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# A Rational Development Process

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## 1. Introduction

This paper gives a high level description of the philosophy and structure of the Rational Software Development Process. It is:

- iterative and incremental
- object-oriented
- managed and controlled

It is generic enough to be tailorable to a wide variety of software products and projects, both in size and application domain.

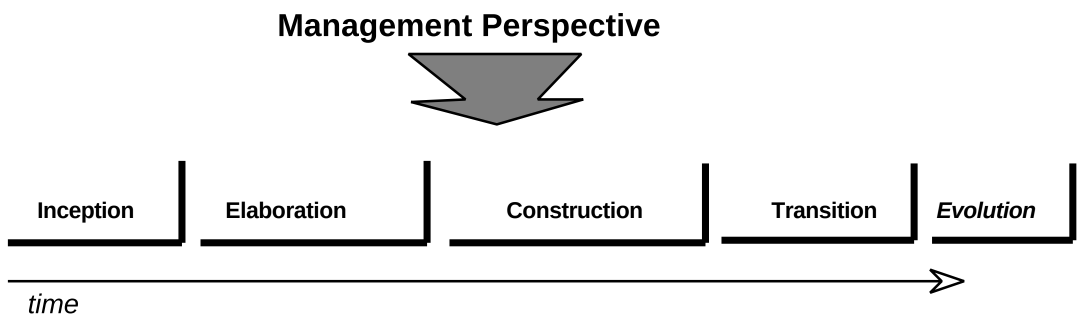
## 2. The Overall Software Life-Cycle

### 2.1 Two Perspectives

The Rational process may be approached from 2 different and integrated perspectives:

- A *management perspective*, dealing with the financial, strategic, commercial, and human aspects.
- A *technical perspective,* dealing with quality, engineering and design method aspects.

### 2.2 Cycles and Phases



As seen from a management perspective, i.e., the business and economics point of view, the software life-cycle is organized along four main phases, indicators of the progress of the project:

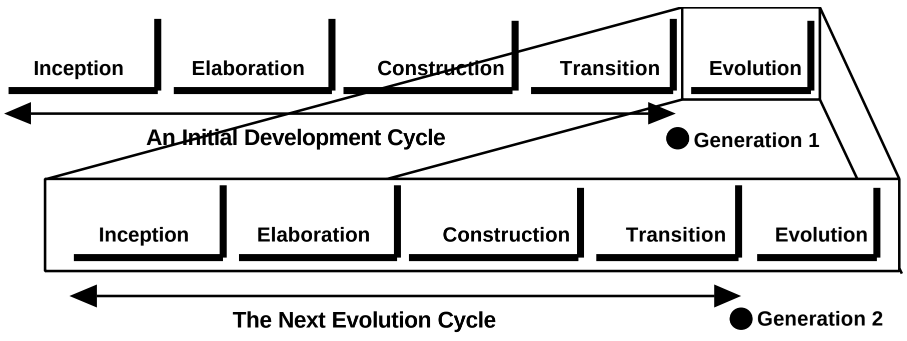
- **Inception**—The good idea: specifying the end-product vision and its business case, defining the scope of the project.[1]

- **Elaboration—**Planning the necessary activities and required resources; specifying the features and designing the architecture.[2]

- **Construction**—Building the product, and evolving the vision, the architecture and the plans until the product—the completed vision—is ready for transfer to its users community.

- **Transition—**Transitioning the product to its user's community, which includes manufacturing, delivering, training, supporting, maintaining the product until the users are satisfied.

Going through the 4 phases is called a development *cycle*, and it produces a software *generation*. Unless the life of the product stops, an existing product will evolve into its next generation by repeating the same sequence of inception, elaboration, construction and transition phases, with a different emphasis however on the various phases. We call this period *evolution.* As the product eventually goes through several cycles, new generations are being produced.
For example, evolution cycles may be triggered by user suggested enhancements, changes in the users' context, changes in the underlying technology, reaction to the competition, etc.



