communicate between multiple network nodes (usually all in the client and server role at the same time) without involving a central hub node (in the role of a server) — except for the initial network entry discovery.

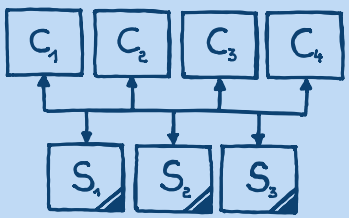
Rationale: communication without central control (although a seed peer is required).



C/S Client/Server

Communicate between multiple nodes in the client role (making requests, and usually with ephemeral addresses) and multiple nodes in the server role (serving responses, and usually with fixed addresses).

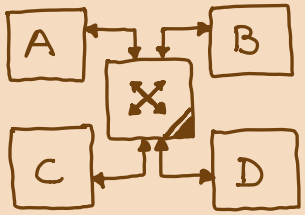
Rationale: communication with central orchestration, control and data storage.



BUS Bus/Broker/Relay

Communicate between multiple nodes with the help of a central packet forwarding hub node in a star network topology.

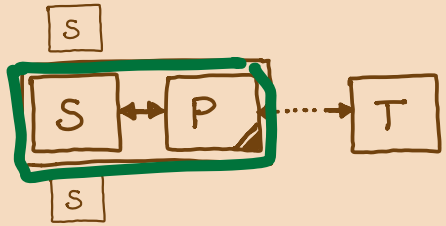
Rationale: decouple communication nodes: instead of Point-to-Point (PTP) communications between all nodes, there are just PTP communications with the hub.



FPR (Forward) Proxy

Communicate between two nodes by using an intermediate forwarding proxy node in front of the source node.

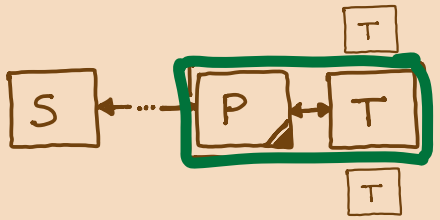
Rationale: bridge network topology constraints (segmented networks); caching at source side; auditing of communication.



RPR Reverse Proxy

Communicate between a source and a target node by using a masquerading proxy node directly in front of the target node.

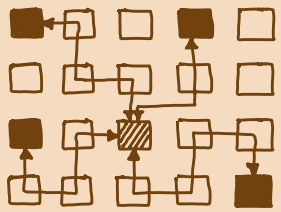
Rationale: load balancing for multiple target nodes; caching at target side; auditing of communication; security shielding of target nodes; protocol conversions.



VPN Virtual (Private) Network

Communicate between nodes in a logical star network topology on top of an arbitrary physical routed network topology.

Rationale: secure private network overlaying an unsecure public network; simplify network topology.



ARCHITECTURE FUNDAMENTALS

Communication Architectures

(Patterns)

TECHNISCHE UNIVERSITÄT MÜNCHEN

UCT Unicast (one-to-one)

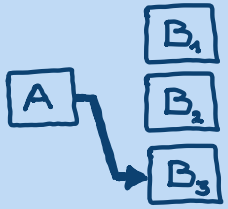
Communicate messages from one source to exactly one destination node. The destination node is explicitly and individually addressed.

Rationale: private communication between exactly two nodes which both know each other beforehand.

ACT Anycast (one-to-any)

Communicate messages from one source to one of many destination nodes. The picked destination node usually is the network-topology-wise "nearest" or least utilized node in a group of nodes.

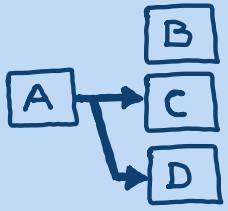
Rationale: Unicast, optimized for network failover scenarios, load balancing and CDNs.



MCT Multicast (one-to-many)

Communicate messages from one source to many destination nodes. The destination nodes usually form a group and are usually not individually addressed.

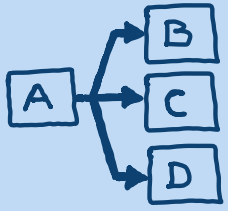
Rationale: node communication where destination nodes dynamically change or where total traffic should be reduced.



BCT Broadcast (one-to-all)

Communicate messages from one source to all available destination nodes. The destination nodes usually are implicitly defined by the extend of the local communication network segment.

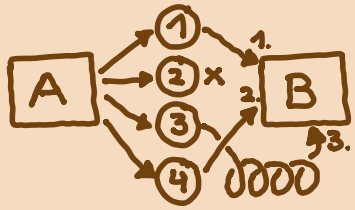
Rationale: spreading out messages to all available nodes for potential responses.



DGR Datagram (Single Packet)

Communicate messages as an unordered set of single packets, usually without any network congestion control, retries or other delivery guarantees.

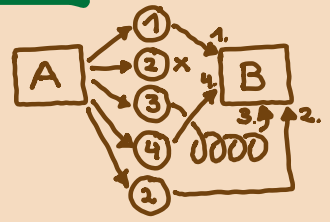
Rationale: simple low-overhead communication without prior communication establishment (handshake).



STR Stream (Sequence of Packets)

Communicate messages as an ordered sequence (stream) of packets, usually with network congestion control, retries and delivery guarantees (at-most-once, exactly-once, at-least-once).

Rationale: reliable communication between nodes.



PLL Pull (Request/Response, RPC)

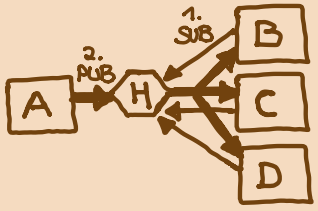
Communicate by performing a request (from the client node) and pulling a corresponding response (from the server node).

Rationale: Remote Procedure Call (RPC) like Unicast or Anycast communication.

PSH Push (Publish/Subscribe, Events)

Communicate by "subscribing" to "channels" of messages (on one or more receiver nodes or on an intermediate hub) once and then publishing events to those "channels" (on the sender node) multiple times.

Rationale: event-based Multicast or Broadcast communication.



AF 08.2

ARCHITECTURE FUNDAMENTALS

Data Structure Architectures

(Patterns)

TECHNISCHE UNIVERSITÄT MÜNCHEN

AF 09.1

Data Structure Types

Scalar, Atom, Primitive Type

Plain integer or real number,
single character or character string,
not indexed and (for string only)
accessed in O(1) by character position.

Tuple, Object, Structural Type, Record

Ordered, fixed-size sequence of scalar elements,
each of individual type, indexed by name and
accessed in O(1) by element name.

Sequence, Array, List

Ordered sequence of elements,
each of same type, indexed by position and
accessed in O(1) or O(n) by element position.

Set, Bag, Bucket

Unordered set of elements,
each of same type, not indexed and
accessed in O(1) or O(n) by element reference.

Map, Hash, Associative Array

Unordered sequence of elements,
each of same type, indexed by (scalar) key and
accessed in O(1) by key.

Graph, Nodes & Edges

Unordered set of linked elements (nodes),
each of individual type, indexed by (scalar) key
and accessed in O(1) by key or by following a
directed link (edge).

Data Evolution Approaches

In-Place Editing

Modify data through direct in-place editing,
overwriting the previous revision.

Stacking Revisions

Modify data through stacking revisions,
preserving all previous revisions.
Latest revision is always on top of stack.

Structural Difference

Modify data through merging, journaled
domain-unspecific structural differences.

Operational Transformation (OT)

Modify data through applying journaled,
domain-specific operational transformations.

Data Sharing Approaches

Event Sourcing & CRDT

Share data as a chronological sequence of data
change events from which the data states can be
(re)constructed. Optionally, use a Conflict-Free
Replicated Data Type (CRDT) protocol for the
change events.

Ref.-Counting & Copy-on-Write

Share data between resources by using
reference counted data chunks, duplicating a
chunk (and resetting its reference count to one)
on write operations only and destroying a chunk
only if the reference count drops to zero.

Data Store Types

Key-Value Store

Storage of values in an unordered manner,
indexed and queried by key.

Redis, Riak, MemcacheD, RocksDB, LevelDB

Large-Object Store

Storage of unstructured binary-large object
(BLOB) data and its associated meta-data,
indexed and queried by unique id.

Minio, SeaweedFS, AWS S3

Triple Store

Storage of subject-predicate-object triples,
indexed and queried by subject/predicate/object
values and example triples.

Redstore, Virtuoso

File-Tree Store

Storage of unstructured data as named files in a
directory tree, indexed and queried by name path
from root directory to leave file.

ZFS, XFS,
UFS2, APFS

Graph Store

Storage of values as vertices and edges in a
graph, both optionally referencing associated
key/value pairs. Indexed and queried by key/
value pairs and traversed by following edges.

Neo4J, OrientDB, ArangoDB

Document Store

Storage of structured "documents",
indexed by id and key/value fields and
queried by id and example documents.

MongoDB, CouchDB,
RethinkDB

Relational/Table Store

Storage rows of fixed-size, typed value columns,
indexed and queried by column values.

PostgreSQL, MariaDB, SQLite,
H2, ORACLE DB, IBM DB2

Full-Text Store

Storage of unstructured text,
indexed and queried by content words.

ElasticSearch, Solr,
Groonga

Wide-Column Store

Distributed storage of rows of sparse (often
untyped) value columns, indexed and queried
by column values.

Cassandra, MonetDB,
HBase, ScyllaDB

Time-Series Store

InfluxDB, MetricTank,
RRDTool

Storage of integer or real values (y-axis) of a time-
series (x-axis) into a fixed-size storage format in a
round-robin manner where older values are
increasingly aggregated (leading to lower
resolutions at older times) and finally overwritten.

DataVault Store

Long-term historical storage of foreign, arbitrary
relational data in a fixed schema of hubs, links
and satellites, indexed and queried for analysis
and reporting purposes.

DataVault 2.0

BlockChain Store

Storage of values in an unordered manner within
information blocks which are cryptographically
chained through their hash values and
distributed in a peer-to-peer way.

Ethereum, Quorum,
Tendermint, Hyperledger

ARCHITECTURE FUNDAMENTALS

Data Persistence Architectures

(Patterns)

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AF 09.2

Data Guarantees

CAP (Trade-In)

A distributed data store cannot provide more than two out of three guarantees: Consistency (C), Availability (A), Partition-Tolerance (P). So, it has to choose between Consistency (CP) and Availability (AP) when a network partition or failure happens.

BASE (NoSQL)

The semantics (usually of NoSQL systems) of (B)asically (A)vailable, (S)oft state, and (E)ventual consistency. BASE systems favor Availability over Consistency in the CAP-context.

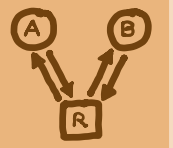
ACID (RDBMS, NewSQL)

The four guarantees provided in parallel (usually by RDBMS and NewSQL systems): Atomicity, Consistency, Isolation and Durability. ACID systems usually favor Consistency over Availability in the CAP-context.

Data Access

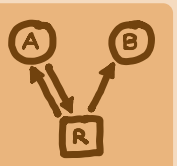
Shared Read/Write

Shared access to data for both read and write operations. Example: Multiple threads on heap or Master-Master database setup.



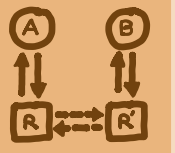
Shared Read / Exclusive Write

Shared access to data for read operations and exclusive access (via a single "owning" component) to data for write operations. Example: RDBMS Master-Slave cluster with shared storage.



Shared Nothing

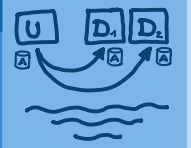
No shared access to data at all for both read and write operations. Example: Leader-Follower setup with RAFT consensus where Leader writes data only.



Data Spreading & Aggregation

Data River (1-to-N)

A real-time fan-out replication of data from a single upstream/source data repository to multiple downstream/target data repositories.



Data Mart (N-to-1), ODS

A massive sized, easily accessible data repository for storing "big data" from many upstream sources in a (real-time and) structured way and with knowing the actual subsequent analysis usage.

Data Lake (N-to-1), Cache

A massive sized, easily accessible data repository for storing "big data" from many upstream sources in a (real-time) semi-structured way and without knowing the actual subsequent usage.

Data Access Grouping

Transaction

Protect a sequence of operations from interim exceptions by bracketing the operations in a technical transaction (ensuring that either all or none of the operations succeed).

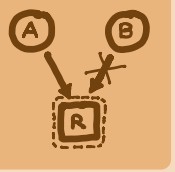
Compensation

Protect a sequence of operations from interim exceptions by undoing the already succeeded operations through domain-specific compensating (reverse) operations.

Data Consistency

Exclusive Locking (Mutex)

Protect data from concurrent access and resulting inconsistencies with a mutual exclusion lock (mutex) which allows just a single peer to access the data at a time.



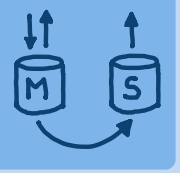
Optimistic Locking

Protect data from concurrent access and resulting inconsistencies by taking note of a revision number or content hash during read operations and checking that this information has not changed before writing the data.

Data Transfer

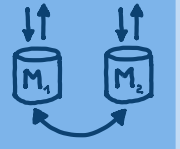
Replication

Continuously stream or regularly copy data from a master system to one or more slave systems in order to either read the data from slave systems faster or have slave systems available as a fallback/ backup in case of a failure of the master system.



Synchronization

Continuously stream or regularly copy data between multiple master systems and resolve potential concurrent data modification conflicts. This way allow distributed and even disconnected computing.



