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Software Engineering in Industrial Practice (SEIP)

Dr. Ralf S. Engelschall

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Software Engineering Workflow

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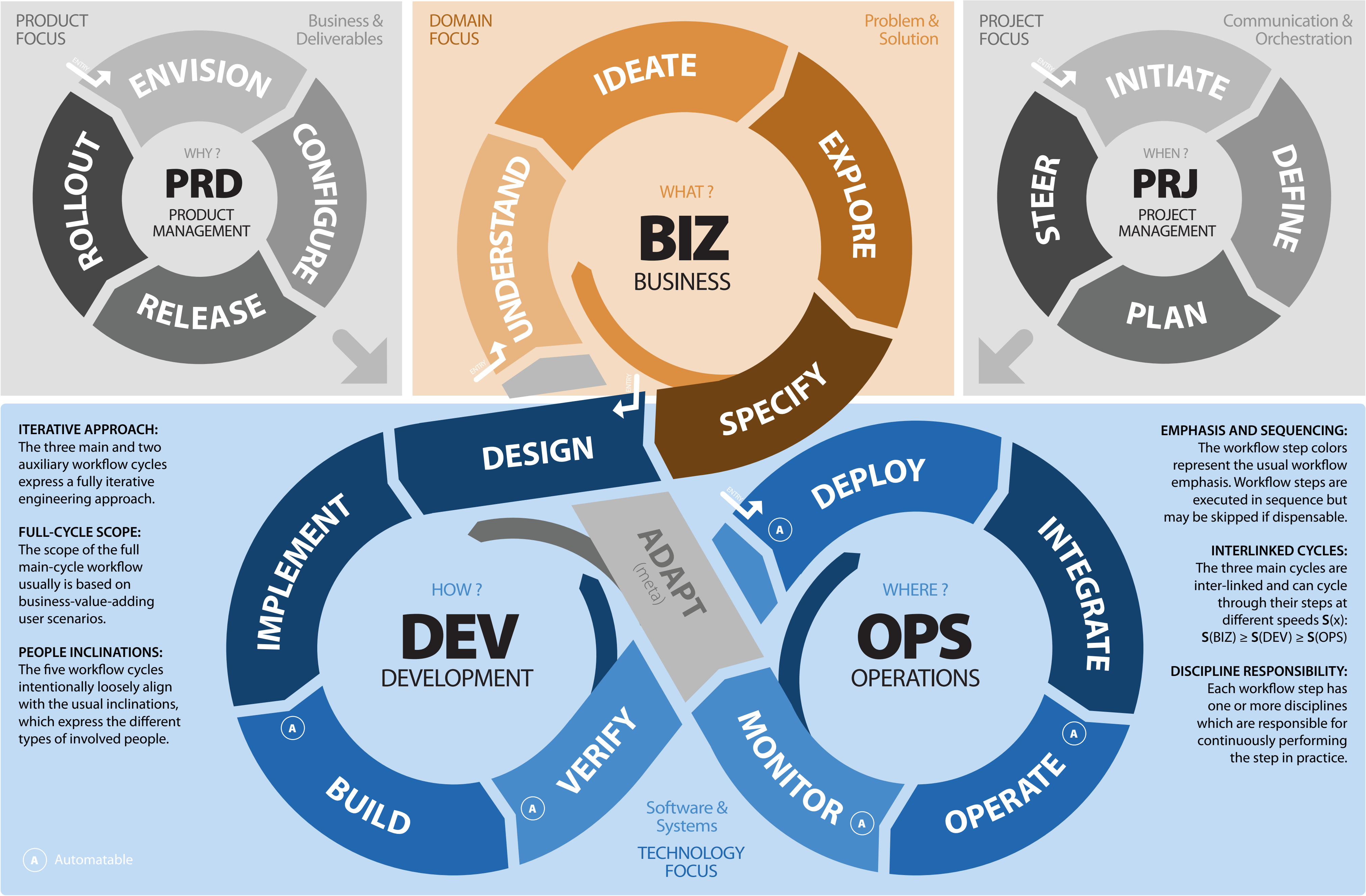

ITERATIVE APPROACH:
The three main and two auxiliary workflow cycles express a fully iterative engineering approach.

FULL-CYCLE SCOPE:
The scope of the full main-cycle workflow usually is based on business-value-adding user scenarios.