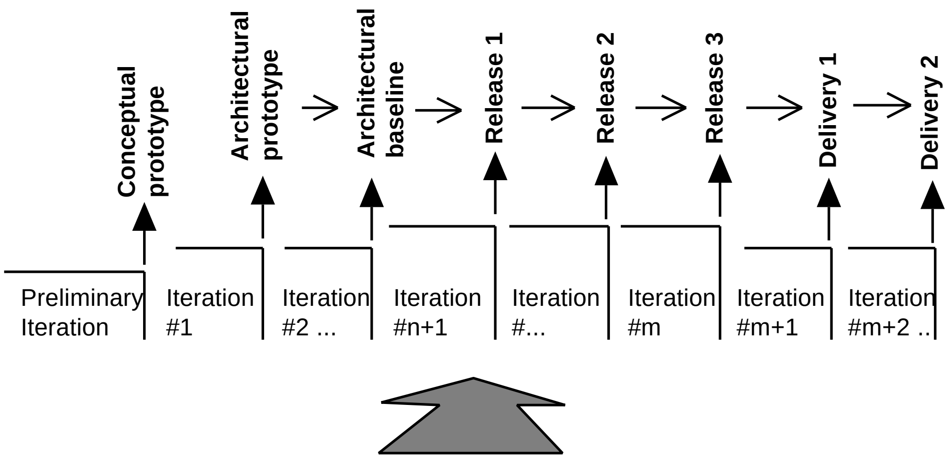
In practice, cycles may slightly overlap: the inception and elaboration phase may start during the trailing part of the transition phase of the previous cycle.

## 2.3. Iterations

From a technical perspective the software development is seen as a succession of *iterations*, through which the software under development evolves incrementally. Each iteration is concluded by the *release* of an executable product which may be a subset of

[1] The American Heritage Dictionary defines *inception* as "the beginning of something, such as an undertaking, a commencement."
[2] The American Heritage Dictionary defines *elaboration* as the process "to develop thoroughly, to express at greater length or greater detail."

the complete vision, but useful from some engineering or user perspective. Each release is accompanied by supporting artifacts: release description, user's documentation, plans, etc.

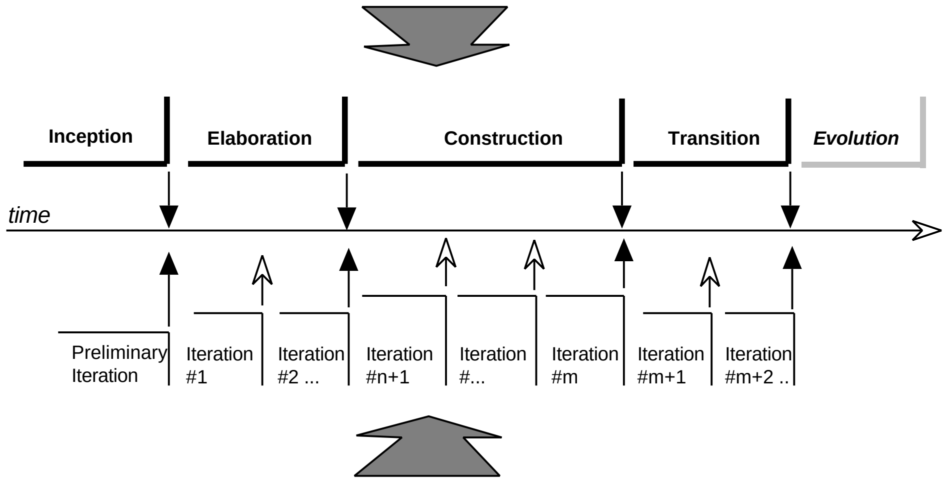


**Technical Perspective**

An iteration consists of the activities of planning, analysis, design, implementation, testing, in various proportions depending on where the iteration is located in the development cycle.

The management perspective and the technical perspective are reconciled, and in particular the end of the phases are synchronized with the end of iterations. In other words, each *phase* is broken down into one or more *iterations*.

**Management Perspective**



**Technical Perspective**

(Note: The number of iterations per phase shown on this diagram is merely for illustration purposes.)

However the two perspectives—management and technical—do more than just synchronize on a few well identified *milestones*, they both contribute to a common set of products and artifacts that evolve over time. Some artifacts are more under the control of the technical side, some more under control of the management side. Cf. section5.

The availability of these artifacts, and the satisfaction of the established evaluation criteria for the product and the artifacts are the tangible elements that constitute the milestones, much more than mere dates on a calendar.

Like cycles, iterations may slightly overlap, e.g., the planning or architecture activities of iteration N may be started towards the end of iteration N–1. In some cases, some iterations may proceed in parallel: a team, working on one part of the system, may have no deliverable for a given iteration.