ARCHITECTURE FUNDAMENTALS

Application Reference Architecture

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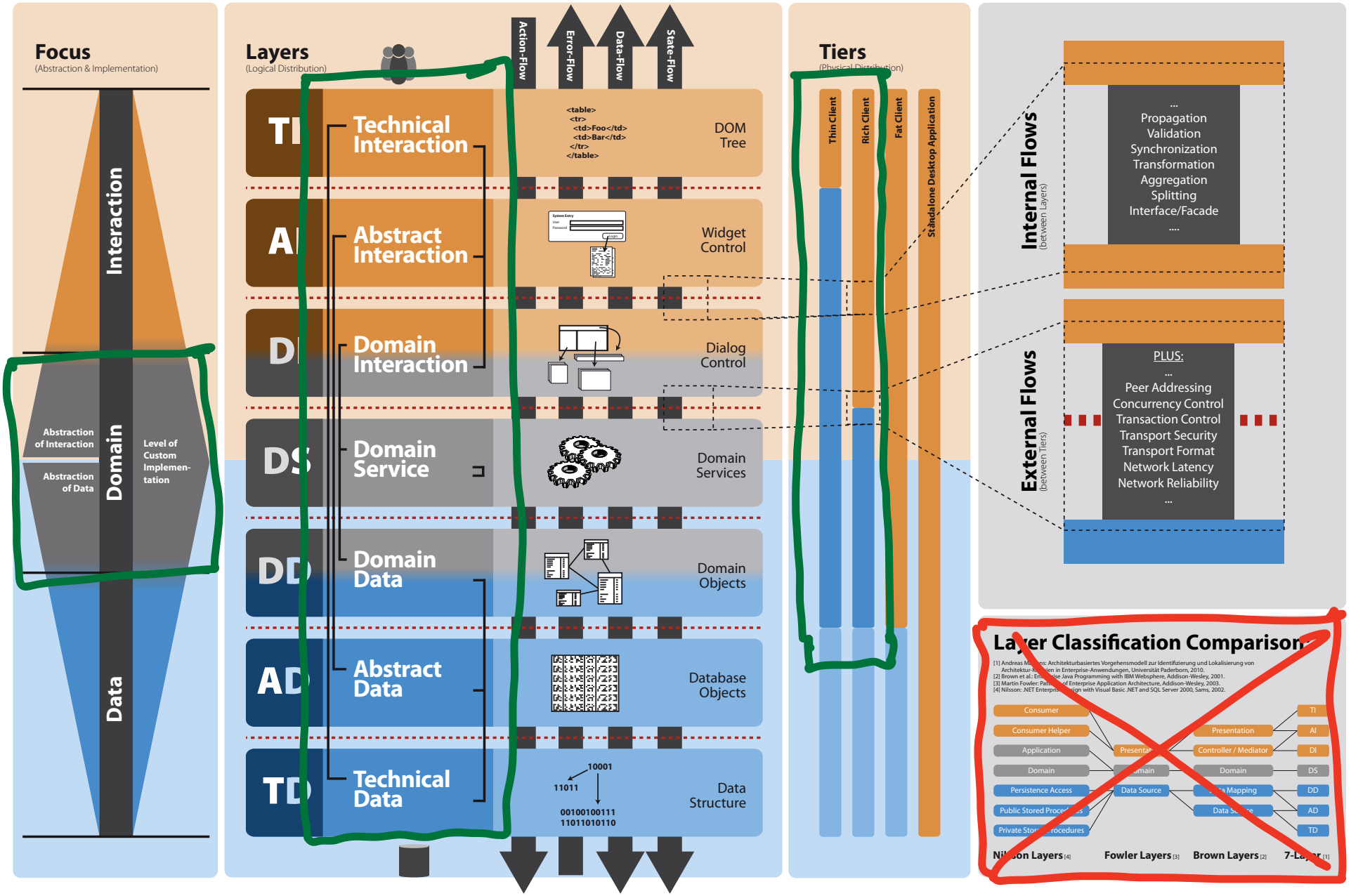
AF 10.1



ARCHITECTURE FUNDAMENTALS

Client-Server Architecture

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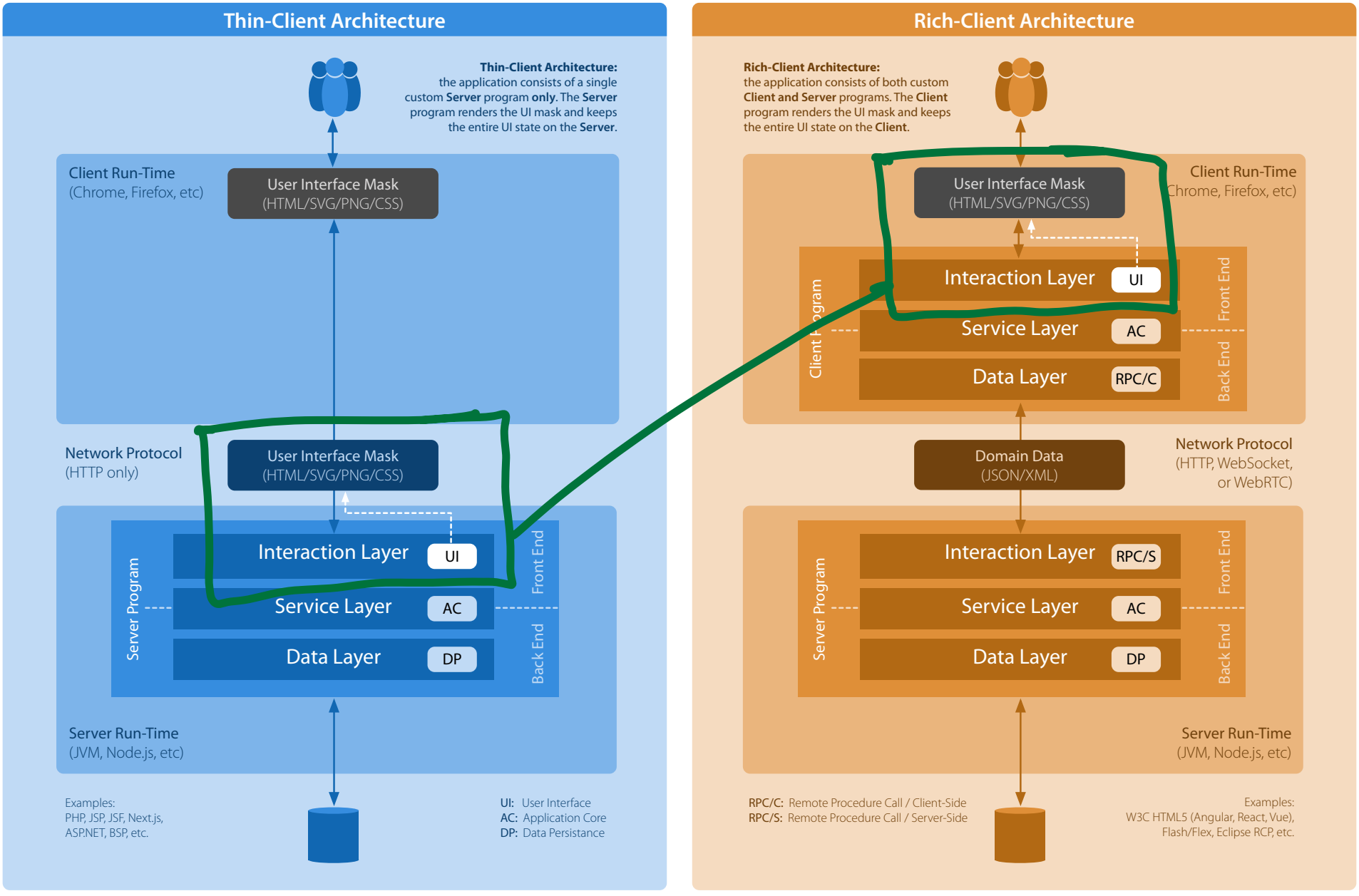
AF 10.2



ARCHITECTURE FUNDAMENTALS

Information System Architecture

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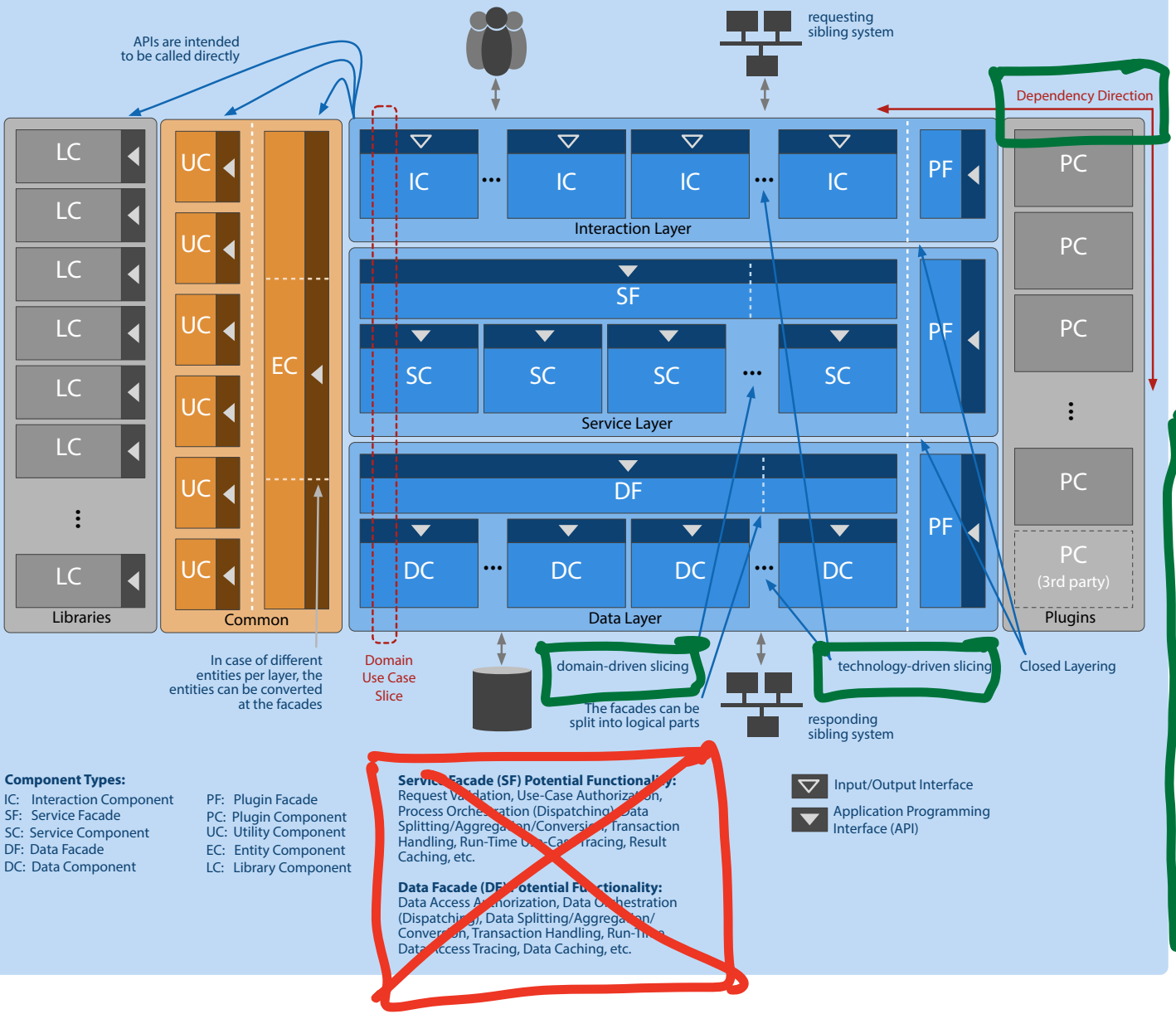
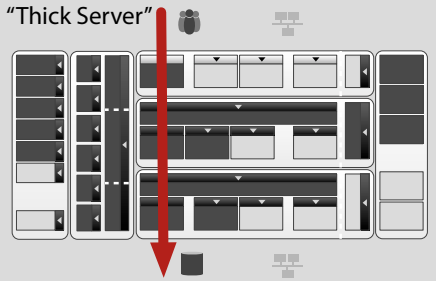
Reference Architecture Blueprint



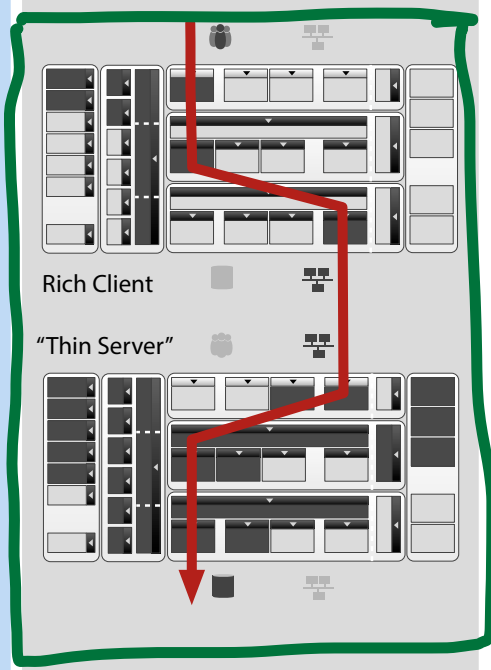
Blueprint Usage

Example Scenario 1

Thin Client / "Thick Server"



Example Scenario 2



AF 10.3

ARCHITECTURE FUNDAMENTALS

Reactive System Architecture

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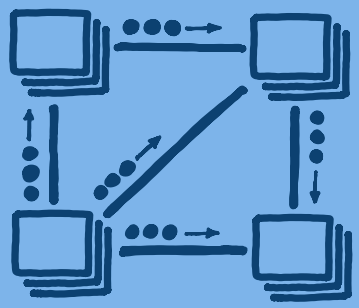
AF 10.4

Architecture & Systems

DEF Definition

Reactive System Architecture enables the realization of *Reactive Systems*.

Reactive Systems are in *subordinated interaction* with their *dominating environment*. They *continuously* process *endless data streams* as *small messages*, react at *any time* and respond within *tight time limits*. For this, they continuously *observe* their *environment* and adapt their *behaviour* to the current situation.



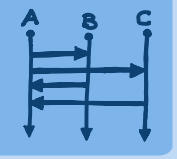
Demand & Deliverables

CTX Context

Real-time communication in the context of Digitization, Internet, Internet of Things (IoT), Systems of Engagement, Media and Analytics.