PEOPLE INCLINATIONS:
The five workflow cycles intentionally loosely align with the usual inclinations, which express the different types of involved people.

EMPHASIS AND SEQUENCING:
The workflow step colors represent the usual workflow emphasis. Workflow steps are executed in sequence but may be skipped if dispensable.

INTERLINKED CYCLES:
The three main cycles are inter-linked and can cycle through their steps at different speeds **S**(x): **S**(BIZ) ≥ **S**(DEV) ≥ **S**(OPS)

DISCIPLINE RESPONSIBILITY:
Each workflow step has one or more disciplines which are responsible for continuously performing the step in practice.

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focus & steps

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Software Engineering Steps

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PRODUCT MANAGEMENT PRD

ENVISION
PRD
UXP

Envision Solution: We envision the solution functionality and quality from the business and user perspectives.

CONFIGURE
PRD
VER

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

RELEASE
PRD
ASM
DOC

Release Version: We create and release a distinct version of the solution.

ROLLOUT
CHG
TRN

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

BUSINESS EFFORTS BIZ

UNDERSTAND
REQ
UXP
PRD

Understand Problem: We empathically understand the problem and requirements of the users.

IDEATE
UXP
REQ

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

EXPLORE
UXP
UID
SWA
DEV

Explore Ideas: We prototype, explore, and assess ideas, approaches and technologies for the solution.

SPECIFY
DOM
UID

Specify Solution: We rigorously and completely specify the functionality and quality of the solution.

DEVELOPMENT EFFORTS DEV

DESIGN
SWA
SYA

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

IMPLEMENT
DEV
DOC
REF
REV

Implement Solution: We implement the solution outside-in, from coarse to fine aspects.

BUILD
ASM
VER

Build Artifacts: We build and package the solution from versioned artifacts.

VERIFY
TST
REV

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

OPERATIONS EFFORTS OPS

DEPLOY
DPL
OPS
SYA

Deploy Artifacts: We ship and deploy the solution releases and their updates in an automated and repeatable way.

INTEGRATE
DPL
OPS
SYA

Integrate Environment: We integrate the solution with its target environment.

OPERATE
OPS

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

MONITOR
OPS
TST

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

PROJECT MANAGEMENT PRJ

INITIATE
PRJ
COA

Initiate Project: We initially setup the project on the contract and resource level.

DEFINE
PRJ
PRD

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

PLAN
PRJ
PRD

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

STEER
PRJ

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

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steps & goals

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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):

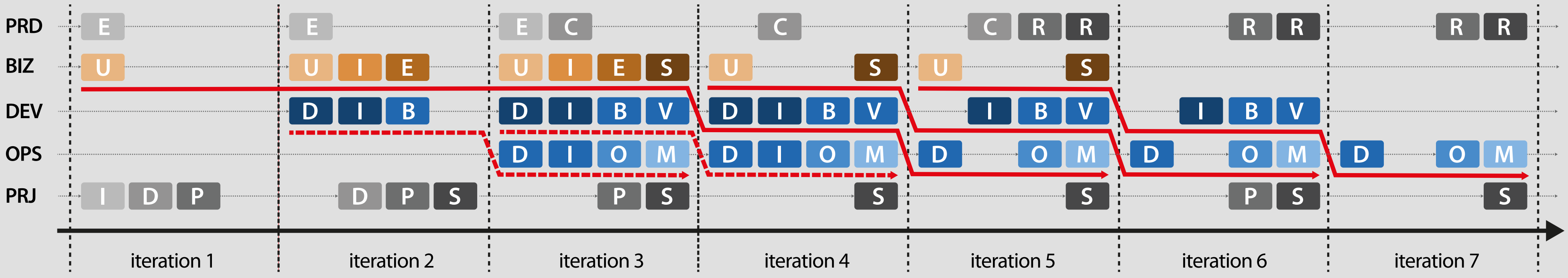
The activities across the cycles can (and should) be linked into individual (diagonal) waterfall-like flows, although the execution schedule, from the perspective of the cycles, is fully iterative. There are multiple such flows in parallel and they are usually highly interleaved on the project timeline 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



roles & tasks

EF
02.5

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Software Engineering Artifacts

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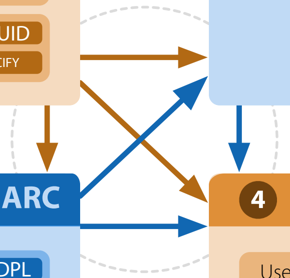
artifacts & deliverables