### 2.4. Discriminants

The emphasis and importance of the various phases, the entry and exit criteria, the artifacts involved along a development cycle, the number and length of the iterations may all vary depending on four major project characteristics that are process *discriminants*. In order of decreasing impact, the most important process dicriminants are:

- The **business context**:
  -contract work, where the developer produce the software on a given customer specification and for this customer only,
  -speculative or commercial development, where the developer produce software to be put on the market,
  -or internal project, where customer and developer are in the same organization.

- The **size** of the software development effort:
  as defined by some metrics, such as Delivered Source Instructions, or in functions points, etc., or number of person-months, or merely in cost.

- The **degree of novelty**:
  how "precendented" this software effort is, *relative to the development organization*, and in particular whether the development is in a second or subsequent cycle. This discriminant includes the maturity of the organization and the process, its assets, its current skill set, and issues such as assembling and training a team, acquiring tools and other resources.

- The **type of application**, the target domain:
  MIS, command and control, embedded real-time, software development environment tools, etc., especially with respect to the specific constraints the domain may impose on the development: safety, performance, internationalization, memory constraint, etc.

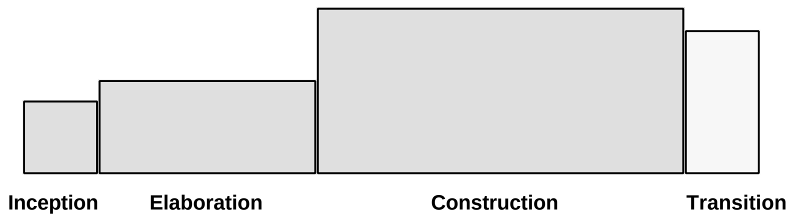
This paper first describes the *generic process*, i.e., the part of the process that applies to all kinds of software developments, across a broad and general range of these discriminants. It then describes some specific instances of the process for some values of the discriminants, as examples

### 2.5 Effort and Schedule

All phases are not identical in terms of schedule and effort. Although this will vary considerably depending on the project discriminants, a typical initial development cycle for a medium size project should anticipate the following ratios:

| | Inception | Elaboration | Construction | Transition |
|---|---|---|---|---|
| Effort | 5 % | 20 % | 65 % | 10% |
| Schedule | 10 % | 30 % | 50 % | 10% |

which can be depicted graphically as:



But for an evolution cycle, the inception and elaboration phases can be considerably reduced. Also, using certain tools and techniques, such as applications builders, the construction phase can be much smaller than the inception and elaboration phase together.

# 3. The Phases of the Rational Process

### 3.1. Inception phase

This phase brings to light an original vision of a potential product, and transforms it into an actual project. Its purpose is to establish the business case for a new product or a major update, and to specify the project scope.

For the development of a new product, the main outcome of this phase is a “go-no go” decision to move into the next phase and to invest time and money to analyze in detail what it to be built, can it be built, and how to build it.
For the evolution of an existing product, this may be a simple and short phase, based on users’ or customers’ requests, on problem reports, on new technological advances.
For a contractual development, the decision to proceed is based on experience of the specific domain and on the competitiveness of the development organization in this domain or market. In this case the inception phase may be concluded by a decision to bid, or by the bid itself. The idea may be based on an existing research prototype, whose architecture may or may not be suitable for the final software.

*Entry criteria:*
The expression of a need, which can take any of the following forms:
- an original vision
- a legacy system
- an RFP (request for proposal)
- the previous generation and a list of enhancements
- some assets (software, know-how, financial assets)
- a conceptual prototype, or a mock-up

*Exit criteria:*
- an initial business case containing at least:
    - a clear formulation of the product vision—the core requirements— in terms of functionality, scope, performance, capacity, technology base
    - success criteria (for instance revenue projection)
    - an initial risk assessment
    - an estimate of the resources required to complete the elaboration phase.

Optionally at the end of the inception phase, we may have:
- an initial domain analysis model (~10%-20% complete), identifying the top key use cases, and sufficient to drive the architecture effort.
- an initial architectural prototype, which at this stage may be a throw-away prototype.

