Life-cycle and Reliability of accelerators

JUAS 2017

part 1: life-cycle

part 2: reliability

SOME OF THE SLIDES

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9th March 2017

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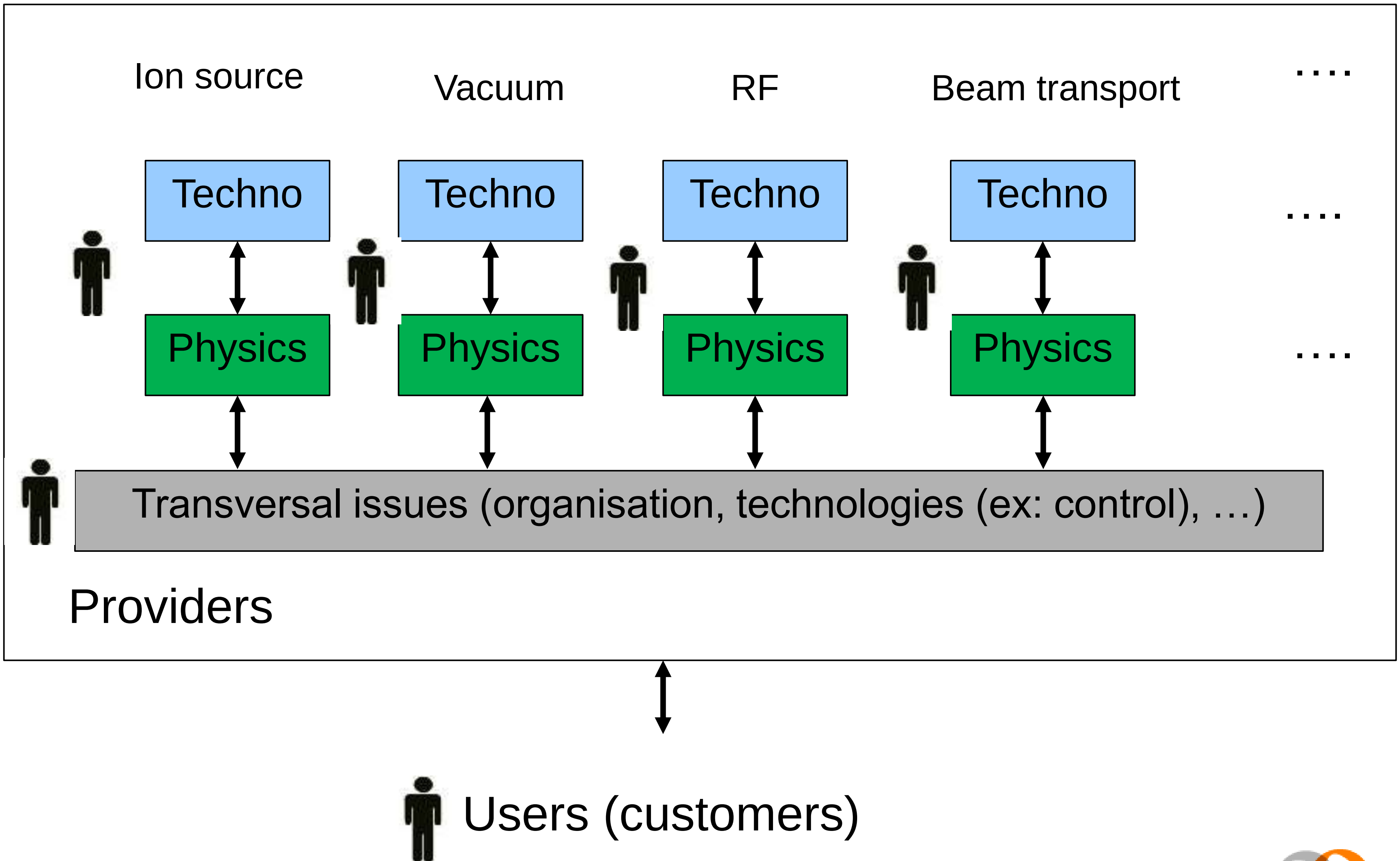

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The typical steps of lifecycle of Accelerators
(one of the naming possible)

- Desire- Need
- Preliminary design
- Detailed design
- Construction-installation
- Tests & Commissioning
- Operations- Maintenances
- Stop

Desire- Need → Preliminary design → Detailed design → Construction- Installation → Tests Com. → Operations Maintenances → Stop

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Australian Synchrotron Construction Timeline

2001

Australian Synchrotron Project funding announced by the Victorian Government

2002

Formation of scientific and machine advisory committees
Site launch and preparation

2003

Machine design announced
Building and associated facilities contract awarded
Construction started
Injection system contract awarded

2004

All particle accelerator systems contracts awarded
Beamline design process starts
Formation of industry advisory committee

2005

Building complete
Machine assembly starts

2006

Installation and commissioning of machine and beamlines begins
Selection of operator

2007

Commissioning of first beamlines complete
31 July: Australian Synchrotron formal opening

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Step « desire-need »

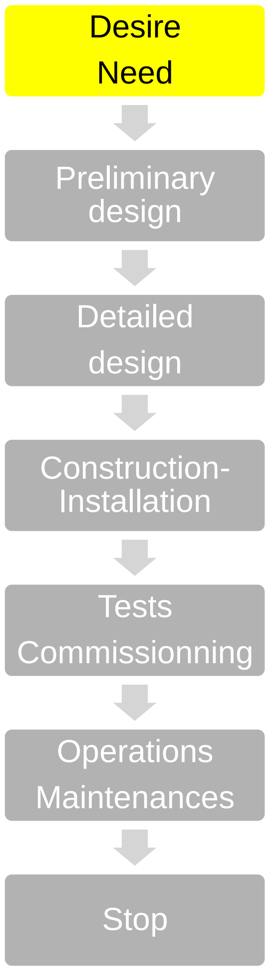
Formulate the desires

Idea-concept-feasibility-willingness

Formulate the needs

Request, requirement, specifies

Description of the need



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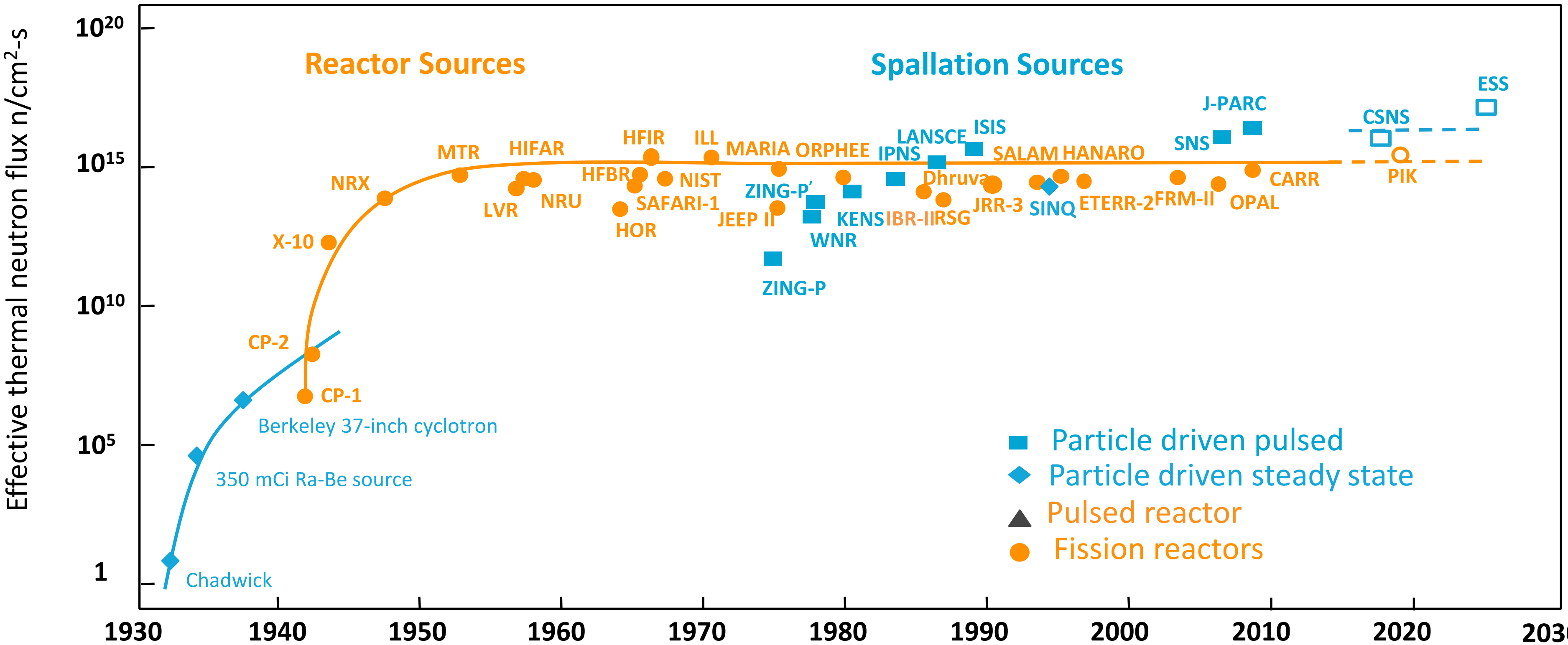
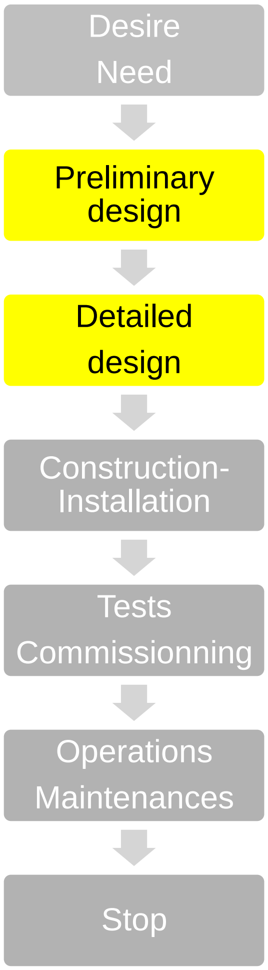
ESS- Future Neutrons Source