VAL Values

Non-blocking input/output data processing, *fast responses* within *tight time limits*, and *continuous availability* of the provided services.

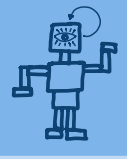


REQ Requirements

Services are *elastic* and provide high scalability, and are *resilient* and provide high fault tolerance.

PRP Properties

Services run *fully autonomously*, *monitor themselves*, and *automatically adapt* to changes in the environment.



Principles

Stay Responsive
Always respond in a timely manner.

Accept Uncertainty
Build reliability despite unreliable foundations.

Embrace Failure
Expect things to go wrong and design for resilience.

Assert Autonomy
Design components that act independently and interact collaboratively.

Tailor Consistency
Individualize consistency per component to balance availability and performance.

Decouple Time
Process asynchronously to avoid coordination and waiting.

Decouple Space
Create flexibility by embracing the network.

Handle Dynamics
Continuously adapt to varying demand and resources.

Patterns & Paradigms

ARC Architecture

Microservices, Cloud-Native Architecture (CNA), Event-Driven Architecture (EDA).

COM Communication

Asynchronous Communication, Non-Blocking I/O, Sequence, Push, Backpressure, Quality of Service (QoS).

DAT Data

Semantical Event, Small Message, Endless Stream.

STY Style

Functional Programming, Asynchronous Programming.

EXE Execution

Parallelization, Concurrency, Actors, Threads, Thread-Pool, Event-Loop.

INF Infrastructure

Message Queue (MQ), Load Balancer, Reverse Proxy, Service Mesh, Virtual Private Network (VPN).

PRC Processing

Complex Event Processing (CEP), EAI Patterns, Stream Processing (map, flatMap, filter, reduce), Event Sourcing.

ASY Asynchronism

Callback, Promise/Future, Observable, Publish & Subscribe.

ARCHITECTURE FUNDAMENTALS

Technology Platforms

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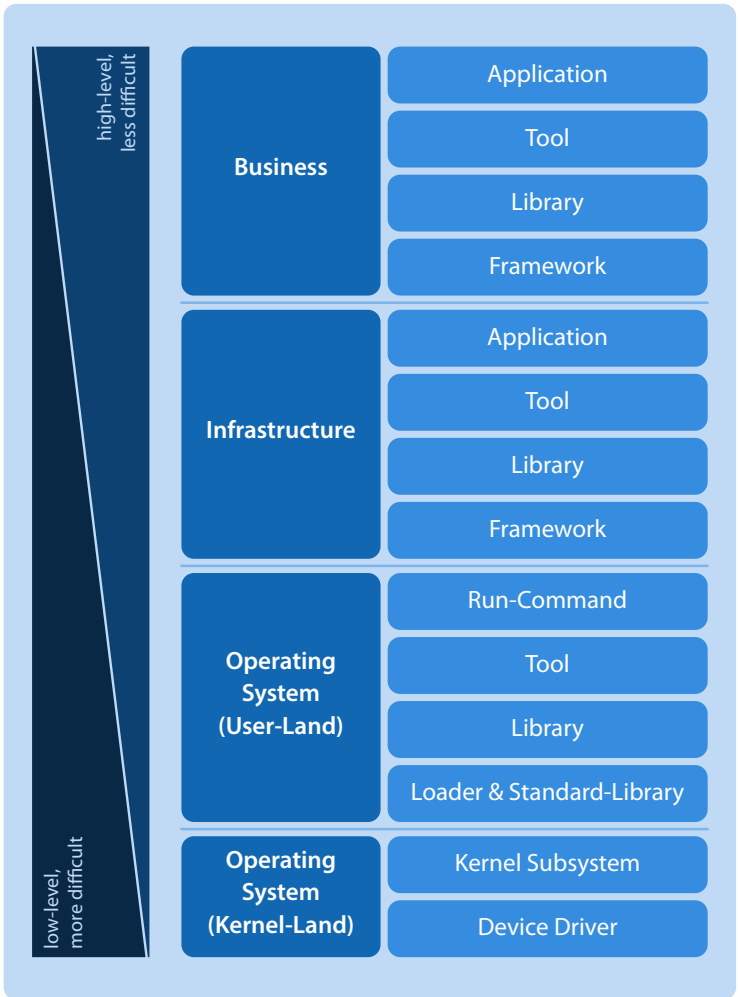
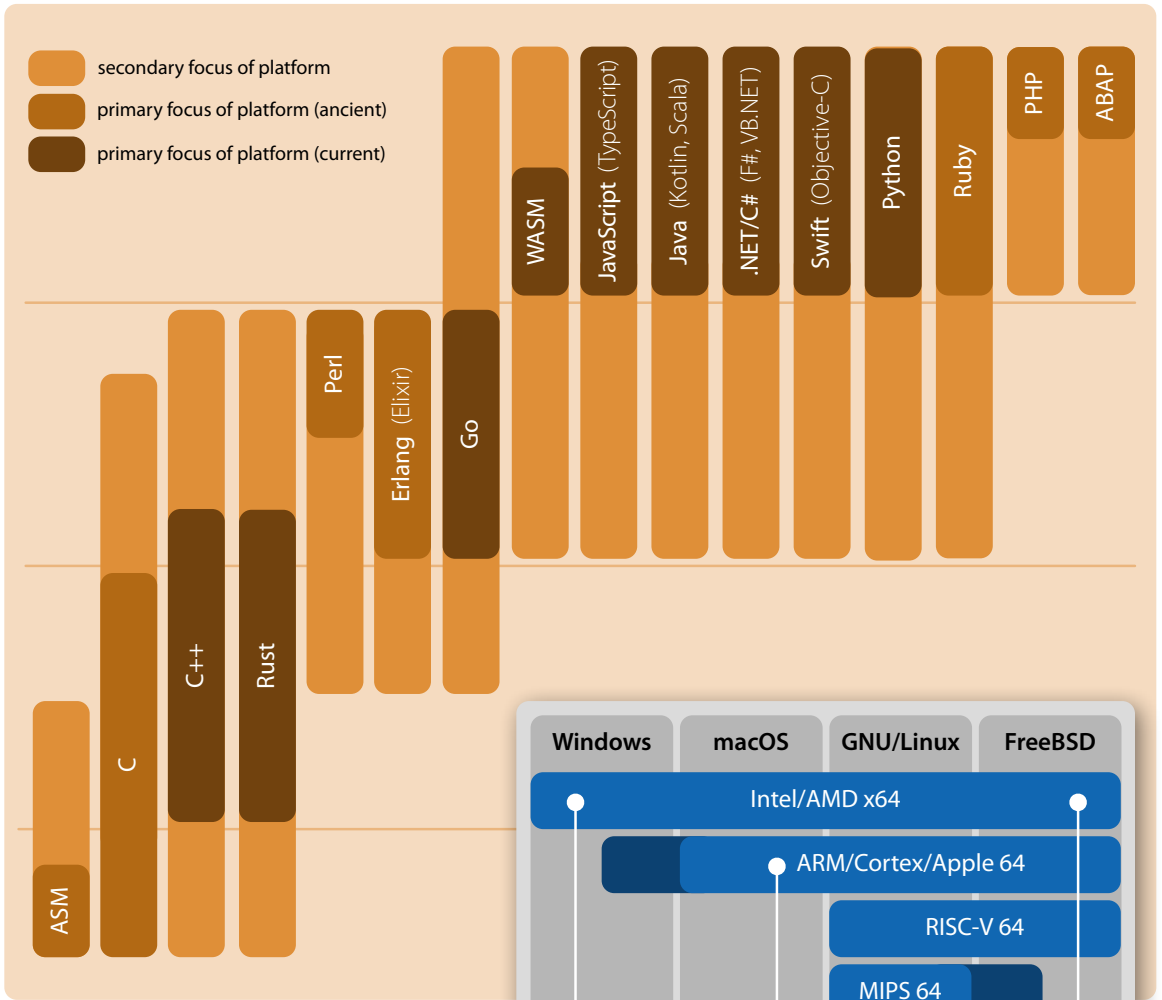
AF 12.3





Remember:
A *Technology Platform* is less about choosing a particular programming language and more about choosing a particular ecosystem for targeting a particular level of software!

Opinionated Recommendation (as of 2022):

Business:	**Scala, Kotlin, TypeScript, AssemblyScript**
Infrastructure:	**Go, Rust, Scala, Kotlin, TypeScript**
Operating System (UL):	**Rust, Go**
Operating System (KL):	**C, Go, Rust**

Typical Computing Devices (as of 2022):

Intel/AMD x64:	**Personal Computer (PC)**
ARM/Cortex/Apple 64:	**Raspberry PI, BeagleBone, ROCKSPro64, iMac**
RISC-V 64:	**Beagle-V, HiFive Unmatched**
MIPS 64:	**Compex WPJ344**

ARCHITECTURE FUNDAMENTALS

Technology Stack

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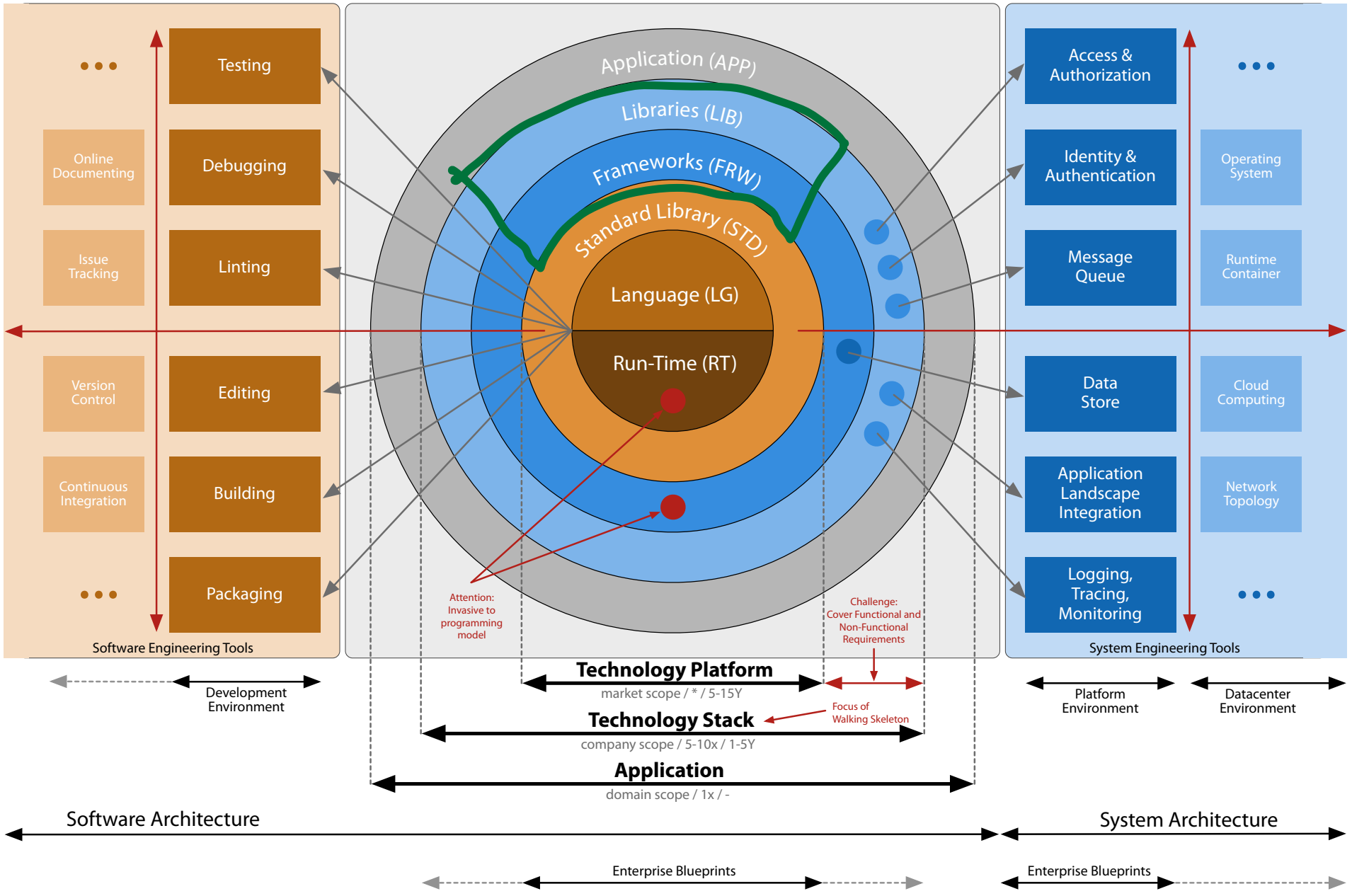

Rich-Client Aspects

ARCHITECTURE FUNDAMENTALS

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AF 12.5

IT Interface Theme

Style Reset, Shape, Color, Gradient, Shadow, Font, Icon

Bootstrap | TypoPRO, FontAwesome, Normalize

IW Interface Widgets

Icon, Label, Text Paragraph, Image, Form, Text-Field, Text-Area, Date Picker, Toggle, Radio Button, Checkbox, Select List, Slider, Progress Bar, Hyperlink, Popup Menu, Dropdown Menu, Toolbar, Tooltip, Tab, Pill, Breadcrumb, Pagination, Badge, Alert, Panel, Modal, Table, Scrollbar, Carousel

Bootstrap | Select2, SlickGrid, ...

IL Interface Layouting

Responsive Design, Media Query, Frame, Grid, Padding, Border, Margin, Alignment, Force, Magnetism

Bootstrap | Swiper, jQuery Page, ...

IE Interface Effects

Transition, Transformation, Keyframes, Easing Function, Sound Effect, Physics

VueJS | **Animate.css**, DynamicJS, Howler, ...

II Interface Interactions

Mouse, Keyboard, Touchscreen, Gesture, Clipboard, Drag & Drop

VueJS | **Hammer, Mousetrap,** Dragula, ...