## 3.2. Elaboration Phase

The purpose of this phase is to more thoroughly analyze the problem domain, to define and stabilize the architecture and to address the highest risk elements of the project. So that at the end of the phase we can produce a comprehensive plan showing how the 2 next phases will be done:
- A baseline product vision (i.e., an initial set of requirements) based on an analysis model
- Evaluation criteria for at least the first construction iteration
- A baseline software architecture
- The resources necessary to develop and deploy the product, especially in terms of people and tools
- A schedule
- A resolution of the risks sufficient to make a “high fidelity” cost, schedule and quality estimate of the construction phase.

In this phase an executable architectural prototype is built, in one or several *iterations* depending on the scope, size, risk, novelty of the project, which addresses at least the top key use cases identified in the inception phase, and which addresses the top technical risks of the project.
This is an evolutionary prototype, of production quality code which becomes the architectural baseline, but it does not exclude the development of one or more

exploratory, throw-away prototypes to mitigate specific risks: refinements of the requirements, feasibility, human-interface studies, demonstrations to investors, etc.

At the end of this phase, there is again a "go-no go" decision point to actually invest and build the product (or bid for the complete development of the contract). The plans produced must be detailed enough, and the risks sufficiently mitigated to be able to determine with accuracy the cost and schedule for the completion of the development.

*Entry criteria:*

- The products and artifacts described in the exit criteria of the previous phase.
- The plan was approved by the project management, and funding authority, and the resources required for the elaboration phase have been allocated.

*Exit criteria:*

- a detailed software development plan, containing:
    - an updated risk assessment
    - a management plan
    - a staffing  plan
    - a phase plan showing the number and contents of the iteration
    - an iteration plan, detailing the next iteration
    - the development environment and other tools required
    - a test plan
- a baseline vision, in the form of a set of evaluation criteria for the final product
- objective, measurable evaluation criteria for assessing the results of the initial iterations(s) of the construction phase
- a domain analysis model (80% complete), sufficient to be able to call the corresponding architecture 'complete'.
- a software architecture description (stating constraints and limitations)
- an executable architecture baseline.

## 3.3. Construction Phase

This phase is broken down into several *iterations*, fleshing out the architecture baseline and evolving it in steps or increments towards the final product. At each iteration, the various artifacts prepared during the elaboration phase (see above) are expanded and revised, but they ultimately stabilize as the system evolves in correctness and completeness.

New artifacts are produced during this phase beside the software itself: documentation, both internal and for the end-users, test beds and test suites, and deployment collaterals to support the next phase: marketing collaterals for example.

For each iteration we have:

*Entry criteria:*

- The product and artifacts of the previous iteration. The iteration plan must state the iteration specific goals:
    - additional capabilities being developed: which use cases or scenarios will be covered
    - risks being mitigated during this iteration
    - defects being fixed during the iteration.

*Exit criteria:*
The same products and artifacts, updated, plus:
- A release description document, which captures the results of an iteration
- Test cases and results of the tests conducted on the products,
- An iteration plan, detailing the next iteration
- Objective measurable evaluation criteria for assessing the results of the next iteration(s).

Towards the end of the construction phase the following artifacts must be produced, and are additional exit criteria for the last iteration of the phase:
- a deployment plan, specifying as necessary:
    - packaging
    - pricing
    - roll out
    - support
    - training
    - transition strategy (e.g., an upgrade plan from an existing system)
    - production (e.g., making floppies and manuals)
- user documentation

## 3.4. Transition Phase

The transition phase is the phase where the product is put in the hands of its end users. It involves issues of marketing, packaging, installing, configuring, supporting the user-community, making corrections, etc.

From a technical perspective the *iterations* continue with one or more releases (or deliveries): ‘beta’ releases, general availability releases, bug fix or enhancement releases.

The phase is completed when the user community is satisfied with the product: formal acceptance for example in a contractual setting, or when all activities on this product are terminated. It is the point where some of the accumulated assets can be made reusable by the next cycle or by some other projects.

*Entry criteria:*
- The product and artifacts of the previous iteration, and in particular a software product sufficiently mature to be put into the hands of its users.

*Exit criteria:*

- An update of some of the previous documents, as necessary, the plan being replaced by a “post-mortem” analysis of the performance of the project relative to its original and revised success criteria;
- a brief inventory of the organization’s new assets as a result this cycle.