Increase flux of neutrons



(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

Difference between
Preliminary design/ Detailed design



Preliminary design

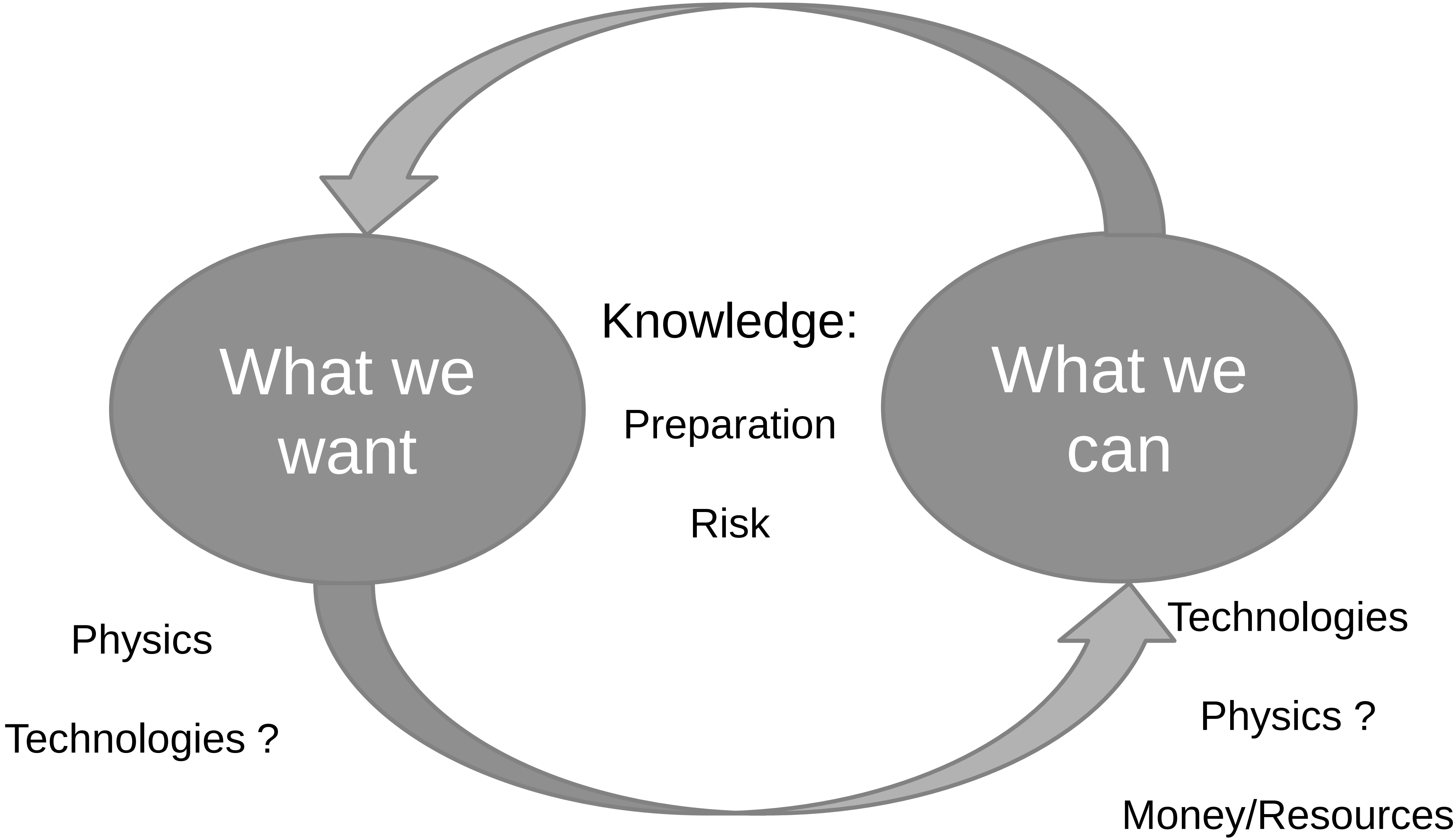
Obtaining the dimensioning data

Detailed design

All the data required for the construction

Paramètres FCC-hh comparés à LHC

parameter	LHC	HL-LHC	FCC-hh
c.m. energy [TeV]	14		100
dipole magnet field [T]	8.33		16 (20)
circumference [km]	36.7		100 (83)
luminosity [10^{34} $cm^{-2}s^{-1}$]	1	5	5 [→20?]
bunch spacing [ns]	25		25 {5}
events / bunch crossing	**27**	**135**	**170 {34}**
bunch population [10^{11}]	1.15	2.2	1 {0.2}
norm. transverse emitt. [μm]	3.75	2.5	2.2 {0.44}
IP beta-function [m]	0.55	0.15	1.1
IP beam size [μm]	16.7	7.1	6.8 {3}
synchrotron rad. [W/m/aperture]	0.17	0.33	28 (44)
critical energy [keV]	0.044		4.3 (5.5)
total syn.rad. power [MW]	**0.0072**	**0.0146**	**4.8 (5.8)**
longitudinal damping time [h]	**12.9**		**0.54 (0.32)**



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What we know-what we can (internal, external)

Internal: experience, skills (people, teams), methods, …

External: we can ask to do

(partnership, collaborations, sub-contract, …)

Development – the V cycle

Needs Analysis

Operations maintenance

System Specification

System Validation

Sub-systems Design

Sub-systems Validation

Preliminary Design

Tests & integration

Detailed Designed

sub-system Tests

Realisation

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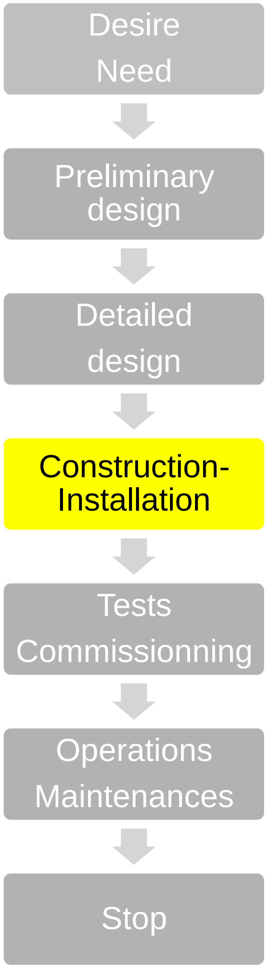
Construction-Installation

The Building

The Equipment

(the overall: the « facility »)



The building-the infrastructure

- The instrument is the « overall »
- Building first: 1st milestone “Building Occupancy Date”
- Building and ancillaries are specific and complex
- Interfaces, large numbers of areas
- To be designed for users, maintenance, upgrades, …
- Cost ?
- Cost = 30%to 50% of the total cost

- 1 Good point : designers&builders often with more experience than Large Instruments stakeolders (ex: The building world as the reference for the naming of steps)
- 1 Bad point : many features are no more ajustable after first design

Construction-Installation

The Equipment

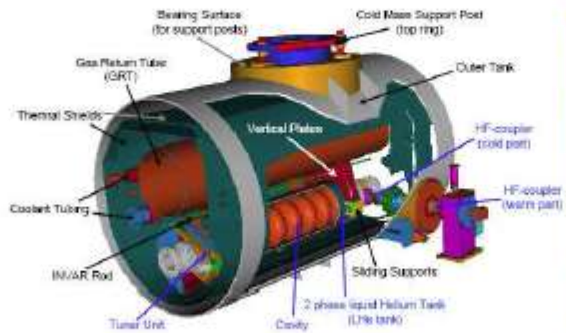


Figure 6-1: Cut-away diagram of an XFEL vacuum vessel.