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

Requirements:	**Customer Journey**	REQ UXP PRD	2	ENVISION
Requirements:	**Solution Vision**	REQ UXP PRD	2	ENVISION
Requirements:	**Functional Requirements**	PRD UXP REQ	1	UNDERSTAND
Requirements:	**Non-Functional Requirem.**	PRD SWA REQ	1	UNDERSTAND
Domain Model:	**Data Model**	REQ DOM	1	SPECIFY
Domain Model:	**Use Cases**	UXP REQ DOM	1	SPECIFY
Domain Model:	**Use Case Scenarios**	UXP REQ DOM	2	SPECIFY
Domain Model:	**Personas**	REQ DOM UXP	3	UNDERSTAND
Domain Model:	**Test Cases**	REQ DOM TST	3	SPECIFY
User Interface:	**Usage Concept**	UXP UID	2	SPECIFY
User Interface:	**Language Conventions**	REQ UXP UID	3	SPECIFY
User Interface:	**Dialog Patterns**	UXP UID	3	SPECIFY
User Interface:	**Dialog Storyboard**	REQ UXP UID	1	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
Viewpoint:	**Functionality View**	DOM SYA SWA	1	DESIGN
Viewpoint:	**Information View**	DOM SWA	1	DESIGN
Viewpoint:	**Concurrency View**	DEV SYA SWA	2	DESIGN
Viewpoint:	**Development View**	ASM VER SWA DEV	3	IMPLEMENT
Viewpoint:	**Deployment View**	SYA SWA OPS DPL	1	DEPLOY
Viewpoint:	**Operations View**	SYA SWA DPL OPS	2	OPERATE
Perspective:	**Configurability & Extensibili.**	DEV SWA DPL	3	INTEGRATE
Perspective:	**Performance & Scalability**	OPS DPL SYA SWA	1	DESIGN
Perspective:	**Availability & Recoverability**	SYA SWA DPL OPS	2	OPERATE
Perspective:	**Reliability & Resilience**	DEV SYA SWA	2	DESIGN
Perspective:	**Interoperability & Compatib.**	DEV SWA	3	DESIGN
Perspective:	**Compliance & Tracability**	PRD TST SWA DEV	3	IMPLEMENT
Perspective:	**Security & Safety**	DEV SWA	1	DESIGN

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

Source Code:	**Application**	REF DEV	1	IMPLEMENT
Source Code:	**Build Automation**	DEV VER ASM	2	BUILD
Source Code:	**Test Automation**	DEV TST	3	VERIFY
Binary Code:	**Application**	ASM	1	BUILD
Source Code:	**Deployment Automation**	DEV VER DPL	3	DEPLOY
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 glue 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
User Guide:	**Functionality Reference**	DOM TRN DOC	1	SPECIFY
User Guide:	**Release Information**	PRD VER	3	RELEASE
Operation Guide:	**Configuration Reference**	TRN DOC DPL DEV	1	IMPLEMENT
Operation Guide:	**Deployment Procedure**	TRN DOC OPS DPL	1	DEPLOY
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.

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Software Engineering Efforts