IS Interface States

Rendered, Enabled, Visible, Focused, Warning, Error, Floating

VueJS | (none)

IM Interface Mask

Markup Loading, Markup Generation, Virtual DOM, Text, Bitmaps, Vectors, 2D/3D Canvas, Accessibility

VueJS | **jQuery-Markup,** D3, Snap.svg, FabricJS, ...

18 Interface Internationalization

Text Internationalization (I18N).

VueJS | vue-i18next, I18Next

DC Data Conversion

Value Formatting, Value Parsing, Localization (L10N).

VueJS | Moment, Numeral, Accounting, ...

DB Data Binding

Reactive, Observer, Unidirectional, Bidirectional, Incremental

VueJS | (none)

PM Presentation Model

Parameter Value, Command Value, State Value, Data Value, Event Value, Value Validation, Presentation Logic

ComponentJS | (none)

DN Dialog Navigation

Deep-Linking, Routing, Dialog Flow

ComponentJS | **Director,** URI.js

DA Dialog Automation

Dialog Macros, Click-Through, Smoke Testing.

ComponentJS | **ComponentJS-Testdrive**

DC Dialog Communication

Service, Event, Model, Socket, Hooks

ComponentJS | **Latching**

DL Dialog Life-Cycle

Component States, Component State Transitions.

ComponentJS | (none)

DS Dialog Structure

Component, Model/View/Controller Roles, Hierarchical Composition

ComponentJS | ComponentJS-MVC

SP State Persistence

Local Storage, Cookies, Caching

(none) | Store.js, JS-Cookie

BM Business Model

Entity, Field, Relationship, Universally Unique Identifiers (UUID)

(none) | DataModelJS, Pure-UUID

UA Use-Case Authorization

User Experience, Dialog Restriction, User, Group, Role, Use-Case, Data, Access.

(none) | (none)

CN Client Networking

Request/Response, Synchronization, Push, Pull, Pulled-Push, REST, GraphQL, Authentication, Session.

(none) | **Axios,** Apollo Client

ED Environment Detection

Runtime Detection, Feature Detection.

(none) | Modernizr, FeatureJS, jQuery-Stage

ARCHITECTURE FUNDAMENTALS

Thin-Server Aspects

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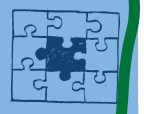
AF 12.6

ED Environment Detection



Detect the run-time environment, like underlying operating system, execution platform, network topology, feature toggles, etc.

Node — process, syspath

AP Argument Parsing

Parse options and arguments of the Command-Line Interface (CLI) to bootstrap application parameters.

(none) — yargs

CP Configuration Parsing

Load and parse directives from configuration file to bootstrap application parameters.

(none) — js-YAML

PD Process Daemonizing

Detach from the startup terminal and host process in order to run fully independently.

(none) — daemonize2

PM Process Management

(Pre-)fork child processes and/or threads of execution and monitor and control them during the life-cycle of the application.

(none) — cluster, nodemon

CM Component Management

Structure the code into components, instanciate them under run-time and manage them in a stateful component life-cycle.

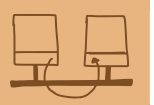
Microkernel — (none)

CC Component Communication

Provide inter-component communication mechanisms like events, hooks, registry, etc.

Microkernel — Latching

SN Server Networking



Listen to network sockets, accept connections and manage request/response and message communication.

HAPI — hapi-plugin-websocket, ws

PI Peer Information

Determine unique identification and add-on information about the client peer.

HAPI — hapi-plugin-peer, geoip

SH Session Handling

Manage secured per-connection sessions to keep state between communication requests and/or client sessions.

HAPI — YAR

UA User Authentication

Determine and validate the unique identity of the user communicating over the current network connection.

HAPI — JWT, Passport

RV Request Validation

Validate the syntactical and semantical compliance of the requests and sanitize the requests.

HAPI — Joi, DuckyJS

RP Request Processing

Process the request by dispatching execution according to the provided request and determined context information.

HAPI — GraphQL.js

RA Role Authorization

Determine whether the role of the current user is allowed to execute the current request.

(none) — GraphQL-Tools-Sequelize

CN Client Networking

Provide mechanisms to connect to peers over the network and perform request/response and/or publish/subscribe communication.

(none) — Axios, MQTT.js, ws

TS Task Scheduling

Schedule and execute recurring tasks independent of regular I/O operations.

(none) — node-scheduler

ET Execution Tracing

Provide mechanisms for tracing the execution by logging event and measurement information at certain points of interest.

Microkernel — Winston

DA Database Access

Map in-memory domain entities onto data store dependent persistent data structure.

Sequelize — GraphQL-Tools-Sequelize

DC Database Connectivity

Locally or remotely connect the database access layer to the underlying data store.

Sequelize — sqlite3, pg

DS Database Schema

Create, update or downgrade the data schema inside the underlying data store.

Sequelize — (none)

DB Database Bootstrapping

Create, update or downgrade both mandatory bootstrapping and optional domain-specific data inside the underlying data store.

Sequelize — ini

ARCHITECTURE FUNDAMENTALS

Software Deployment

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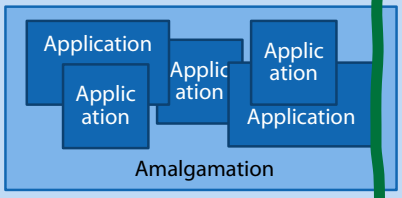
AF 13.1

AMA Bare Amalgamation

Manually deploy all applications into a single, shared, and unmanaged filesystem location. Dependencies are resolved manually. Examples: Windows Fonts, Unix 1990th /usr/local.

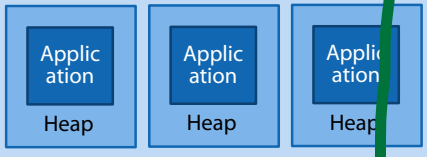
Pro: simple deployment
Con: incompatibilities, hard uninstallation



UHP Unmanaged Heap

Manually deploy all applications into multiple, distinct, and unmanaged filesystem locations. Dependencies are resolved manually. Examples: macOS *.app, OpenPKG LSYNC.

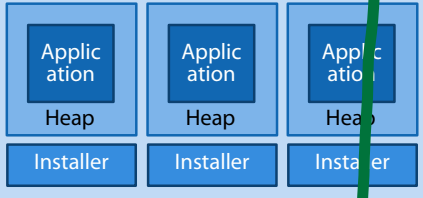
Pro: simple deployment, easy uninstallation
Con: no repair mechanism



MHP Managed Heap

Let individual installers deploy applications into multiple, distinct, and managed filesystem locations. Dependencies are manually resolved or bundled. Examples: macOS *.pkg, Windows MSI, InnoSetup.

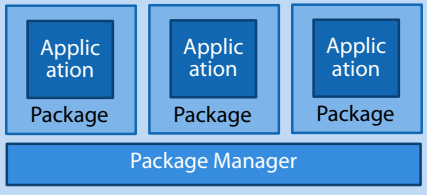
Pro: easy uninstallation, repairable
Con: requires installer, diversity, no dep.



PKG Managed Package

Let a central package manager deploy all applications into a single, shared, and managed filesystem location. Dependencies are automatically resolved. Examples: APT, RPM, FreeBSD pkg, MacPorts, Gradle, NPM.

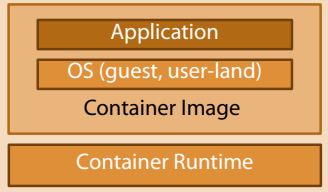
Pro: easy uninstall., repairable, dependencies
Con: P.M. pre-installation, P.M. single instance



CON Container Image

Bundle an application with its stripped-down OS dependencies and run-time environment into a container image. Examples: Docker/ ContainerD, Kubernetes/CRI-O, Windows Portable Apps.

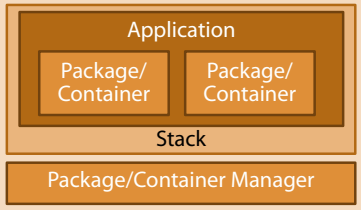
Pro: independent, simple deployment
Con: fewer variations, no dependencies



STK Package/Container Stack

Establish an application out of multiple Managed Packages. Examples: OpenPKG Stack, Docker Compose, Kubernetes/ Kompose, Kubernetes/Helm.

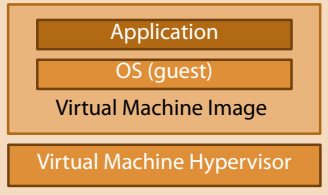
Pro: independent, flexible
Con: overhead



VMI Virtual Machine Image

Bundle an application with its full OS dependencies and run-time environment into a virtual machine image and deploy and execute this on a hypervisor. Examples: VirtualBox, VMWare, HyperV, Parallels, QEMU.

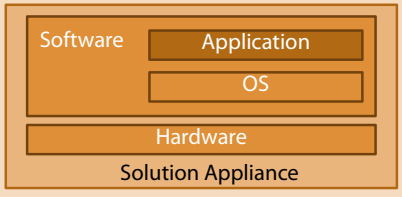
Pro: all-in-one, independent
Con: overhead, sealed, inflexible



APP Solution Appliance

Bundle an application with its full OS dependencies, run-time environment and underlying hardware. Examples: AVM Fritz! Box, SAP HANA.

Pro: all-in-one, independent
Con: expensive, sealed, inflexible



ARCHITECTURE FUNDAMENTALS

Cloud Computing Resources

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AF 13.2

Cloud Characteristics — How?

logically / chronologically related

- ON-DEMAND
- SELF-SERVICE
- AUTOMATABLE
- NETWORK ACCESS

logically / chronologically related

- MULTI-TENANCY
- MEASURED SERVICE
- ELASTICITY
- PAY-PER-USE

Cloud Scope — Who?

outside-inside relationship

- Public Cloud
- Community Cloud
- Private Cloud

Cloud Location — Where?

outside-inside relationship

- Provider-Hosted
- On-Premises

Cloud Approaches — What?

technical layers

- Service
- Application
- Service Mesh
- Service Events
- Application Runtime
- Tools & Libraries
- Container Runtime
- Operating System
- Computer
- Network

	SaaS	FaaS	PaaS	CaaS	IaaS
	e.g. Salesforce e.g. Sharepoint 365 (think: Web-UI-based Service)	e.g. AWS Lambda e.g. Azure Functions (think: Stateless Microservice)	e.g. AWS EKS e.g. Azure AKS (think: Kubernetes)	e.g. AWS ECS & Fargate e.g. Azure Container Apps (think: Docker)	e.g. AWS EC2 e.g. Azure Virtual Machines (think: Virtual Machine)
		aka "Serverless Computing"			
	Software as a Service	**Function** as a Service	**Platform** as a Service	**Container** as a Service	**Infrastructure** as a Service
Duration:	User Session	Function Call	Continuously		
Interfaces:	Proprietary		Standardized		
			(think: OCI)		(think: PC)

ARCHITECTURE FUNDAMENTALS

Cloud-Native Architecture

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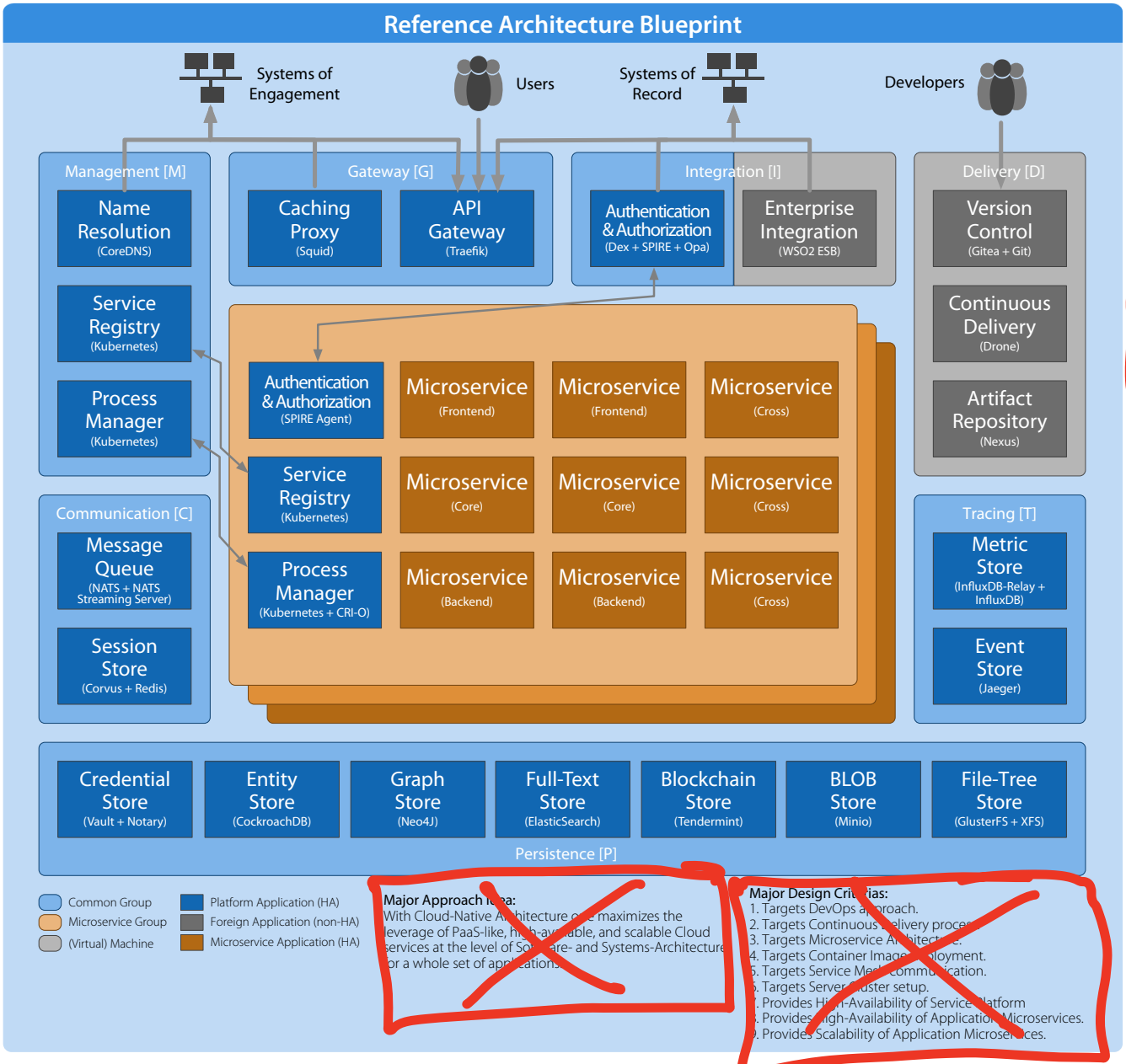
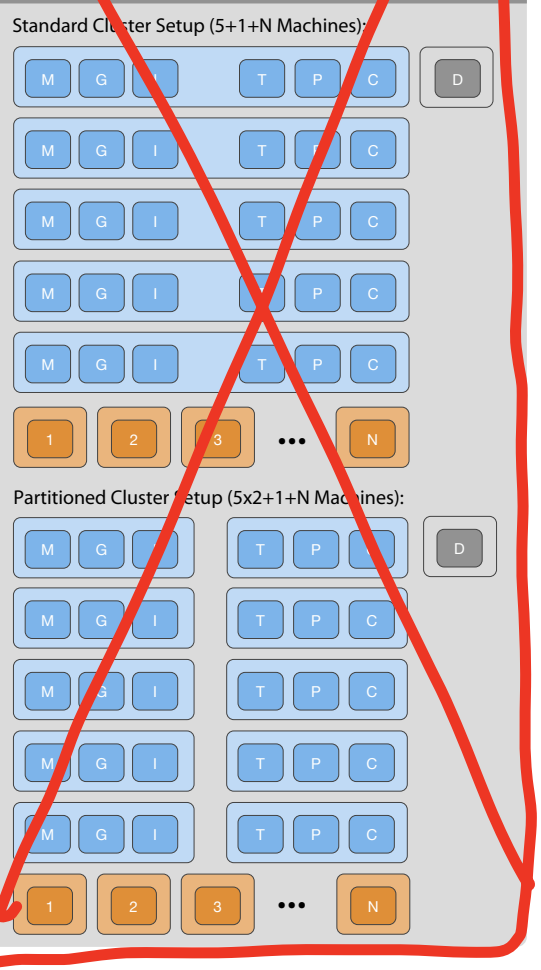