### 3.5. Evolution Cycles

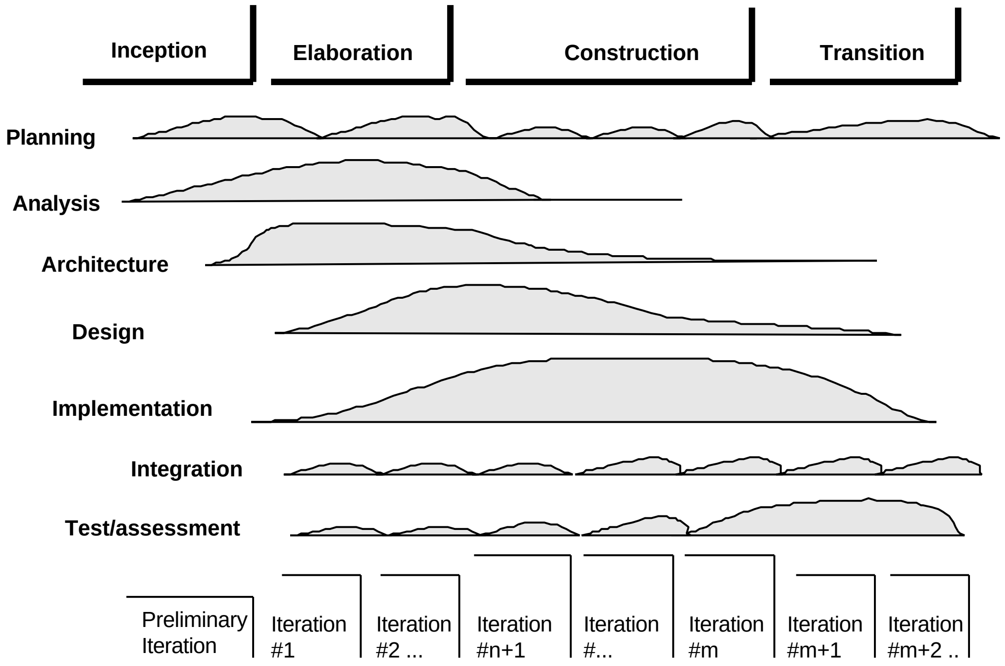
For substantial evolutions, we apply the whole process recursively, starting again at the inception phase, for a new cycle. Since we already have a product, this inception phase may be considerably reduced, compared to an initial development cycle. The elaboration phase also may be limited, and focused more on the planning aspects than evolving the analysis or the architecture. Said otherwise: cycles can slightly overlap.

Minor evolutions are done in extending the transition phase, adding one or more iterations.

Alternatively, the transition phase may be concluded by an end-of-life process, i.e., the product does not evolve any more, but some specific actions must be taken in order to terminate it, or retire it.

## 4. Activities in the Rational Process

The names of the phases of the Rational process stay away from the terms describing an intellectual activity: analysis, design, test, etc., so that it will be understood that this activity is not confined to that phase, and also to remain independent of terms employed by other authors, standards, and domain-specific jargon. These activities do take place, but in varying degree in each phase and iteration. The following figure illustrates how the emphasis and effort evolves over time.



This change of focus explains also that, although all structured in the same way, the exact nature and contents of the iterations evolves over time.

This also shows that the beginning of an activity is not bound to the end of another, e.g., design does not start when analysis completes, but the various artifacts associated with the activities are revised as the problem or the requirements are better understood.

Finally, in an iterative process, the activities of planning, test and integration are spread incrementally throughout the cycle, in each iteration, and not massively lumped at the beginning and at the end, respectively. They do not appear as separate steps or phases in the process.

Although this will vary considerably depending on the project discriminants, a typical initial development cycle for a medium size project should anticipate the following ratios for various activities:

| | |
|---|---:|
| Planning and management | 15% |
| analysis/requirements | 10% |
| design/integration | 15% |
| implementation/functional tests | 30% |
| measurement/assessment/acceptance test | 15% |
| tools/environment/change management | 10% |
| maintenance (fixes during development) | 5% |

# 5. Life-cycle Artifacts

The process is not document-driven: its main artifact must remain at all time the software product itself. The documentation should remain lean and limited to the few documents that bring real value to the project from a management or technical point of view. Rational suggests the following typical set of documents.

## 5.1 Management artifacts

The management artifacts are not the product, but are used to drive or monitor the progress of the project, estimate the risks, adjust the resources, give visibility to the customer (in a contractual setting) or the investors.