Example of the cryo-modules X-Fel

- Desire Need
- Preliminary design
- Detailed design
- **Construction-Installation**
- Operations Maintenances
- Tests Commissionning
- Stop

irfu cea saclay / European XFEL	**Technical Specification for XFEL Cryomodule Assembly**	REFERENCE : CEA-XFEL-TS-00001-01
		Page : 100/100

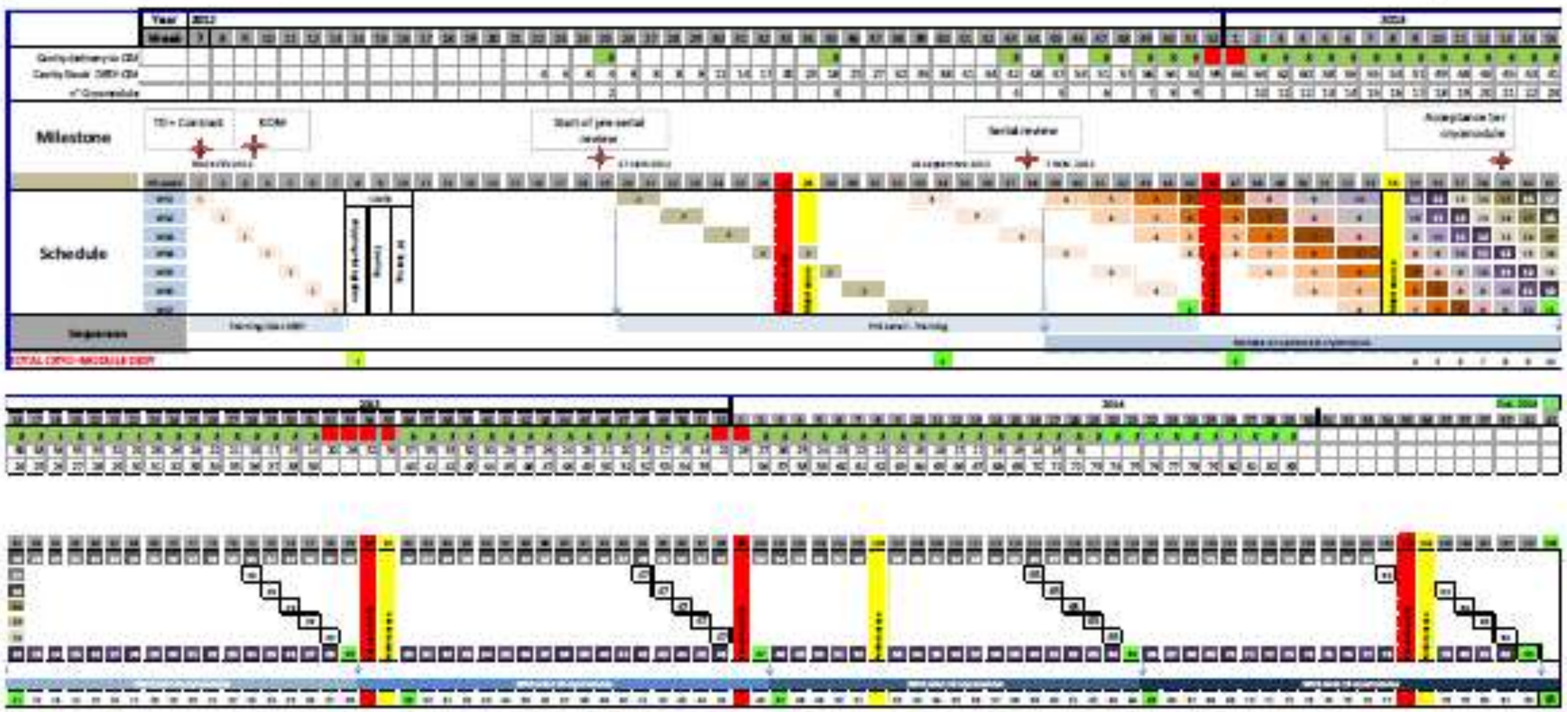
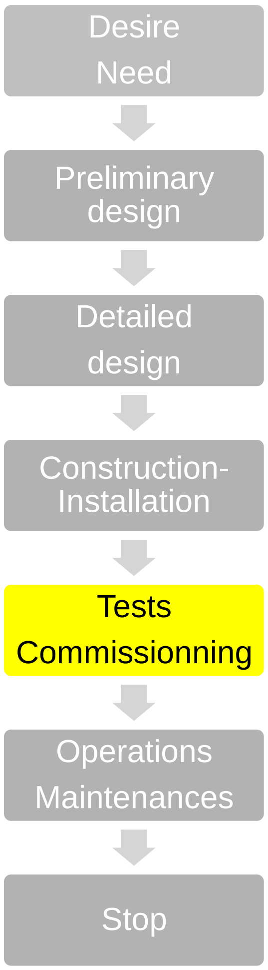


Figure 12-1 : schedule of the assembly according with the availability of cavity.

Tests and Commissionning

Tests, Tests, Tests, …

The commissionning: « The process during which components and systems, after construction, are made operational and verified to be in accordance with design assumptions and performance criteria”.



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4 main dimensions during life-cyle

- Politics
- Money-Fundings
- Customers/Providers
- Regulatories

European Spallation Source

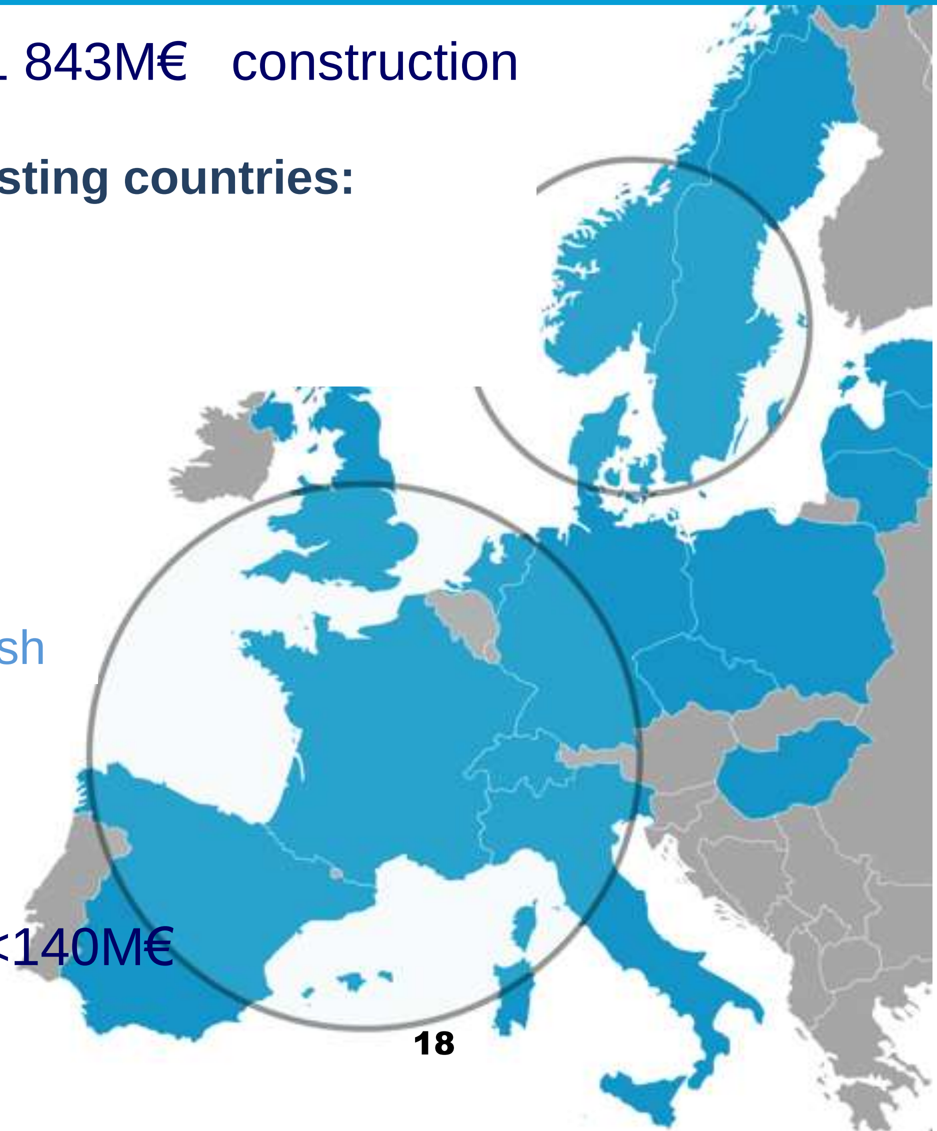
International collaborations 1 843M€   construction

Suède et Danemark – hosting countries:

47.5%	Construction
15%	Operations
100%	Cash

Partners countries:

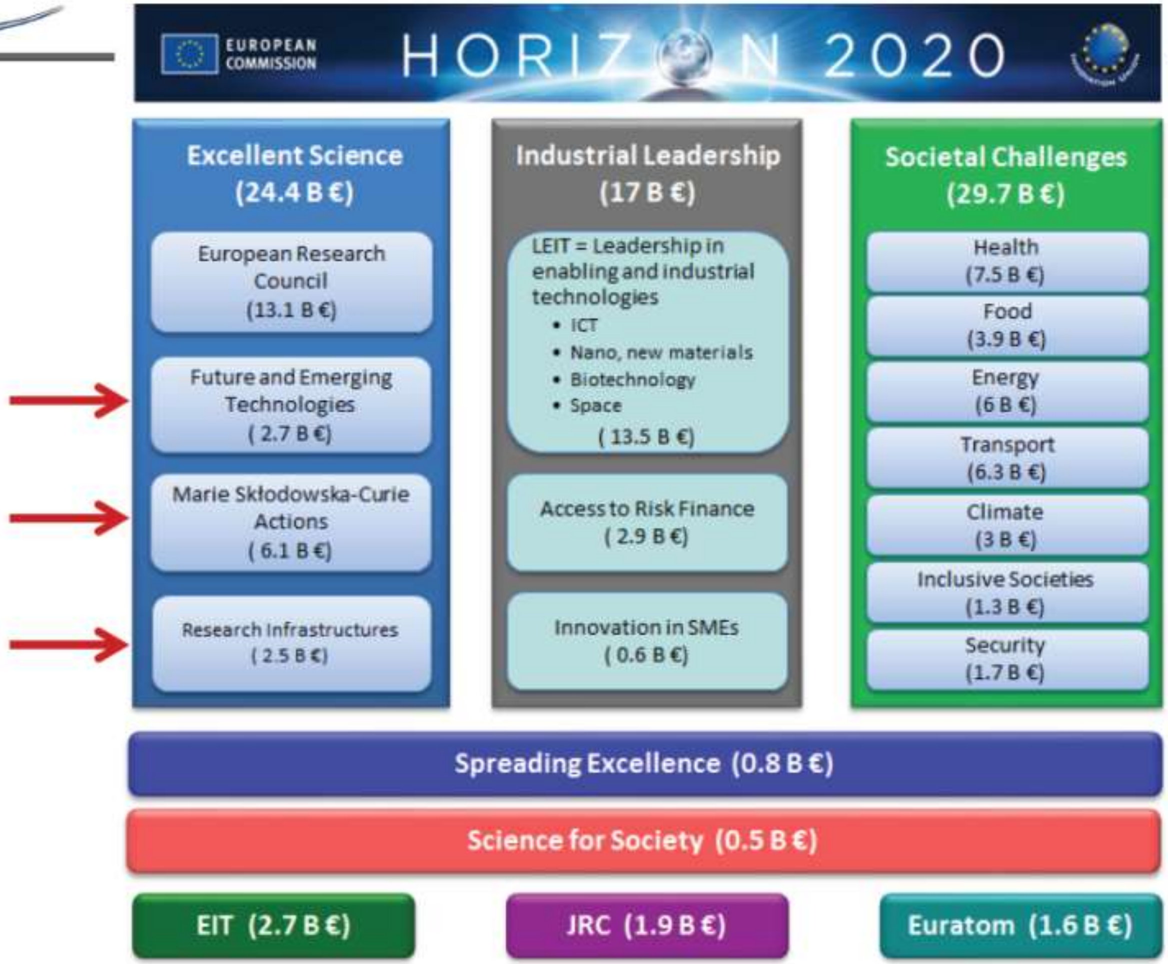
52.5%	Construction
85%	Operations
70%/30%	in kind / in cash



Estimated running budget <140M€

Life-time ~40 years

H2020 Structure



Of interest for accelerators

Fundings and budgets

1. For studies
2. for construction (investment)
3. for operations

    salaries

    fees (consumables, running costs…)

    upgrades

1. in cash
2. in kind (contribution)

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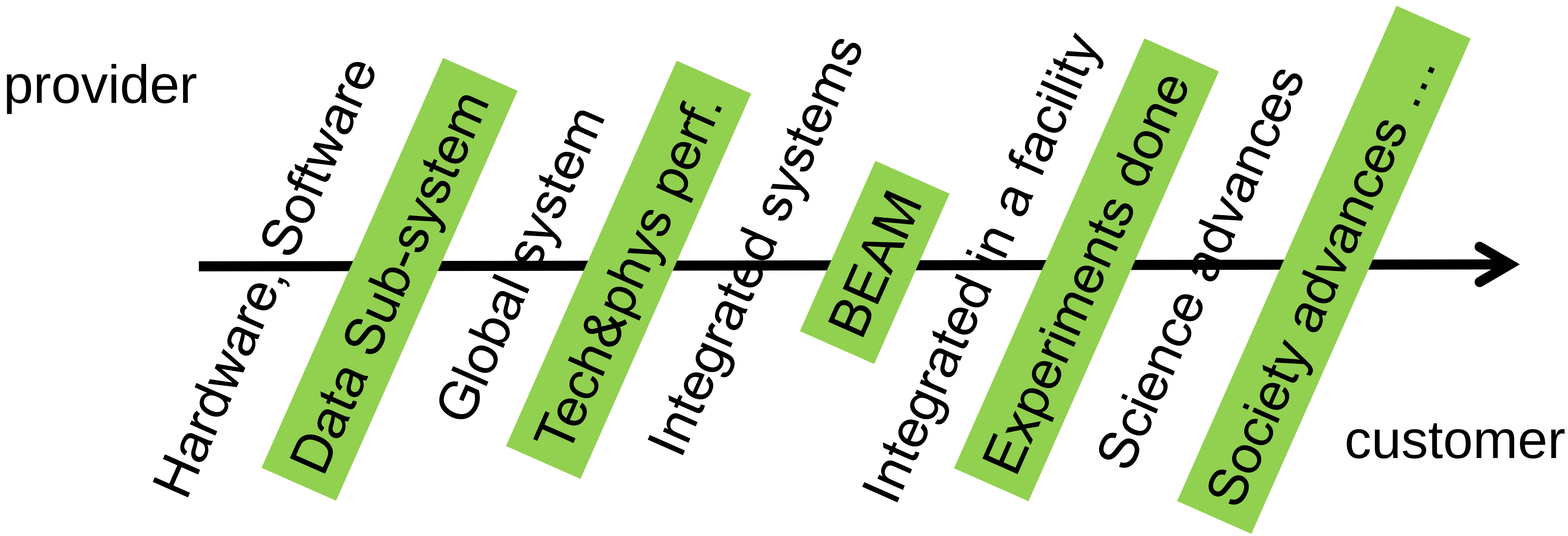

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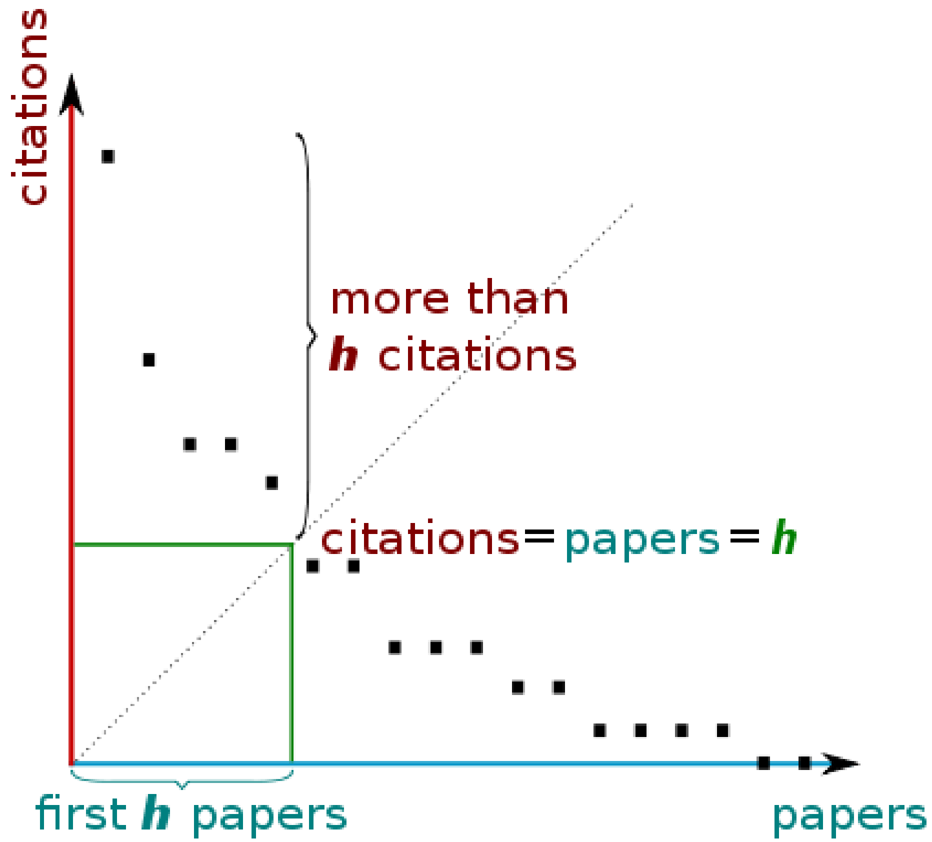
Hirsch index or Hirsch number



Level of delivery	The supplier is delivering	The customer is expecting (so testing, accepting)	Example in particle accelerator
Parts	Part of hardware, part of software	technological data	Power supply
System	A global system	Individual technological &physics performances	RF Cavity
Systems Integrated	Many systems integrated	Global performances	BEAM
Facility	Conditions to perform the whole « job »	Resultst: experiments or production achieved	Users of Synchrotron
Societal	Service or science advances	New society	Higgs boson completing the standard model

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Regulatories (why ?)