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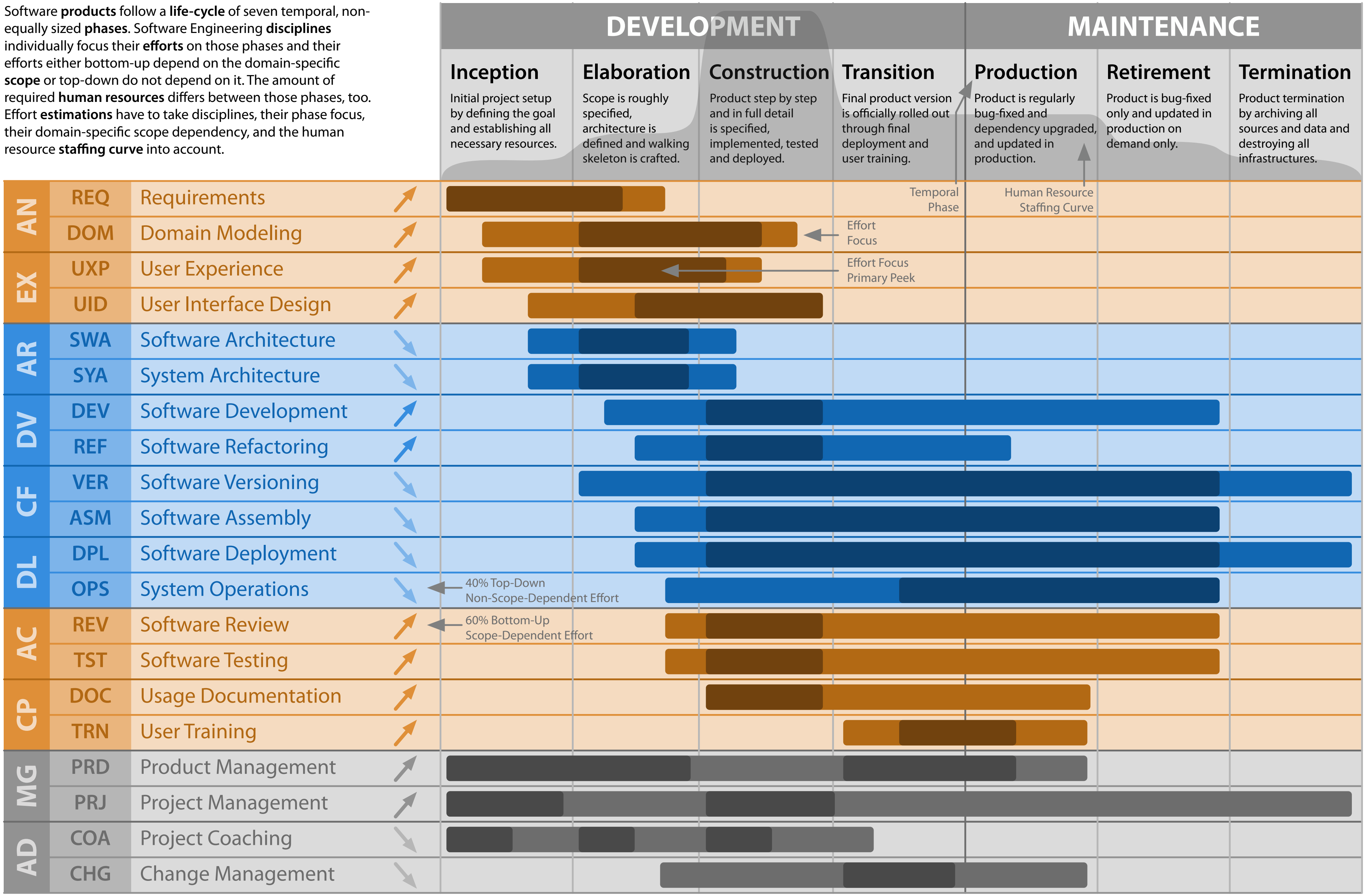
Software **products** follow a **life-cycle** of seven temporal, non-equally sized **phases**. Software Engineering **disciplines** individually focus their **efforts** on those phases and their efforts either bottom-up depend on the domain-specific **scope** or top-down do not depend on it. The amount 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.



DEVELOPMENT

Inception
Initial project setup by defining the goal and establishing all necessary resources.

Elaboration
Scope is roughly specified, architecture is defined and walking skeleton is crafted.

Construction
Product step by step and in full detail is specified, implemented, tested and deployed.

Transition
Final product version is officially rolled out through final deployment and user training.

MAINTENANCE

Production
Product is regularly bug-fixed and dependency upgraded, and updated in production.

Retirement
Product is bug-fixed only and updated in production on demand only.

Termination
Product termination by archiving all sources and data and destroying all infrastructures.

AN	REQ	Requirements	↗
	DOM	Domain Modeling	↗
EX	UXP	User Experience	↗
	UID	User Interface Design	↗
AR	SWA	Software Architecture	↘
	SYA	System Architecture	↘
DV	DEV	Software Development	↗
	REF	Software Refactoring	↗
CF	VER	Software Versioning	↘
	ASM	Software Assembly	↘
DL	DPL	Software Deployment	↘
	OPS	System Operations	↘
AC	REV	Software Review	↗
	TST	Software Testing	↗
CP	DOC	Usage Documentation	↗
	TRN	User Training	↗
MG	PRD	Product Management	↗
	PRJ	Project Management	↗
AD	COA	Project Coaching	↘
	CHG	Change Management	↘