CNCF Cloud-Native Definition 1.0

Cloud-native technologies empower organizations to build and run scalable applications in modern, dynamic environments such as public, private, and hybrid clouds. Containers, service meshes, microservices, immutable infrastructure, and declarative APIs exemplify this approach. These techniques enable loosely coupled systems that are resilient, manageable, and observable. Combined with robust automation, they allow engineers to make high-impact changes frequently and predictably with minimal toil.

Practical Cluster Setups



ARCHITECTURE FUNDAMENTALS

Offline Capability

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GOAL

UX Exceptional User Experience

Provide exceptional *User Experience* by taking temporary client/server network offline situations into account and establish trust in the offline capability of the application.

CONTEXT

IS Business Information Systems

Client/server applications which drive business processes through use-cases, based primarily on the editing, storing, and retrieving of information.

CC Cloud Computing

On-demand availability of computing resources, especially data storage and computing power, without direct active management by the customer.

CHALLENGES

VPN Toggled Virtual (Private) Networks

Network offline situations caused by the explicit on/off toggling of overlayed *Virtual (Private) Networks* by the user.

MNC Switched Mobile Network Cells

Network offline situations caused by the implicit switching between the mobile network cells by the device during mobile use.

NCO Failed Network Components

Network offline situations caused by the failure of any network components between the client and server tiers of an application.

MATURITY LEVELS

Hint: you cannot solve offline scenarios at the technical level if your use-cases are not already aligned to them.

L2 Offline Read

During offline phase, client allows **read**-operations, but **no write**-operations, to locally cached data.

Data Access Layer Proxy
Web Storage API

L1 Offline Aware

During offline phase, client **explicitly** disables user interface and **shows modal error message**.

Rich-Client
Web Network Information API

L0 Offline Unaware

During offline phase, client **implicitly** fails with network errors.

Thin-Client

Notice: each level increases user experience, but also increases technical complexity.

L5 Offline Transactional Read / Write

During offline phase, client allows **non-atomic (transactional)** read/write-operations to any locally cached data.

SAGA
Compensation

L4 Offline Read & Atomic Write

During offline phase, client allows **atomic read/write**-operations to **any** locally cached data.

CRDT, Event Sourcing
CQRS, Optimistic Locking

L3 Offline Read & User-Exclusive Write

During offline phase, client allows atomic **read**-operations to **any**, and **write**-operations to **user-exclusive**, locally cached data.

Data Synchronisation
Last-Win Conflict Resolution

ARCHITECTURE FUNDAMENTALS

Version Control Architecture

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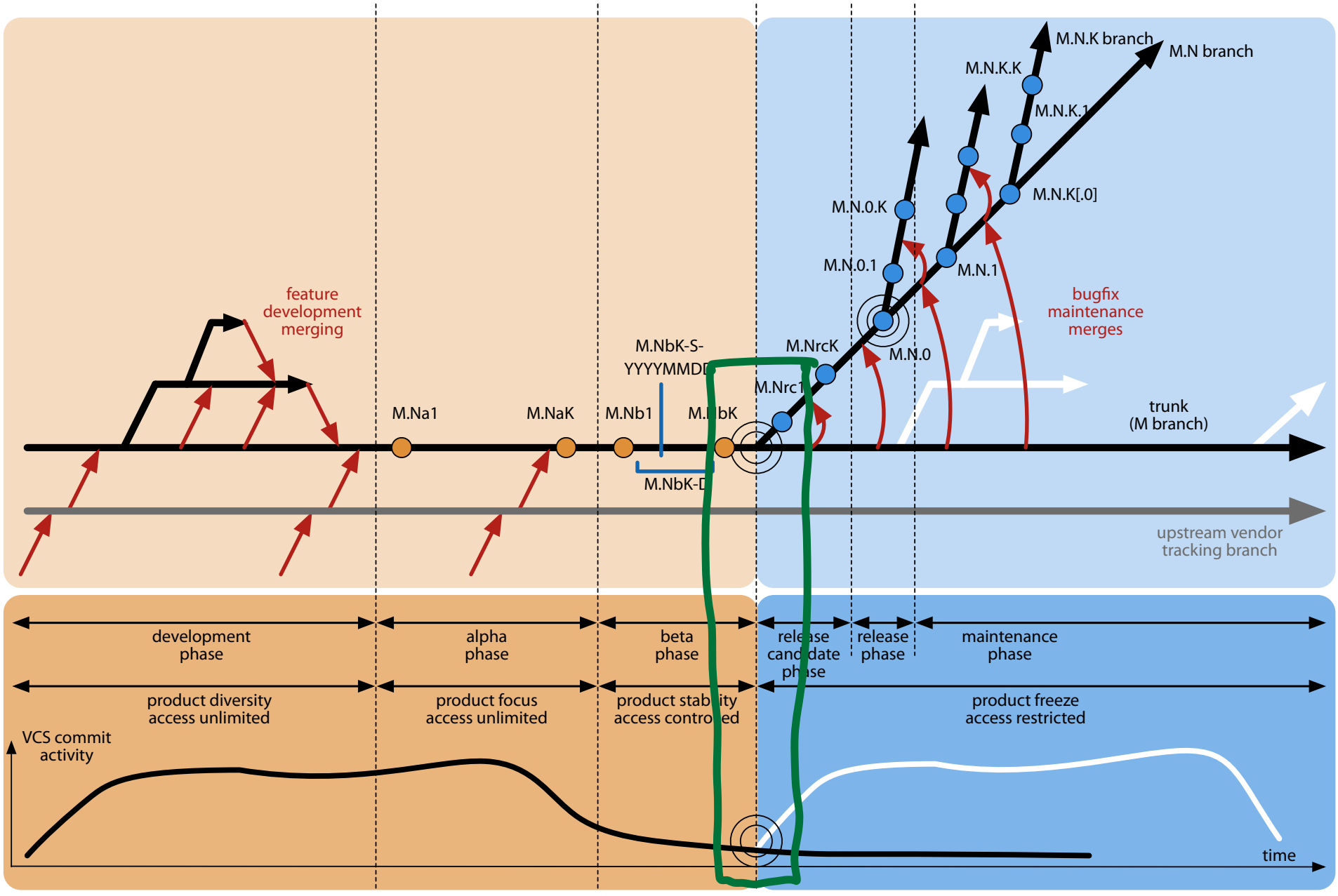

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ARCHITECTURE FUNDAMENTALS

Assembly Process Architecture

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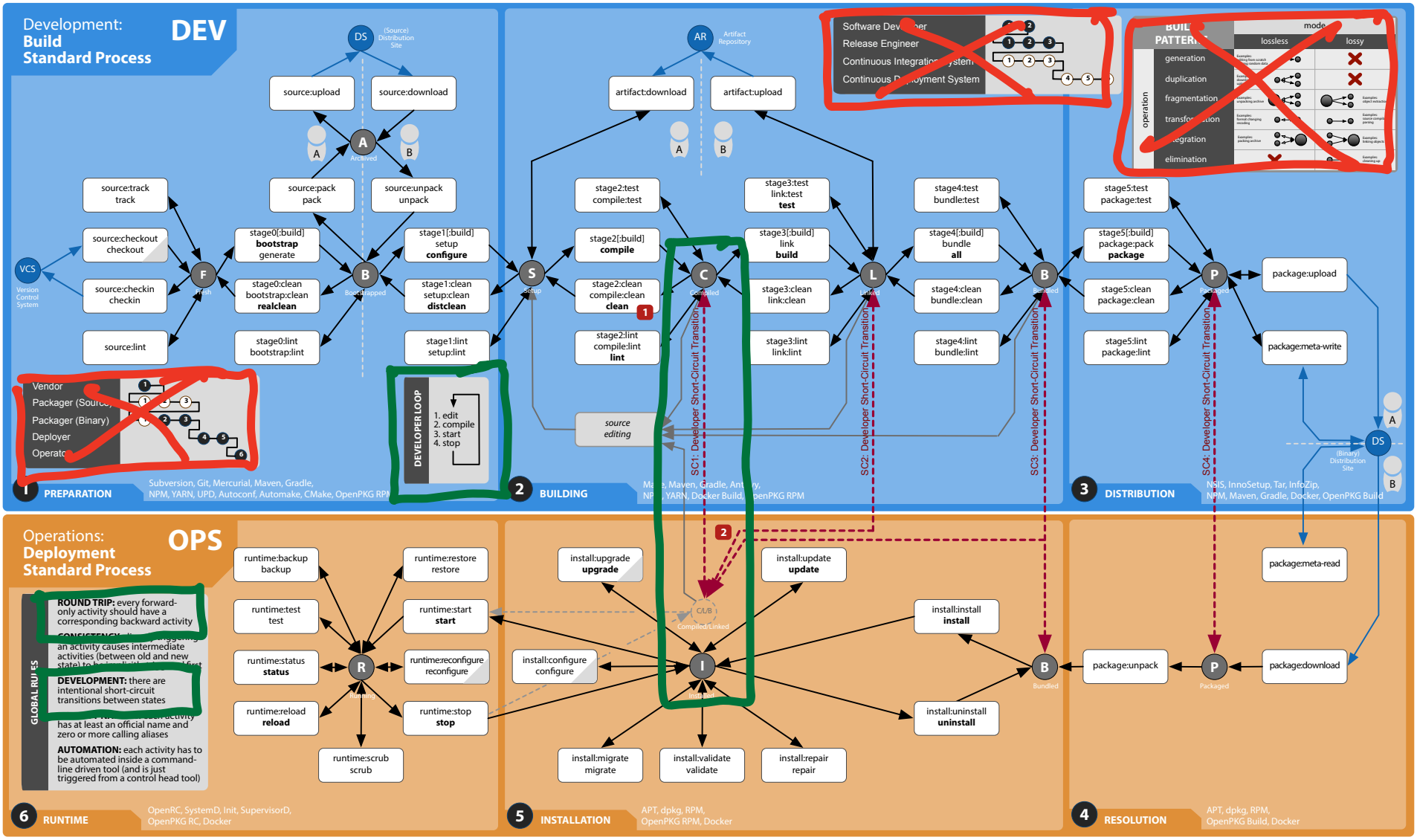

ARCHITECTURE FUNDAMENTALS

Environments & Quality Assurance

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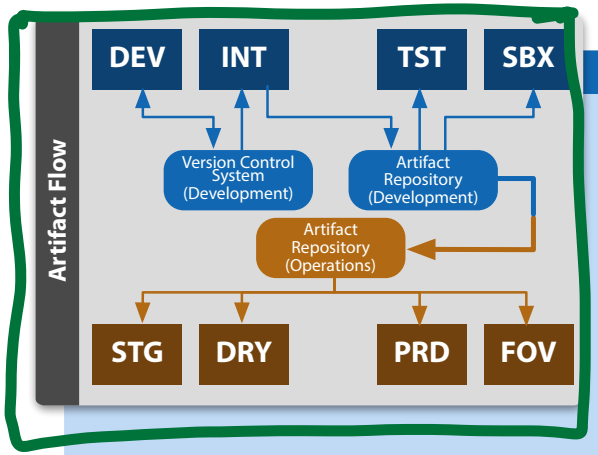

Development Environments

DEV Development

(Potentially destructive) Environment for the (separated) development of all artifacts of the system, typically located on each developer's respective system.

INT Integration

(Potentially destructive) Environment for integrating all artifacts of the system, usually located centrally to the developers and driven automatically.

SBX Sandbox

Destructive environment mirroring the Test environment for demonstration and experimentation purposes, including trainings and showcases.