Why

- Risks on personal (workers)
  - radiation protection, fire, mechanical …
- Risks on environment

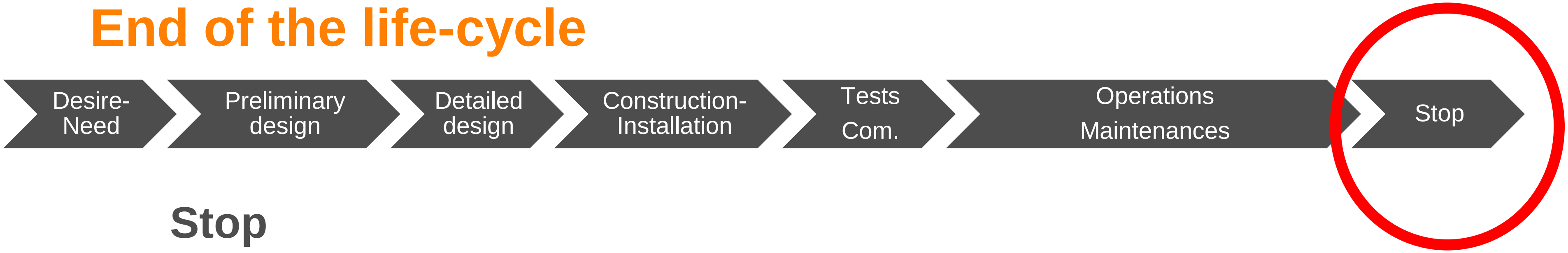
2 kinds of approach:

- Authorization
- Control

Internal/ external

- internal: safety officer, radiation officer , procedures, rules
- external: national authorities, control office, norms

End of the life-cycle



Stop

Consignate

Lock-out all the networks and clearences

Dismantle

"Decommissioning"

The process by which the facility is permanently taken out of operation at the end of the plant lifecycle with adequate regard for the health and safety of workers and the public, and protection of the environment.

A little history on management of facilities

years	Facilities considered	Classical management of the end of the facility
Before the 19th century	buildings, « classical » factories, etc …	abandon, reconversion, demolition.The garbage are put in … the trash
from 1970	Begining of the complex factories, including nuclear facilities	Dismantlement considered at the end of the use. The garbage are stocked.
1970-2000	Begining of the end of some nuclear facilities	Authorities introduce the question of the dismantlement at the begining of the facility
From 2000	all	Sustainable approach

some of the definitions

Main term	Other terms and notions	goal
Desire-need	Feasibility -exploration	Express of interest
Preliminary design		Data to dimension
Detailed Design		All the data ready to build
Construction/ installation	Realisation-Production Building /Equipement Academic/Industrial	From design to real
Test/ commissionning	Acceptance/Qualification	Before starting the operations
Operations	Maintenance/upgrade	Use
Stop	Decommissionning Dismantle	Clean & clear (re-use)

Specificities of accelerators

Many parameters linked to the **beam** (IS, magnetic field,vaccuum, RF, …)

Large: money (threshold), politics, time, building…

Long Duration (knowledge management, quality , obsolescence, …)

Science: uncertainties-risk, complexity,…

International (language, culture, politics, interface, regulatories, …)

Radiation: risk, safety, long-term, regulatories, …

Dimensions of analysis :

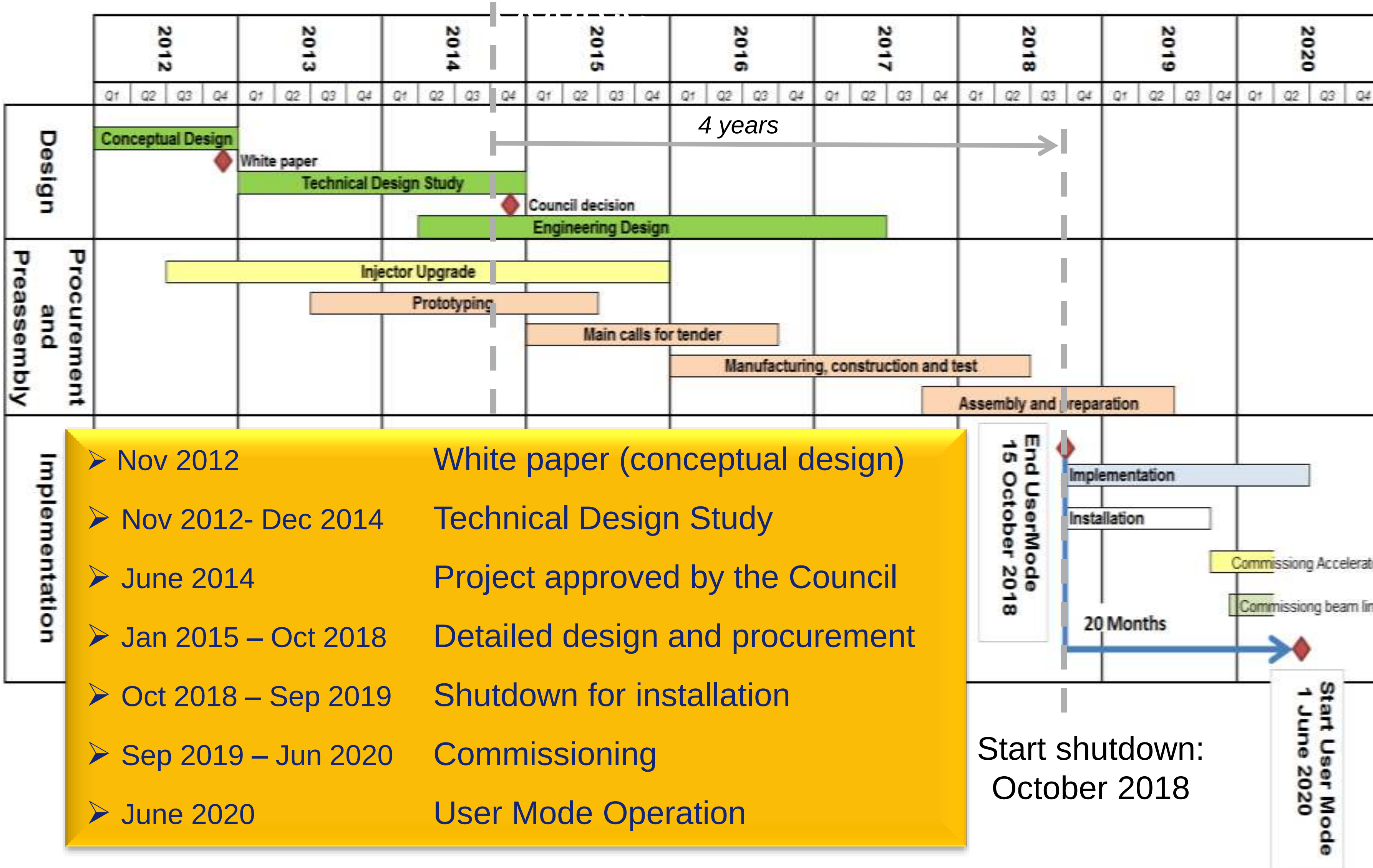
Technologies/Physics

Academics / industrials

Projects/Operations

Time scale

Upgrade de l'ESRF : ESRF II



- Nov 2012 — White paper (conceptual design)
- Nov 2012- Dec 2014 — Technical Design Study
- June 2014 — Project approved by the Council
- Jan 2015 – Oct 2018 — Detailed design and procurement
- Oct 2018 – Sep 2019 — Shutdown for installation
- Sep 2019 – Jun 2020 — Commissioning
- June 2020 — User Mode Operation

Start shutdown: October 2018

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Definition of reliability

1st basic approach

$$\text{Reliability} = \frac{\text{Time the systems works – Time of breakdowns}}{\text{Time the system works}}$$

Definitions of reliability

The **reliability** is the ability of a system or component to perform its **required functions** under **stated conditions** for a specified **period of time**

The reliability (R(t)) is the probability to have no failure at the time t.

MTBF: Mean Time Between Failures

MTTR: Mean Time To Repair

The **availibility** of the system is the ratio of the time when the system is operational by the time it was supposed to be operational

Availibility = MTBF / (MTBF+ MTTR)

exercise

An accelerator is used from 10:00 to 20:00

During this time, there were:

- 10 small failures of ion sources lasting 5 min for each

- 2 times (15h and 19h) a failure of a magnet power supply, requiring 30 min to retune the beam

What is the MTBF ?

What is the problem to solve first to do the best « physics » ?

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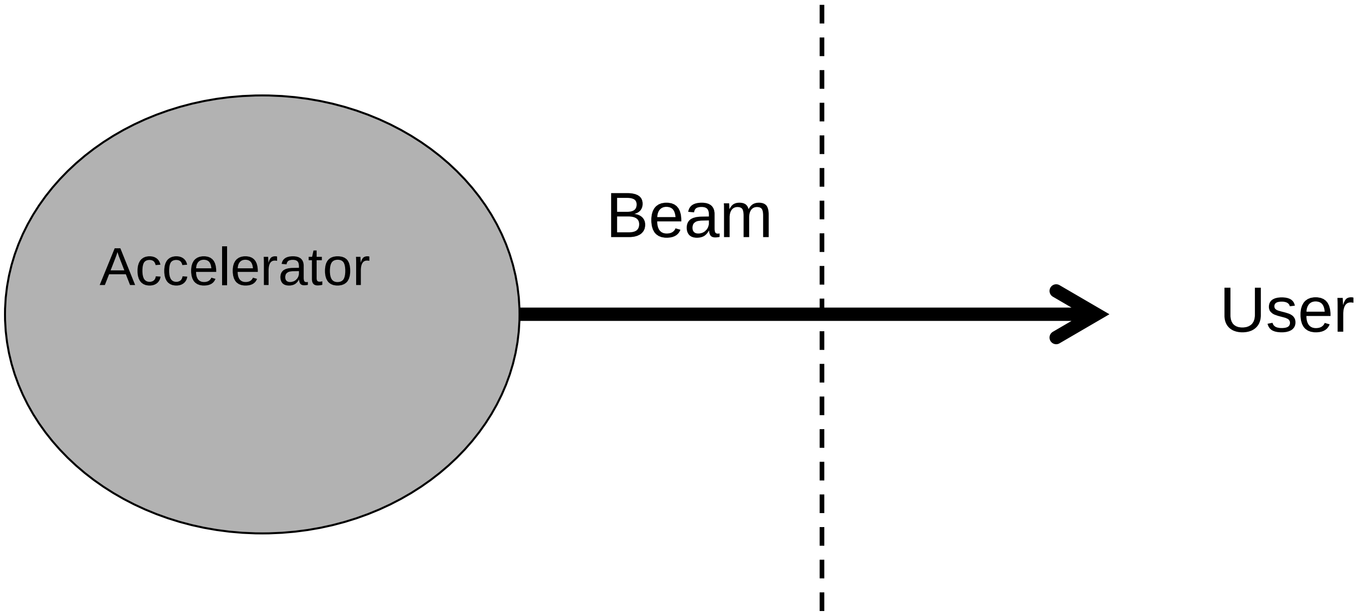

What is the **product (service)** delivered ?