- An *Organizational Policy* document, which is the codification of the organization's process; it contains an instance of this generic process.
- A *Vision* document, which describes the system level requirements, qualities and priorities.
- A *Business Case* document, describing the financial context, contract, projected return on investment, etc.
- A *Development Plan* document, which contains in particular the overall iteration plan, and plan for the current and upcoming iteration.
- An *Evaluation Criteria* document, containing the requirements, acceptance criteria and other specific technical objectives, which evolves from major milestone to major milestone. It contains the iteration goals and acceptance levels.
- *Release Description* documents for each release,
- *Deployment* document, gathering additional information useful for transition, training, installation, sales, manufacturing, cut-over.
- *Status Assessment* documents: periodic snapshots of project status, with metrics of progress, staffing, expenditure, results, critical risks, actions items, post-mortem.

## 5.2 Technical artifacts

These artifacts are either the *delivered goods*: executable software and manuals, or the *blueprints* that were used to manufacture the delivered goods: software models, source code, and other engineering information useful to understand and evolve the product. The

- *User's Manual*, developed early in the life-cycle.
- *Software documentation*, preferably in the form of self-documenting source code, and models (uses cases, class diagrams, process diagrams, etc.) captured and maintained with appropriate CASE tools.
- A *Software Architecture* document, extracted (abstracted) from the software documentation, describing the overall structure of the software, its decomposition in major elements: class categories, classes, processes, subsystems, the definition of critical interfaces, and rationale for the key design decisions.

The artifacts enumerated in the entry and exit criteria in §3 can all be mapped onto one of these 11 documents.

Depending on the type of project, this typical document set can be extended or contracted, some documents can be merged. The documents do not have to be *paper* documents—they can be spreadsheet, text-files, database, annotations in source code, hypertext documents, etc.—but the corresponding information source must be clearly identified, easily accessible and some of its history preserved.

### 5.3 Requirements

The Rational process is not requirement-driven either. The requirements for the product evolve during a cycle, and take different forms:

- The *business case* gives the main constraints, mostly in terms of resources that can be expended.
- The *vision* document describes only the key requirements of the system from a user's perspective, and it evolves only slowly during the development cycle.
- The more detailed requirements are elaborated during the elaboration phase, in the form of use cases and scenarios, and are refined incrementally throughout the construction phase, as the product and the users needs become better understood. These more detailed requirements are in the *evaluation criteria* document; they drive the definition of the contents of the construction and transition iterations, and are referenced in the iteration plan.

# 6. Examples of Rational Processes

The Rational process takes different aspects depending on the discriminants described in section 2.4. Heere are two extreme examples.

### 6.1 Rational Process for Large Contractual Software Development

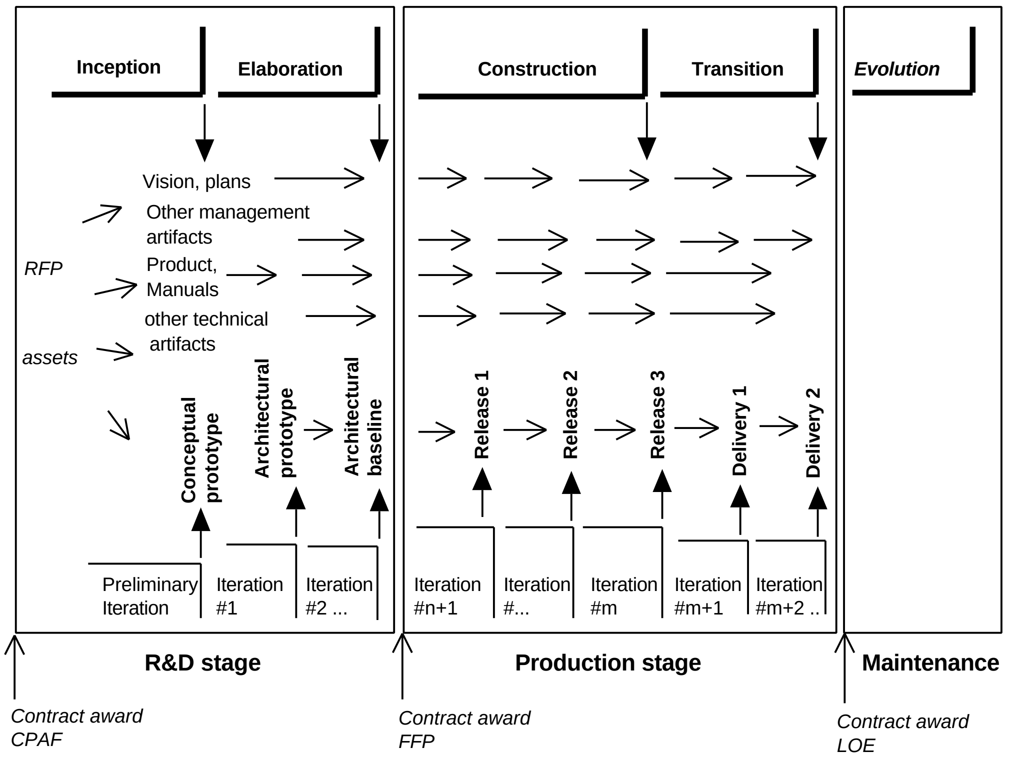
Rational proposes to set up the procurement of large software in 3 stages, associated with 3 different kinds of contract.