TST Test

Environment for testing the system as a whole in a production-resembling context.

Operations Environments

DRY Dry-Run

Destructive environment mirroring the Staging environment for experimentation purposes, including operating system and major dependency upgrades.

STG Staging

Environment for staging the system as a whole in a production-equal context in order to deploy it to the Production environment subsequently.

Environment Mirroring

FOV Failover

Destructive environment mirroring the Production environment for failover situation, including disaster recovery situations.

PRD Production

Environment for running the system as a whole in production.

Replicated Environments

Original Environments

Testing Targets:

Testing Approaches

UT Unit Testing

Whitebox testing the inner details of individual units (components) against their functional specification.
Specialization: Regression Testing

IT Integration Testing

Whitebox testing the outer interplay of individual units (components) against the technical design of the solution.
Specialization: Smoke Testing

ST System Testing

Blackbox testing the system as a whole against the functional and non-functional requirements of the solution.
Specialization: Load Testing

UAT (User) Acceptance Testing

Blackbox testing and formal approval of the system as a whole against the end-to-end functionality and user experience requirements.

OT Operation Testing

Blackbox testing the system as a whole against the availability and proper operation of the intended services.
Specialization: Service Monitoring

Quality Promise, Bugfix Effort

ARCHITECTURE FUNDAMENTALS

DevOps Toolchain

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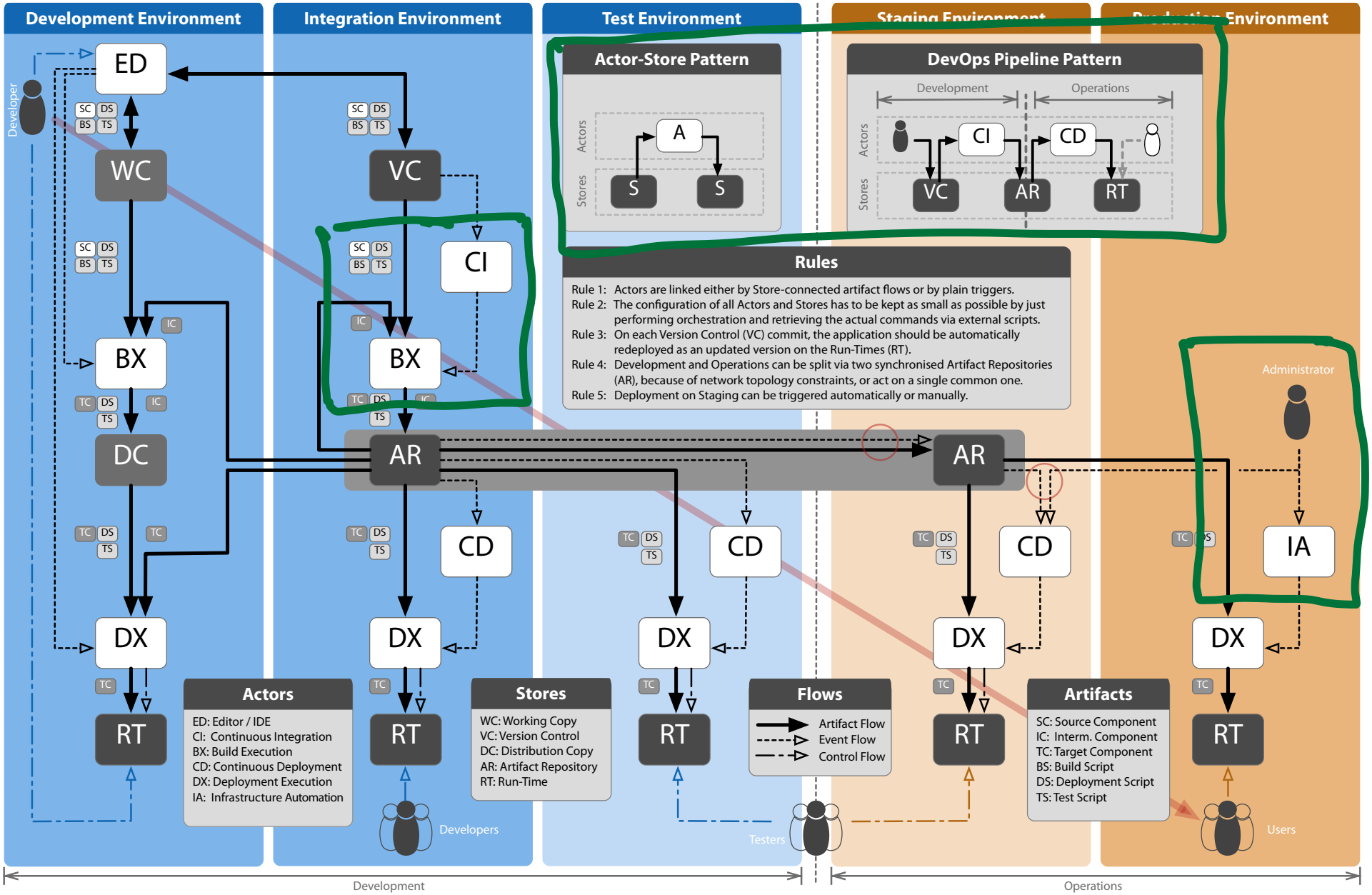
AF 14.4



ARCHITECTURE FUNDAMENTALS

Software Release Management

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Evolution Stage — What?

WF Wireframe
Distraction-free low-fidelity illustration of the solution and its base features, displaying its pure structure and core functionality only.

WS Walking Skeleton
Realization of all technical, fundamental aspects of the solution, ensuring the domain specific aspects can be realized later on top of it without problems.

PT Prototype
High-fidelity mostly interactive sample, mockup, model or simulation of the solution and its base features, showcasing its structure and functionality.

MVP Minimum-Viable Product
Early version of solution with just enough functionality to enable full turn of Build-Measure-Learn loop with minimal amount of effort and time.

PoC Proof of Concept
Pure realization of most-risky aspects of the solution, proofing their feasibilities. Might still be based on a different technology than WS, MVP and FP.

FP Full Product
Final version of the solution with all intended functionality and targeting the mainstream market.

arbitrary technology | target technology

Version Number — When?

M Major Version
Major Version of solution. Usually bumped on major technical or domain-specific changes only. A bump resets the Minor Version and the Revision, too.

N Minor Version
Minor Version of the solution within the Major Version. Usually bumped on new features. A bump resets the Revision, too.

R Revision
The Revision of the Release Phase within Major and Minor Version. Bumped for every A/B/C/R Release Phase.

Release Phase (p) — When?

A Alpha
Early version of the solution with incomplete and unstable functionalities to get feedback on product. Usually tagged as "M.NaR" (R > 0).

C Candidate
Mature version of solution with complete and stable functionalities to catch last-minute problems. Usually tagged as "M.NrcR" (R > 0) around RTM.

B Beta
Early version of the solution with complete but still unstable functionalities to stabilise product. Usually tagged as "M.NbR" (R > 0).

R Release
Release version of the solution with complete and stable functionalities, available for production use. Usually tagged as "M.N.R" (R >= 0).

Points-In-Time (PiT) — When?

DEV Development
Arbitrary permanent points-in-time during development. This is the default tag for the source code. Intended for no availability releases.

SNP Snapshot
Distinct temporary point-in-time for a release of the current version without a version increase. Intended for limited availability releases.

REL Release
Distinct temporary point-in-time for a release of the current version with a version increase. Intended for early and general availability releases.

Product Edition — Which?

CE Community Edition
Edition of the solution for the Open Source Community. Contains just the base functionality and has limited volunteering support.

STD Standard Edition
Edition of the solution with just the standard functionality and regular support.

EE Enterprise Edition
Edition of the solution for the Enterprise market. Contains the base and additional functionality and has full commercial support.

PRO Professional Edition
Edition of the solution with both the standard and extra functionalities and extended support.

Availability Scope (S) — Who?

XA No Availability
No public availability of solution at all. The scope for all Development and sometimes Snapshot point-in-times.

EA Early Availability
Early public availability of solution for early market. Usually for Beta or Release Candidate levels or for Release and initial Release Update levels.

LA Limited Availability
Limited public availability of solution. Usually for releases after the End-of-Life-Announcement (EOLA) or for releases with specific customer features.

GA General Availability
Late public availability of solution for mainstream market. Usually for Release and sometimes just for Release Update levels.

Distribution Channel — Where?

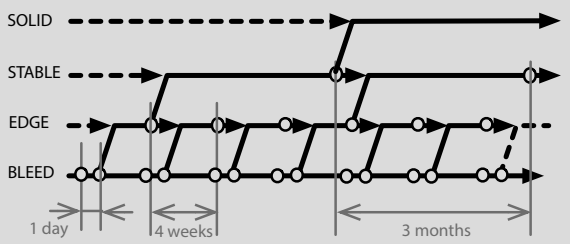
BLEED Bleed Channel
Distribution channel for all daily snapshots ("YYYY.MM.DD") with experimental features turned on. Intended for testing purposes only.

STABLE Stable Channel
Distribution channel for all quarterly releases ("YYYY.QN") with experimental features turned off. Intended for fast mainstream market and production use.

EDGE Edge Channel
Distribution channel for all monthly releases ("YYYY.MM") with experimental features turned on. Intended for early market or testing purposes.

SOLID Solid Channel
Distribution channel for all (half-)year releases ("YYYY[.N]") with experimental features turned off. Intended for slow mainstream market and production use.

Distribution Channel Artifacts



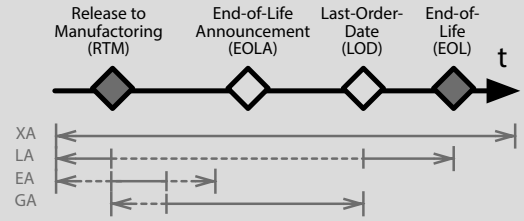
Versioning Scheme (stdver.org)

M . N p R [. D] [+ H] [- S]

Examples:

```
1.2a3.20230101+F42A-XA
1.2b3-EA
1.2.3-GA
1.2.3
```

Product Life-Cycle



ENGINEERING FUNDAMENTALS

Sustainability

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EF 01.7

HI — Minimize HARDWARE Idleness

Minimize the idleness and maximize the utilization of existing hardware resources.

Rationale: Unused or under-utilized hardware are an unnecessary waste of already available resources.

Keywords: Virtualization, Utilization.

DE — Minimize DESIGN Excessiveness

Minimize the excessiveness and maximize the adequacy of solution designs.

Rationale: Non-adequate designs cause unnecessary complexity and waste resources.

Keywords: Reduced Libraries, Immutability.

HE — Minimize HUMAN Effort

Minimize the efforts of humans and maximize the efforts of machines in all production and operation processes.

Rationale: Delegating tasks to machines gives humans the possibility to concentrate on more important tasks.

Keywords: Computer, Robot, Automation.

SI — Minimize SOFTWARE Inefficiency

Minimize the inefficiency and maximize the efficiency of software applications and their development processes.

Rationale: Efficient software and development processes consume less resources.

Keywords: Caching, Monolith.

SE — Minimize SOLUTION Ephemerality

Minimize the ephemerality and maximize the life-span of any type of solutions.

Rationale: Short life-spans of solutions cause unnecessary short renewals and this way wastes resources.

Keywords: High Quality, Best Practice.

EC — Minimize ENERGY Consumption

Minimize the consumption and maximize the saving of energy in all production and operation processes.

Rationale: Electric energy still has to be partially generated from non-renewable resources.

Keywords: Eco Mode, Reduced CI/CD.

IA — Minimize INFORMATION Amount

Minimize the total amount of gathered, transmitted, stored and spreaded information.

Rationale: Reduced amount of information means less data transmission, less data storage, less GDPR issues, etc.

Keywords: Compression, No Big Data.

EE — Minimize ECOSYSTEM Exploitation

Minimize the exploitation and maximize the back-contribution in any type of ecosystems.

Rationale: The consumer and provider behaviour have to be in balance for every long-lasting ecosystem.

Keywords: Open Source Software.

CE — Minimize CARBON Emission

Minimize the carbon emission and hence the footprint during any type of production and operation processes.

Rationale: Climate change and global warming is partially caused or at least accelerated by carbon emissions.

Keywords: Reduced CO2 Footprint.