What is the **quality** defined ?

Who is defining the reliability ?

Reliability and Accelerators

- Power- Energy & Motion

Electricity, cooling, regular motion systems

-**Critical and/or sensitive Technologies**

Radio-Frequency, vacuum, electronics, cryogenics, software, …

- **Risks**

radiation-protection, costs, …

-**Complexity**

mix of technologies, %research%production, regulations

- **Using &Users (Customers / Providers)**

beams: current, energies, duration, …

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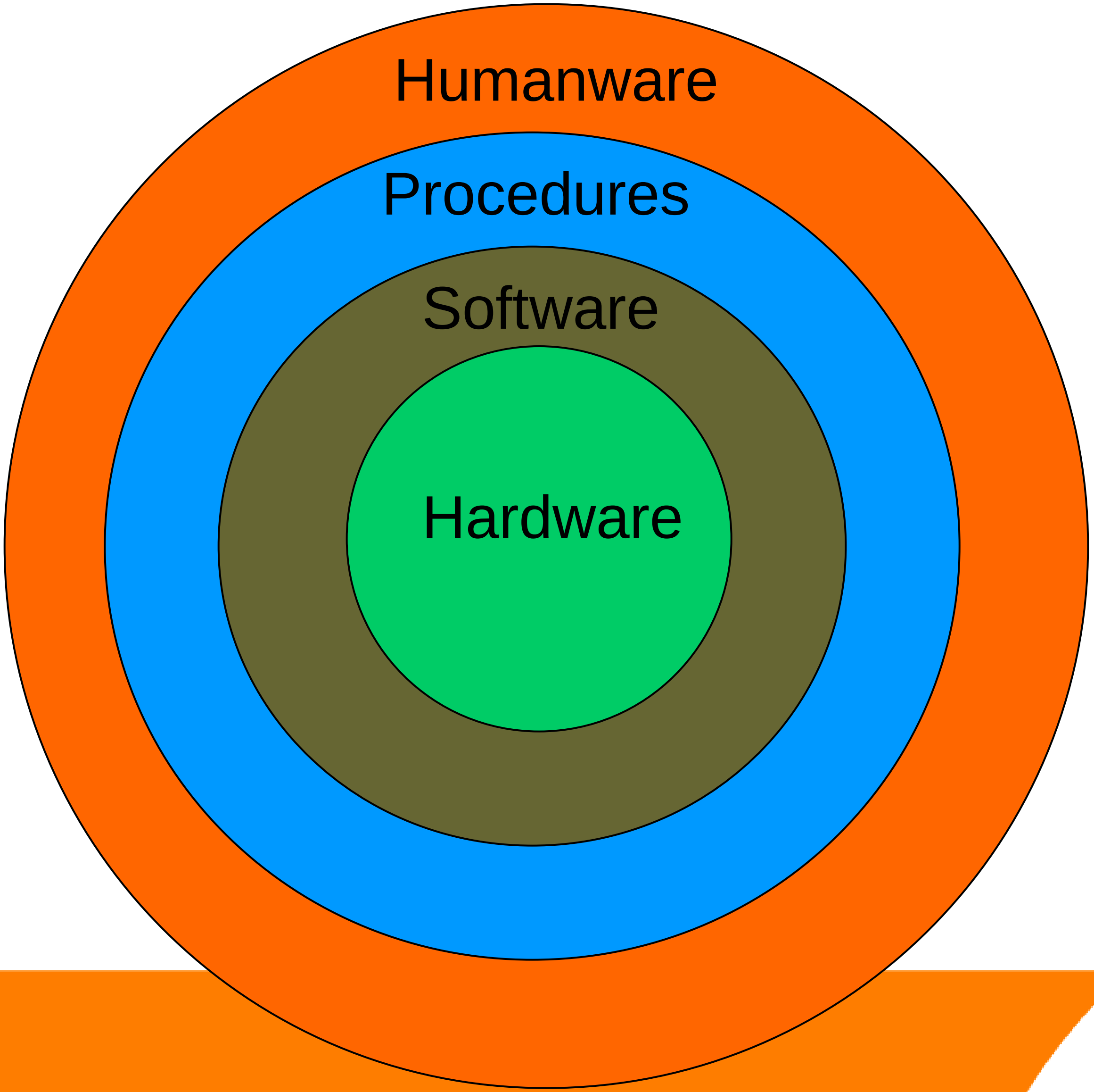
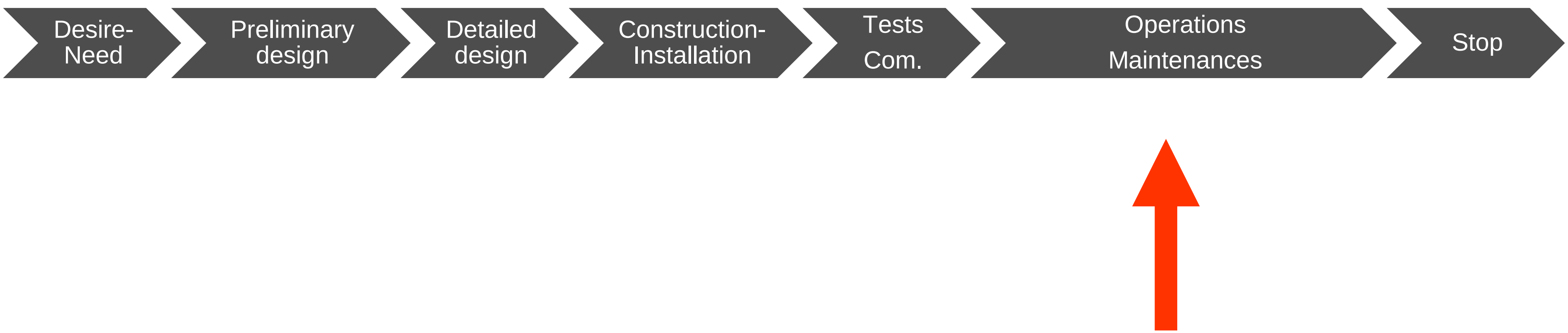
the 4 layers of reliability



Life-cycle of Large Instruments



The « operations » for an accelerator

- **All the process to be managed in order to deliver the required beam (and associated services) during the planned period**

This includes:

- Startup of the system, Tuning of the beam
- check of the normal behaviour of the systems during
- monitor and record parameters (automatic or manual, log-books, …)
- fix any unplanned event (troubleshooting, corrective actions level 1,2,…)

- planning of the activities (discussion with users): day, month, year
- managing the documentation (procedures, drawings, …)
- training of operators level 1, 2, …

- in direct relation with maintenance and project issue

Operations / Projects

Goal: keeping a process stable

Key Performances Indicators (KPI): **reliability**, production outputs for users (ex: hours of beam)

Goal: reaching a specific target (new)

Key Performances Indicators (KPI): Milestones (dates), level of completion achieved, performances reached,**reliability** of planning …