- An **R&D** stage, comprising the inception and elaboration phase, typically bid in a risk sharing manner, e.g., as a cost plus award fee contract (CPAF).

- A **production** stage, comprising the construction and transition phases, typically bid as a firm, fixed price contract (FFP)

- A **maintenance** stage if any, corresponding to the evolution phase, typically bid as a level of effort contract (LOE).

Due to the higher level of visibility that is required from the customer on the evolution of the project, and because of the larger number of people and organizations involves, more formalism is required in the process and there may be more emphasis on *written* artifacts, than would be the case in a small, internal project. All 11 documents listed in §5 are present in some form or name.



## 6.2 Rational Process for a small commercial software product

At the other extremity of the scale of the family of processes, a small commercial development would see a more fluid process, with only limited amount of formalism at the major milestones and a more limited set of documents:

- a product *vision*
- a *development plan*, showing schedule and resources
- *release description* documents, specifying the goal of an iteration at the beginning of the iteration, and updated to serve as release notes at the end.
- *user documentation*, as necessary

Software architecture, software design, development process and procedures can be documented by the code itself or the software development environment.

## 7. Conclusion

The Rational process puts an emphasis on addressing very early high risks areas, by developing rapidly an initial version of the system, which defines its architecture. It does not assume a fixed set of firm requirements at the inception of the project, but allows to refine the requirements as the project evolves. It expect and accommodate changes. The process does not put either a strong focus on documents or ‘ceremonies’, and it lends itself to the automation of many of the tedious tasks associated with software development. The main focus remains the software product itself, and its quality, as measured by the degree to which it satisfies its end-users, and meets its return on investment objective altogether.

A process derived from the generic process described here would fully conform to the requirements of a standard such as ISO 9000.

## Further Readings

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## Glossary

| | |
|---|---|
| Artifact | Any document or software other than the software product itself. |
| Baseline | A release that is subject to change management and configuration control |
| Construction | The 3rd phase of the process, where the software is brought from an executable architectural baseline to the point where it is ready to be transitioned to its user’s community. |
| Cycle | One complete pass through the 4 phases: inception-elaboration-construction-transition. The span of time between the beginning of the inception phase and the end of the transition phase. |
| Elaboration | The 2nd phase of the process where the product vision and its architecture are defined. |
| Evolution | The life of the software after its initial development cycle; any subsequent cycle, where the product evolve. |
| Generation | The result of one software development cycle. |
| Inception | The first phase of the process, where the seed—idea, RFP, previous generation—is brought up to the point of being (at least internally) founded to enter into the elaboration phase. |
| Iteration | A distinct sequence of activities with a baselined plan and an evaluation criteria. |
| Milestone | An event held to formally initiate and conclude an iteration |
| Phase | The span of time between 2 major milestones of the process where a well defined set of objectives are met, artifacts are completed, and decisions are made to move or not into the next phase. |

| | |
|---|---|
| Product | The software that is the result of the development, and some of the associated artifacts (documentation, release medium, training). |
| Prototype | A release which is not necessarily subjected to change management and configuration control |
| Release | A subset of the end-product which is the object of evaluation at a major milestone (see: prototype, baseline). |
| Risk | An ongoing or upcoming concern which has a significant probability of adversely affecting the success of major milestones |
| Transition | The 4th phase of the process where the software is turned into the hands the hands of the user’s community. |
| Vision | The user’s view of the product to be developed |

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