ARCHITECTURE FUNDAMENTALS

Think Clearly

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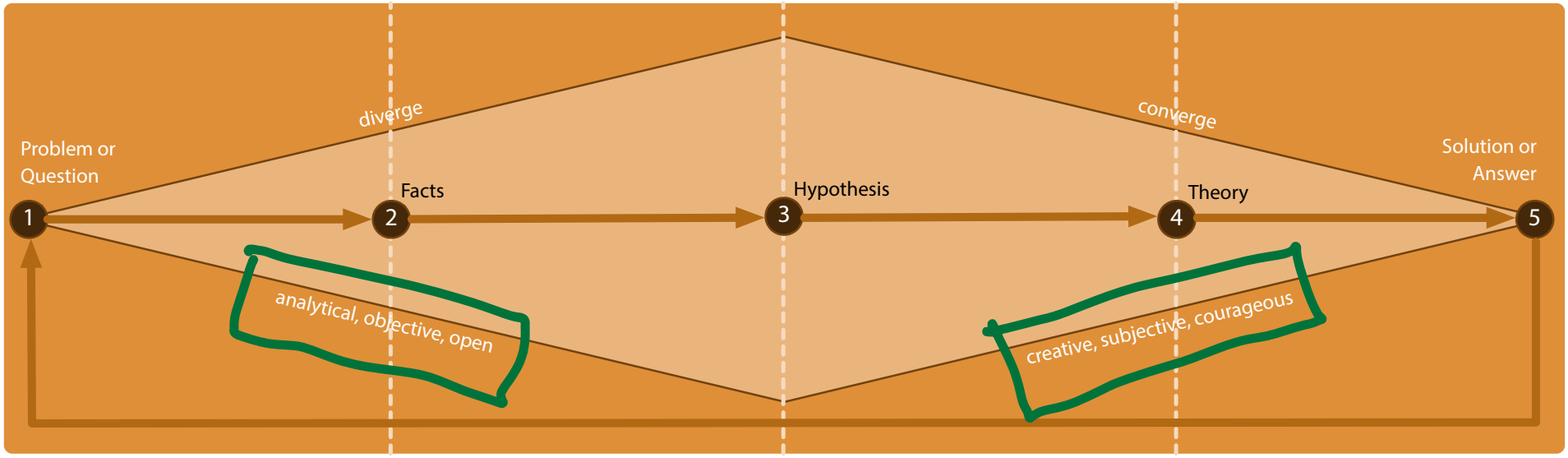

INVESTIGATE & RESEARCH

1. Reflecting
(find facts via own knowledge/experience)

2. Searching
(find facts via body of knowledge)

3. Verification
(cross-check facts according to sources)

4. Tagging
(classify facts with tags)

STRUCTURE & SORT

1. Typing
(split/aggregate facts according to type)

2. Clustering
(hierarchically group facts by tags)

3. Relating
(link source to target facts)

4. Ordering
(order facts in each cluster)

REDUCE & COMPLEMENT

1. Substituting
(substitute/rename facts)

2. Extending
(add still missing facts)

3. Priorization
(priorize facts according to criterias)

4. Rejecting
(reject non-relevant/redundant facts)

INTEGRATE & PRESENT

1. Specialization
(specialize too general facts)

2. Generalization
(generalise too specific facts)

3. Integration
(aggregate/link facts)

4. Presentation
(convert facts into target form)

(primary step) (secondary step)

AF 16.1

ARCHITECTURE FUNDAMENTALS

Problem Solving Heuristics

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Research (RE)

Crawling the problem domain's body of knowledge to find starting points.

Abstraction (AB)

Solving the problem in a model of the problem before applying it to the real problem to get a better understanding.

Lateral Thinking (LT)

Approaching the problem indirectly and creatively to find a not obvious solving lever.

Backward Search (BS)

Looking at the expected results and determine which operations could bring you to them.

Brainstorming (BR)

Suggesting larger number of solution ideas for further combination and development.

Generalization (GE)

Thinking about the problem more abstract to get rid of special cases.

Hypothesis Proof (HP)

Assuming a possible solution and trying to prove (or disprove) the assumption to find starting points.

Q.E.D.

Backtracking (BT)

Remembering path towards the solution and on failure tracking back and choosing a new path.

Analogy (AN)

Thinking in terms of similar problems for which solutions are known to get inspired.

Specialization (SP)

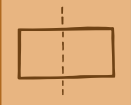
Solving a special case first to get an impression towards the full solution.

Root Cause (RC)

Asking "Why?" five times in sequence to explore the cause-and-effect relationships underlying the problem.

Divide & Conquer (DC)

Breaking down the large complex problem into smaller, easier solvable partial problems.



Reduction (RD)

Transform the problem into another one for which a solutions already exists to reduce solving efforts.

Variation (VA)

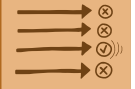
Changing the problem context or expressing the problem differently to find a not obvious solving lever.

Means End (ME)

Choosing an action from scratch just at each step to move closer and closer to the solution.

Trial & Error (TE)

As a last resort brute-force testing all potential solutions in case of a small enough total solution space.



Definition: ***Heuristic*** — fallible experience-based technique or strategy for problem solving in case *Rule of Thumb Guessing*, *Intuitive Judgement*, *Common Sense* and *Stereotyping* are either not sufficient or not appropriate.

AF 16.2

ARCHITECTURE FUNDAMENTALS

Technology Life-Cycles

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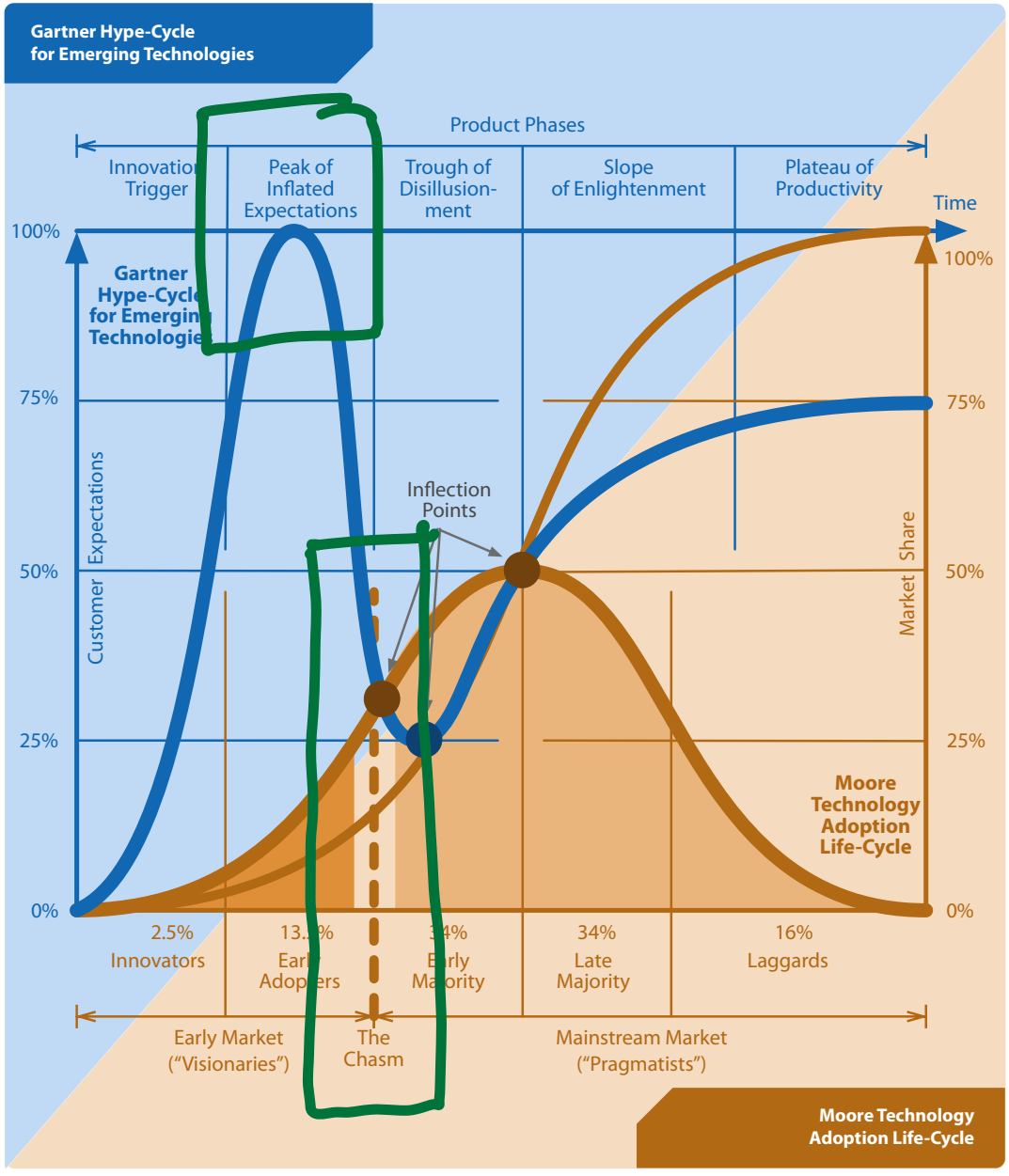

Gartner Hype-Cycle for Emerging Technologies

According to [1], provides "a graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new opportunities." It gives "a view of how a technology or application will evolve over time." The five product phases are:

"**Innovation Trigger:** A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.

Peak of Inflated Expectations: Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not. The peek can be also considered a direct result of the *Dunning-Kruger Effect*, a "cognitive bias in which people mistakenly assess their cognitive ability as greater than it is" [2] and hence exaggerate in their expectations.

Trough of Disillusionment: Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.

Slope of Enlightenment: More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.

Plateau of Productivity: Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off."

Moore Technology Adoption Life-Cycle

According to [3], describes "the adoption or acceptance of a new product or innovation, according to the demographic and psychological characteristics of defined adopter groups." The five distinct adopter groups are:

"**Innovators:** had larger" business, "were more educated, more prosperous and more risk-oriented.

Early Adopters: younger, more educated, tended to be community leaders, less prosperous.

Early Majority: more conservative but open to new ideas, active in community and influence to neighbours.

Late Majority: older, less educated, fairly conservative and less socially active.

Laggards: very conservative, had small" business "and capital, oldest and least educated."

According to [4], there is also a "chasm between the early adopters of the product (the technology enthusiasts and visionaries) and the early majority (the pragmatists)," because "visionaries and pragmatists have very different expectations." and technology is usually switched, at last at the Inflection Points.

Crossing The Chasm [4] is related to the *Innovator's Dilemma* [5], where "new entry next generation products" usually "find niches away from the incumbent customer set to build the new product."

[1] https://gtnr.it/36rBT4X
[2] https://bit.ly/2qZ4Lkx
[3] https://bit.ly/2N3fB1t
[4] https://bit.ly/2NuRNT7
[5] https://bit.ly/34lMkEW

ARCHITECTURE FUNDAMENTALS

Open Source Software

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Open Source Definition

Distribution terms (license) of Open Source Software must be compliant with the following criterias:

- Free **Redistribution**
- (Original) **Source Code** (Availability)
- **Derived Works** (Allowance)
- **Integrity of the Author's Source Code**
- **No Discrimination** Against **Persons** or Groups
- **No Discrimination** Against **Fields** of Endeavor
- **Distribution** of (Non-Exclusive) **License**
- License Must **Not Be Specific to a Product**
- License Must **Not Restrict Other Software**
- License Must Be **Technology-Neutral**

Open Source Personality Streams

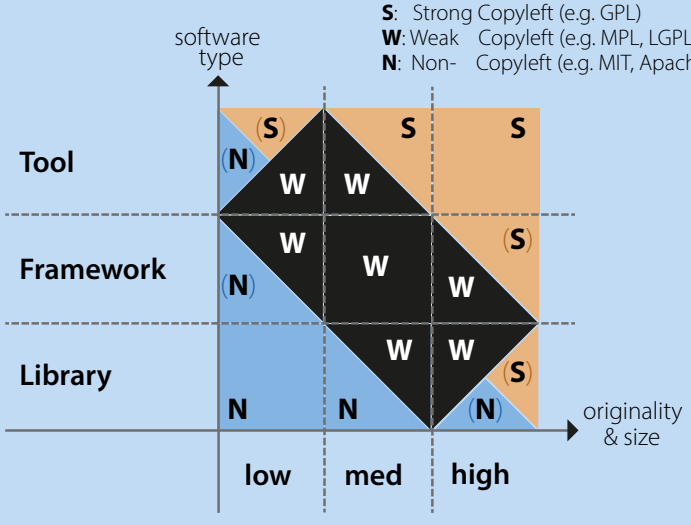
§ **Software Sharing**	Dogmatism Social Equity Politics	Science
@ **Software Hacking**	Fundamentalism Art Hacking	Private
€ **Software Engineering**	Pragmatism Business Engineering	Industry

Most Popular Open Source Licenses

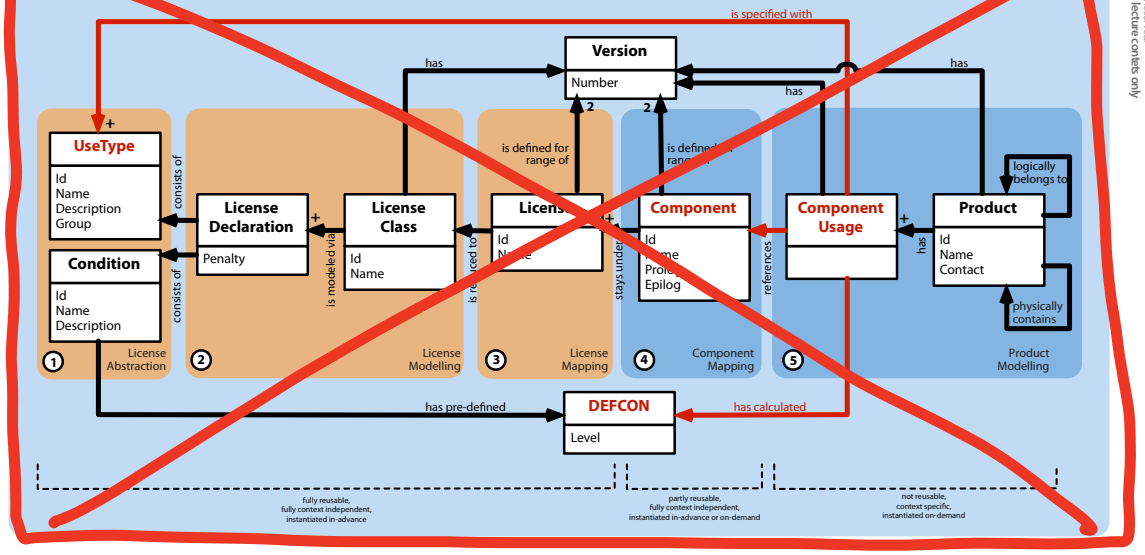
(weak) Non-Copyleft (strong)						(weak) Copyleft (strong)						
CC0 1.0	MIT	BSD [2C]	BSD [3C]	BSD [4C]	Apache 2.0	CDDL 1.0	MPL 2.0	EPL 1.0	LGPL 3.0	CC-BY-SA 4.0	GPL 3.0	AGPL 3.0

Choosing an Open Source License

S: Strong Copyleft (e.g. GPL)
W: Weak Copyleft (e.g. MPL, LGPL)
N: Non- Copyleft (e.g. MIT, Apache)



License Compliance Checking Meta-Model



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Back of the Envelope Calculation

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Specification (Example)

Customer: Twitter Inc.
Business: MicroBlogging

Use-Cases 1/3 (profile):
- user can register an account
- user can "follow" other users
- user can create lists of users he follows