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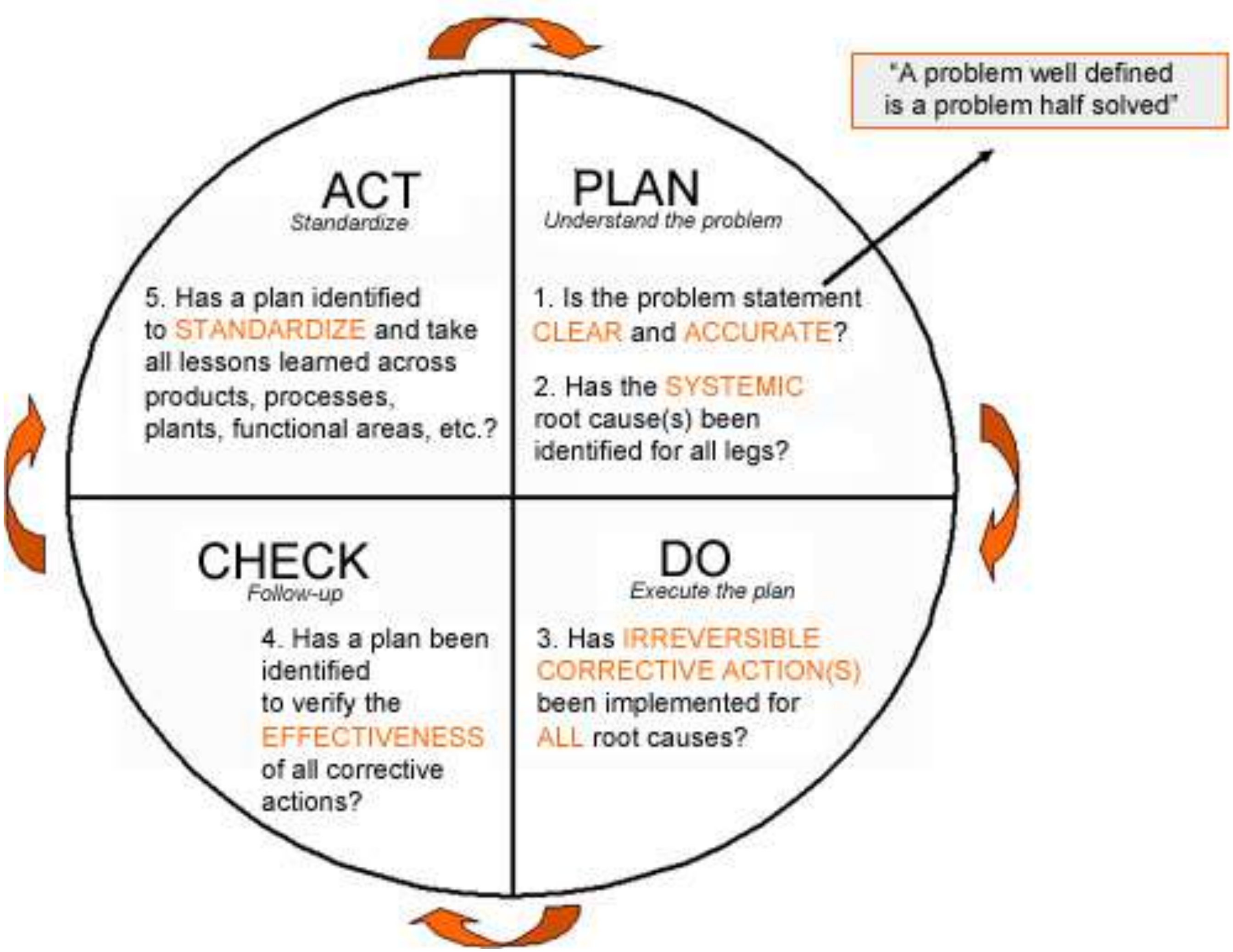
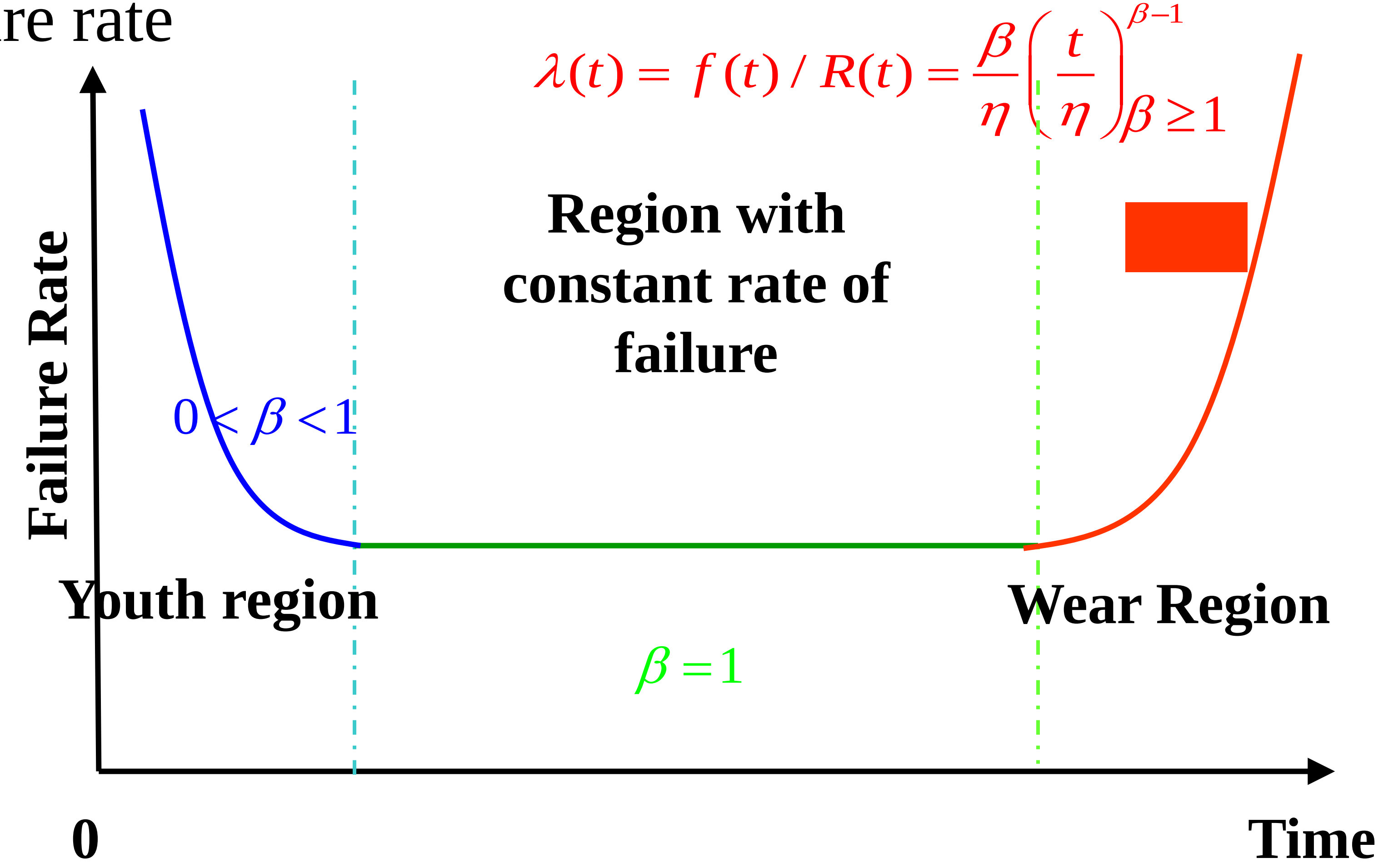
Plan – Do –Check – Act (PDCA)

(to manage Operations)



The reliability Weibull Model

Failure rate



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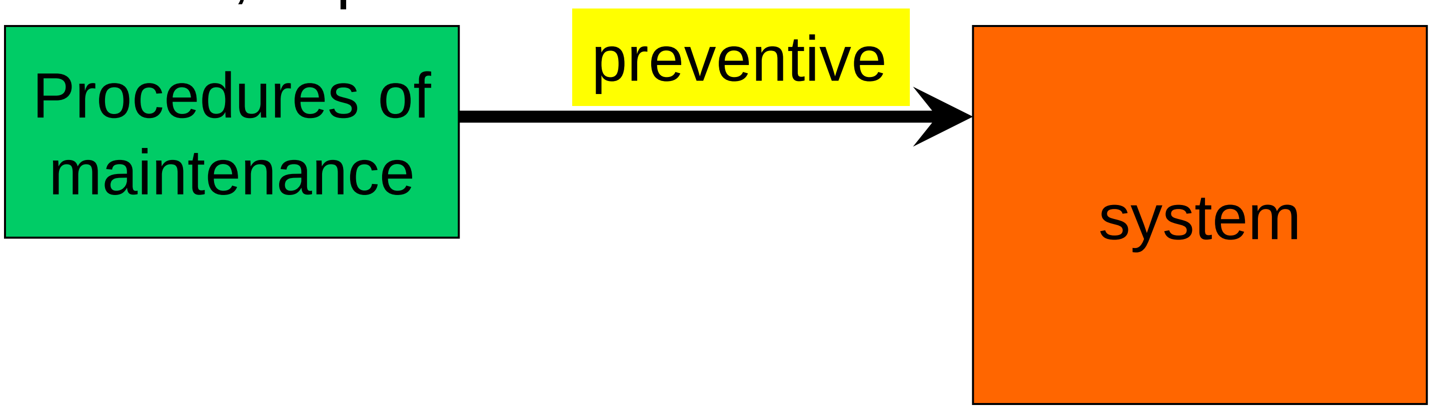
Maintenances