Temporal Phase

Human Resource Staffing Curve

Effort Focus

Effort Focus Primary Peek

40% Top-Down Non-Scope-Dependent Effort

60% Bottom-Up Scope-Dependent Effort

EF 03.1

phases & efforts

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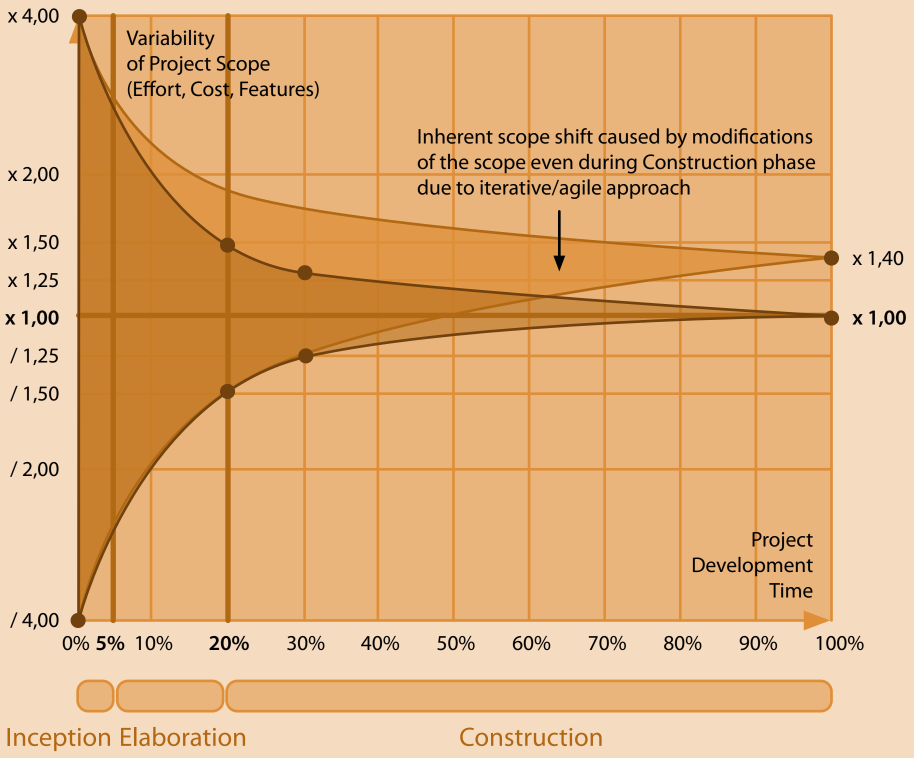
Uncertainty & Elaboration

Cone of Uncertainty



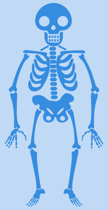
The ***Cone of Uncertainty*** (*Steve McConnell*, 2006) tells how the variability of the project scope (measured in Effort, Cost or Features) in Software Development changes over time. Initially, it usually is within the range of +/- 400% of the final scope.

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.

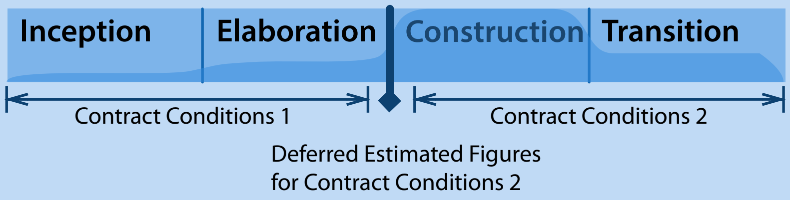
Essential Elaboration Phase

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.

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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)

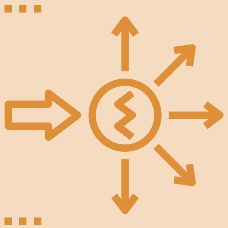
Insane Variability:	+/- 10%
Very Good Variability:	+/- 15%
Good Variability:	+/- 20%
Acceptable Variability:	+/- 25%

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.

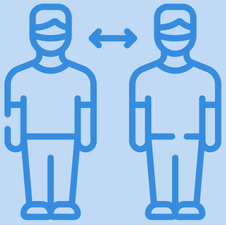


Conversion & Normalization

1. Ask Estimator:
"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)

		Performer				
	Non-Linear Effort Reduction	0%	10%	25%	45%	80%
		Novice	Practitioner	Master	Expert	Guru
Estimator	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



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%

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uncertainty & efforts

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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 structures.