Use Cases 2/3 (send):
- user can send tweets
- tweets are based on words, each either a text "example", tag "#example", user reference "@example" or URL http://example.com
- tweets are either public broadcast or personal/direct messages
- user can re-tweet a message of others

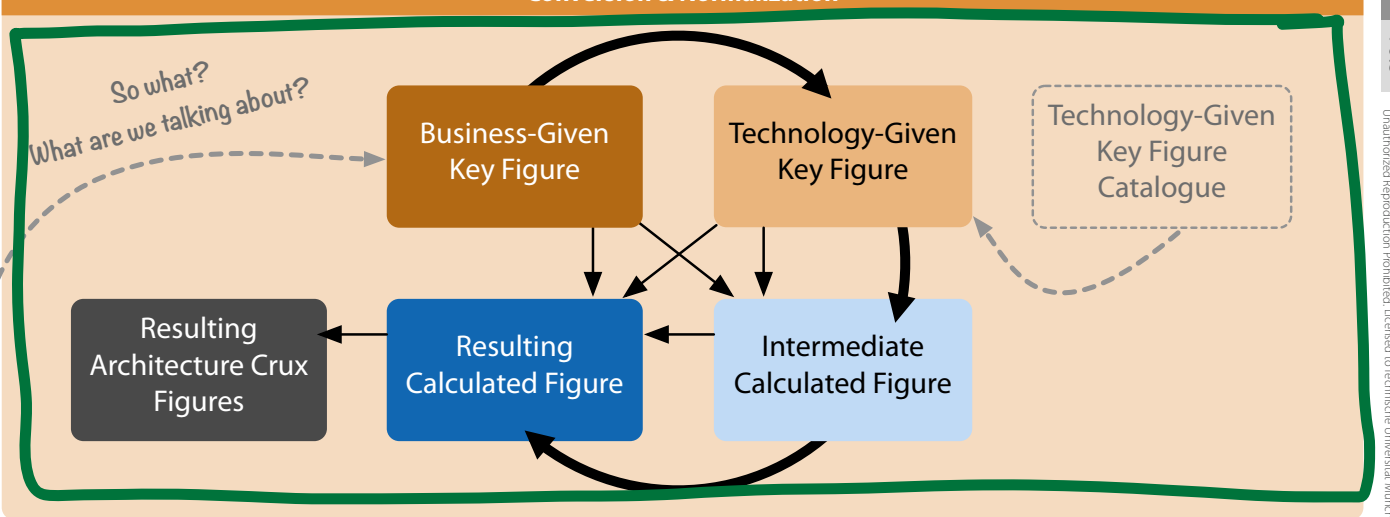
Use Cases 3/3 (query):
- user can view timeline (chronological tweets of others he follows)
- user can search for tweets (by keyword "foo", tag "#foo", or user "@foo")
- user can view tag cloud

Frontends/Clients:
- mobile app (iOS, Android)
- desktop app (Windows, Mac OS X)
- web app
- embedded web widget (query use cases only)

Current Demand (as of 2012):
- 140M user profiles
- 400M tweets/day
- 6393 tweets/second peak
- 140 characters/tweet
- 30K queries/second
- 300 GB/hour data in total
- 4,4 tweets/day/user on average
- 103,4 follower/user
- < 5s tweet-write-to-read-delay

Future Demand:
- quadratic user and traffic growth

Conversion & Normalization



Calculation (Example)

Twitter Information

6.393	tweets/second peak
400.000.000	tweets/day (write)
2.592.000.000	queries/day (read)
6,5	factor read/writes

140	chars/tweet
4.630	tweets/second (write)
30.000	queries/second (read)
10	tweets/query

4,4	tweets/day/user
2,4	tweets/day (M. Fowler)
0,8	tweets/day (R. Engelschall)
621.880.000	tweets/day (average) total
64,3%	users are active at all
277.778	users/minute active

Traffic Bandwidth

350%	overhead HTTP+TCP+IP+Ethernet
2,2	MB/s (write)
140,2	MB/s (read)
142,4	MB/s

10000	Mbps
1000	Mbps
100	Mbps
10	Mbps

1250	MB/s
125	MB/s
12,5	MB/s
1,25	MB/s

Storage Requirements (static)

140.000.000	user profiles
52.000	chars/users for profile
6,62	TB profile (total)
103,4	follower/user
14.474.600.000	user follow links
32	bytes/link
0,42	TB links (total)

Storage Hardware Requirements

0,3	TB/disk (15K rpm)
8,0	disks/server
2,4	TB/server
8,2	server/month (new)

Storage Requirements (dynamic)

300	GB/hour data in total
214	TB/month data in total
200%	overhead storage
1265,9	KB/s tweets
104,3	GB/day tweets
3,1	TB/month tweets
200	chars/log entry
6763,6	KB/s log
557,3	GB/day log
16,6	TB/month log
9,2%	ratio business data
90,8%	ratio infrastructure data

Computing Hardware Requirements

2000	requests/sec (read) AS performance
100	requests/sec (write) As performance
15,0	servers for writes
46,3	servers for reads

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Weighted Decision Matrix

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Weighted Decision Matrix

		A_1	A_2	…	A_n
C_1	w_1	$E_{1,1}$	$E_{1,2}$	…	$E_{1,n}$
C_2	w_2	$E_{2,1}$	$E_{2,2}$	…	$E_{2,n}$
…	…	…	…	…	…
C_m	w_m	$E_{m,1}$	$E_{m,2}$	…	$E_{m,n}$
		R_1	R_2	…	R_n

$C_{i=1..m}$: Criteria i

$A_{j=1..n}$: Alternative j

$w_{i=1..m}$:in [1/4, 1/2, 1, 2, 4]: Weighting i

$E_{i,j}$ in { -2, -1, 0, +1, +2 }: Evaluation i,j

$R_{j=1..n} = SUM_{i=1..m}(w_i * E_{i,j})$: Rating j

$R_{best} = MAX_{j=1..n}(R_j)$: Best Rating

Light-Weight Alternative:
qualitatively cherry-picking major positive/negative backing criterias

	A_1			A_2			…	A_n		
+	C_1	C_4	C_8	C_1	C_2	C_7	…	C_2	C_9	C_8
–	C_2	C_3		C_4			…	C_7	C_5	

Decision for A_{best}

Best Practice Rules

Rule 1: the alternatives have to be really **reasonably comparable**.

Rule 2: the **best** rating should be a least **10% above** the **second** best rating.

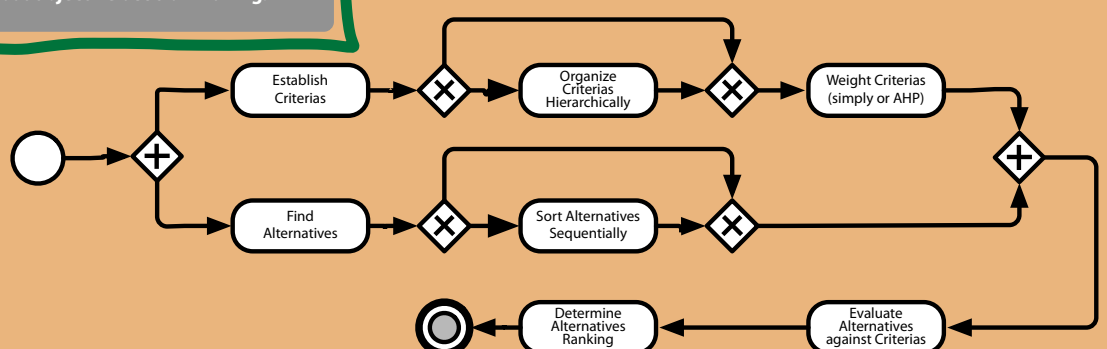
Rule 3: the **best** rating should cover at least **80%** of the **requirements**.

Rule 4: the Weighted Decision Matrices should cover at least all **grand decisions**.

Notice

It's about **subjective** decision **transparency**, not about **objective** decision **making**!

Decision Making Process



Standard Criteria Catalogs

Software Selection:
Suitable Functionality
Available Usage Examples
Reasonable Documentation
Reasonable Support
Permissive License
Long-Term Release Track Record
Current Market Momentum

Software Selection (Open Source):
+ Clean Source Code
+ Clean Build Process
+ Open Source License

Software Selection (Library):
+ Non-Invasive Programming Model
+ Orthogonal Application Programming Interface
+ Minimum/No Dependencies
+ Non-Copyleft Open Source License

Software Selection (Framework):
+ Orthogonal Application Programming Interface
+ Adequate Dependencies
+ Non-Overlapping Scope
+ Non-Copyleft Open Source License

Software Selection (Tool):
+ Clean Deployment Procedure
+ Pleasant Command-Line Interface

Software Selection (Application):
+ Clean Deployment Procedure
+ Pleasant Graphical User Interface

Software Architecture Evaluation:
Meets Functional Requirements
Meets Non-Functional Requirements
Adequate Technology Overhead
Single Dependency Direction
Distance to State of the Art ("modern")
Distance to Most Simple Approach ("adequate")
Distance to Mainstream Approach ("mainstream")
Documented Architecture Decisions ("rationales")
Documented Architecture Views
Documented Architecture Perspectives (NFR)

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ARCHITECTURE FUNDAMENTALS

Focus Area Maturity Model

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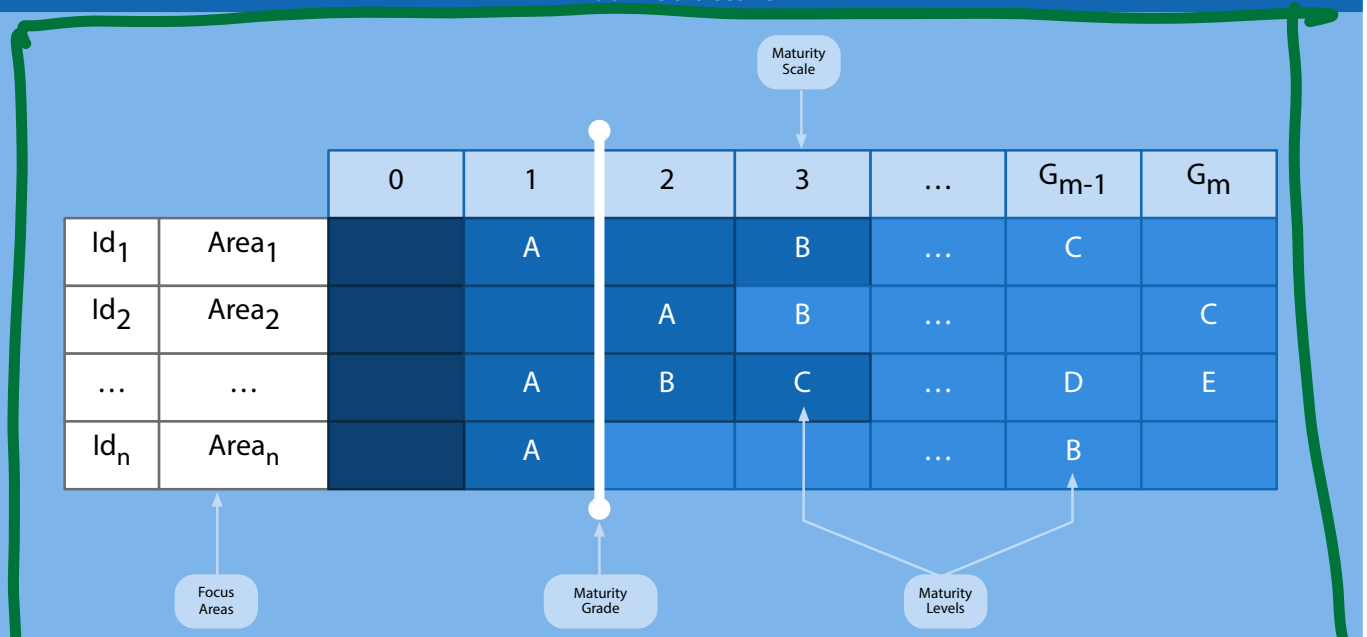
Matrix **Structure**



Focus Area Definition

Id: <unique id of focus area>
Name: <unique name of focus area>

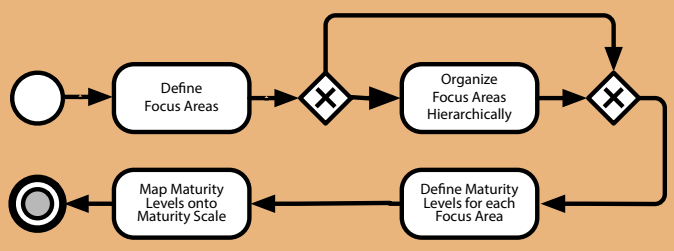
Maturity Level Definition

Id: <unique id of focus area>
Level: <unique letter of maturity level>
Name: <unique name of capability>
Goal: <purpose the capability serves>
Action: <steps how to meet the capability>
Prerequisites: <optional references to Id/Level>
References: <optional external references>

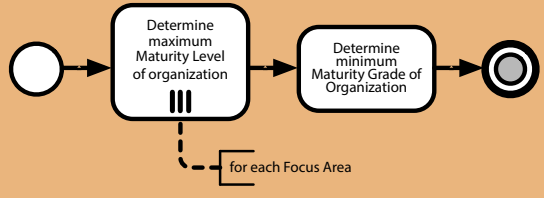
Maturity Level **Prerequisites**

Notice: Maturity Levels are inherently ordered within their Focus Area, but optionally also form a dependency graph by cross-referencing Maturity Levels of other Focus Areas.

Matrix **Design** Process



Maturity **Decision** Process



Maturity Grade **Zero**

Notice: the Maturity Scale always starts with 0, because an organization might not be able to fulfil a Focus Area at all, i.e., it might to not even be on Maturity Level A.

Maturity Grade **Determination**

Determine minimum Maturity Level fulfilled by an organization and project from Maturity Level onto Maturity Scale.