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>

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Non-Functional Requirements

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AF 03.2

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Compliance

CMP	**Compliance**	Ability to meet rules and standards
CRT	**Certification**	Ability to confirm certain characteristics
LCN	**Licensing**	Ability to permit to own and use something
PRC	**Pricing**	Ability to have reasonable price and permit charging for a product

Operation

OPR	**Operability**	Ability to be reasonably operated
SPP	**Supportability**	Ability to be reasonably supported
MNT	**Maintainability**	Ability to cope with changing environments and requirements
TST	**Testability**	Ability to be completely and repeatably tested
TRC	**Traceability**	Ability to track the path something takes
MSR	**Measurability**	Ability to measure characteristics according to defined metrics

Usability

USB	**Usability**	Ability for ease of use, user-friendliness, accessibility, convenience, intuitiveness
CPY	**Comprehensability**	Ability to be easily understood
ACC	**Accessibility**	Ability to be used by people with disabilities.

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Correctness

PRD	**Predictability**	Ability to predict state and behaviour under run-time
FDL	**Fidelity**	Ability to reproduce state and behaviour of the real world
RLV	**Relevance**	Ability to serve as a means to a given purpose
PRN	**Precision**	Ability to be exact and accurate in operation
CRS	**Correctness**	Ability to be algorithmically correct with respect to the specification
PRV	**Provability**	Ability to mathematically prove algorithmical correctness

Protection

SFT	**Safety**	Ability to protect against undeliberate failures, errors and accidents
SEC	**Security**	Ability to protect against deliberate destruction, damage and harm

Availability

AVL	**Availability**	Ability to be operationally available anytime
UBQ	**Ubiquity**	Ability to be operationally present anywhere
RPT	**Repeatability**	Ability to repeat state and behaviour in sequence
RPR	**Reproducability**	Ability to reproduce state and behaviour from scratch
RCV	**Recoverability**	Ability to recover state and behaviour after a disastrous failure

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Quality

RLB	**Reliability**	Ability to perform required functions under stated conditions for a specified time
RSL	**Resilience**	Ability to provide an acceptable level of service in face of faults and challenges
RBS	**Robustness**	Ability to withstand stress, pressure, or changes in procedure or circumstances
STB	**Stability**	Ability to not suffer from internal failures in service
DRB	**Durability**	Ability to keep interfaces and functionality as is for a period of time
INT	**Integrity**	Ability to keep state consistency and avoid data corruption

Performance

PRF	**Performance**	Ability to efficiently perform work, i.e., with a good work to time & resource ratio
SCL	**Scalability**	Ability to scale mostly linearly with changing requirements or conditions
RSP	**Responsiveness**	Ability to respond quickly to external interaction

Structure

SMP	**Simplicity**	Ability to be plain, natural, straight-forward and with no observable complexity
FLX	**Flexibility**	Ability to be easily modifyable in order to respond to altered circumstances
MDL	**Modularity**	Ability to consist of individually comprehensible modules
ORT	**Orthogonality**	Ability to follow great separation of concerns in design

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Execution

EFF	**Efficiency**	Ability to perform work in the most economical way: good input/output ratio
EFC	**Efficacy**	Ability to perform work in order to getting things done and meeting targets
EFV	**Effectiveness**	Ability to perform the "right" work by setting right targets to achieve goals

Interfacing

ITY	**Interoperability**	Ability to correctly operate and exchange information with foreign components
CPT	**Compatibility**	Ability to correctly operate despite expected older or newer interfaces

Evolution

RSB	**Reusability**	Ability to reuse code or data with slight or no modifications
ADP	**Adaptability**	Ability to cope with smaller changes in the run-time environment
PRT	**Portability**	Ability to cope with larger changes in run-time environment
CFG	**Configurability**	Ability to individualize state and behaviour by non-destructive instructions
CST	**Customizability**	Ability to individualize state and behaviour by possibly destructive instructions
EXT	**Extensibility**	Ability to extend state and behaviour in a controlled way
TLR	**Tailorability**	Ability to adjust state and behaviour in a controlled way
MDF	**Modifiability**	Ability to change state and behaviour in an arbitrary way

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