Modelisation, experience

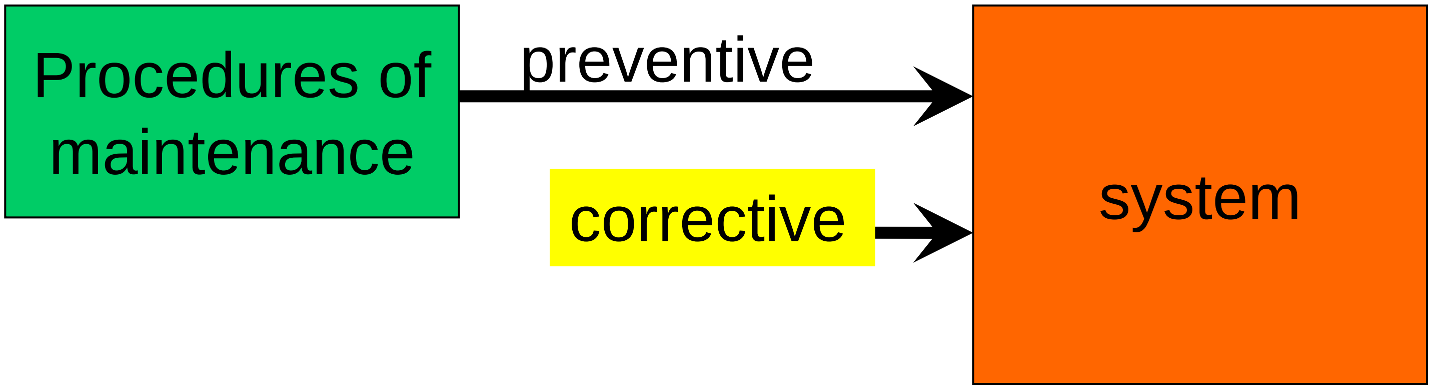


Inspect, clean, check, lubrify, calibrate, read, replace, test ,…

< 20% with high periodicity
Ex: Ions Sources

Maintenances

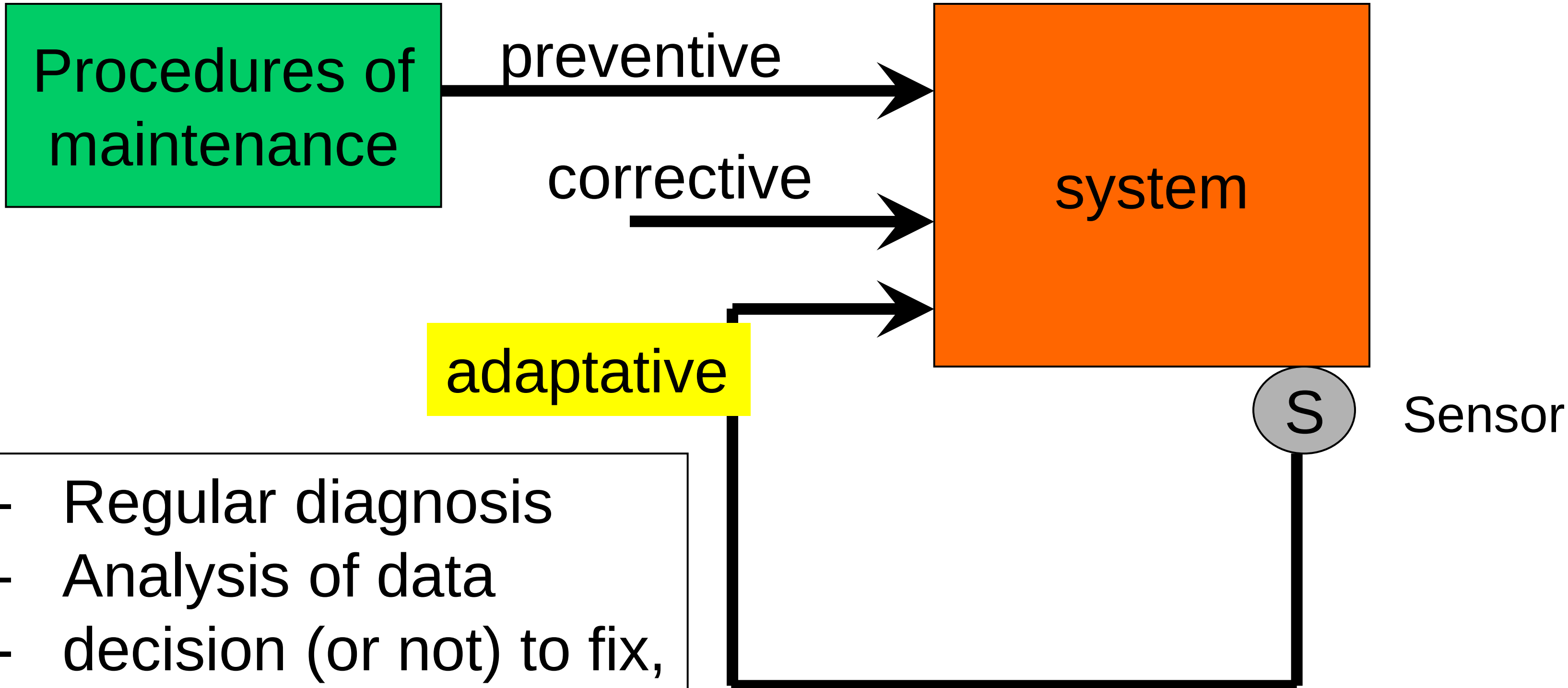
Modelisation, experience



- Awareness of problem(s)
- Diagnosis
- Fix-replace
- test

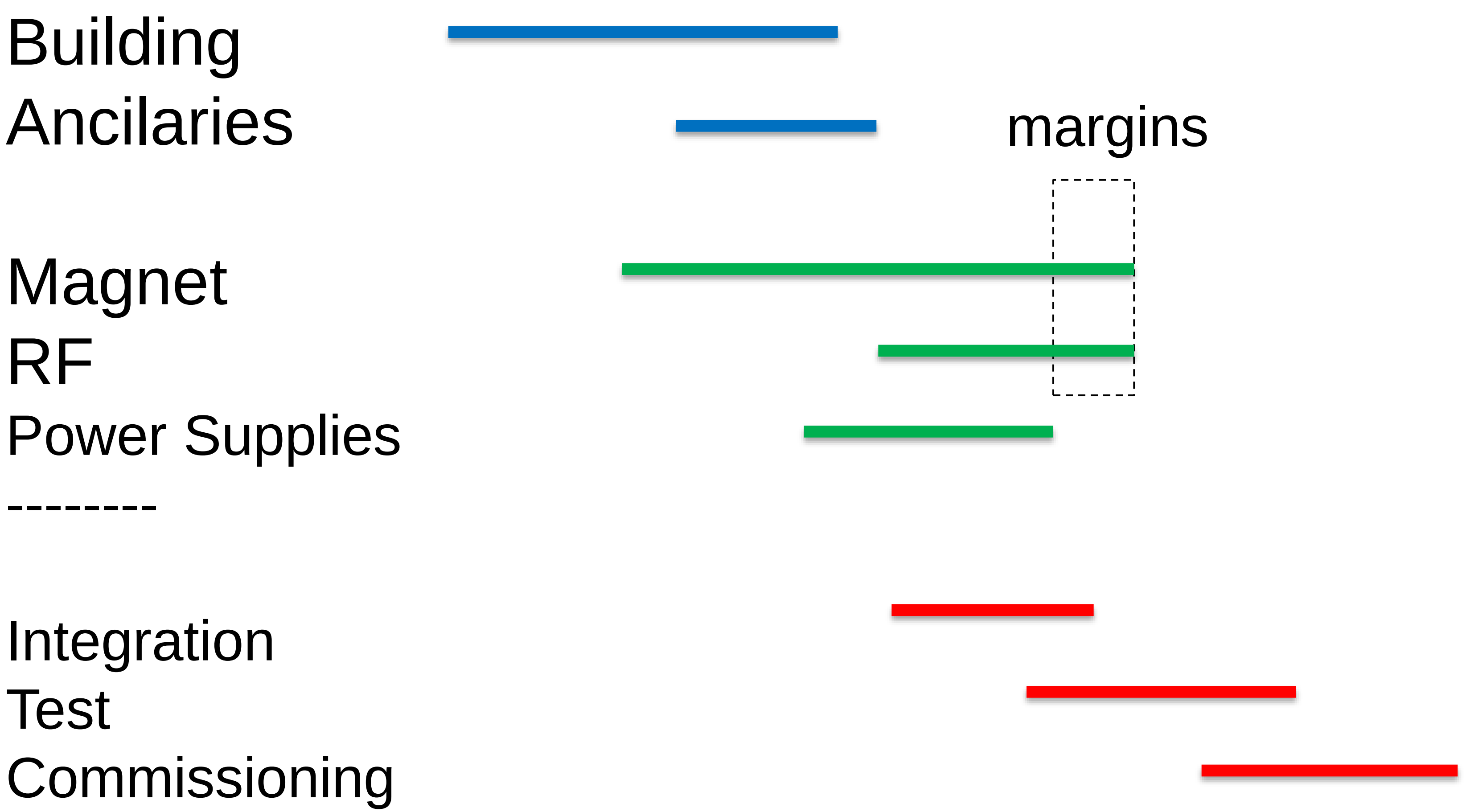
Maintenances

Modelisation, experience



- Regular diagnosis
- Analysis of data
- decision (or not) to fix, inspect, more analysis

planning


Building
Ancilaries
margins
Magnet
RF
Power Supplies

Integration
Test
Commissioning

Contracting with

With the provider of the accelerator

- performances and acceptance tests
- contents and limits of interfaces (beam, building , control, …)
- training - documents
- budgets (bonus / penalties)
- maintenance contract

With the provider of building and ancilaries

With the users (« real » needs, constraints, freedoms, evolutions…)

With the payers (budget and resources)

- for investment
- for ramp-up and contengencies
- for operations, maintenance, …

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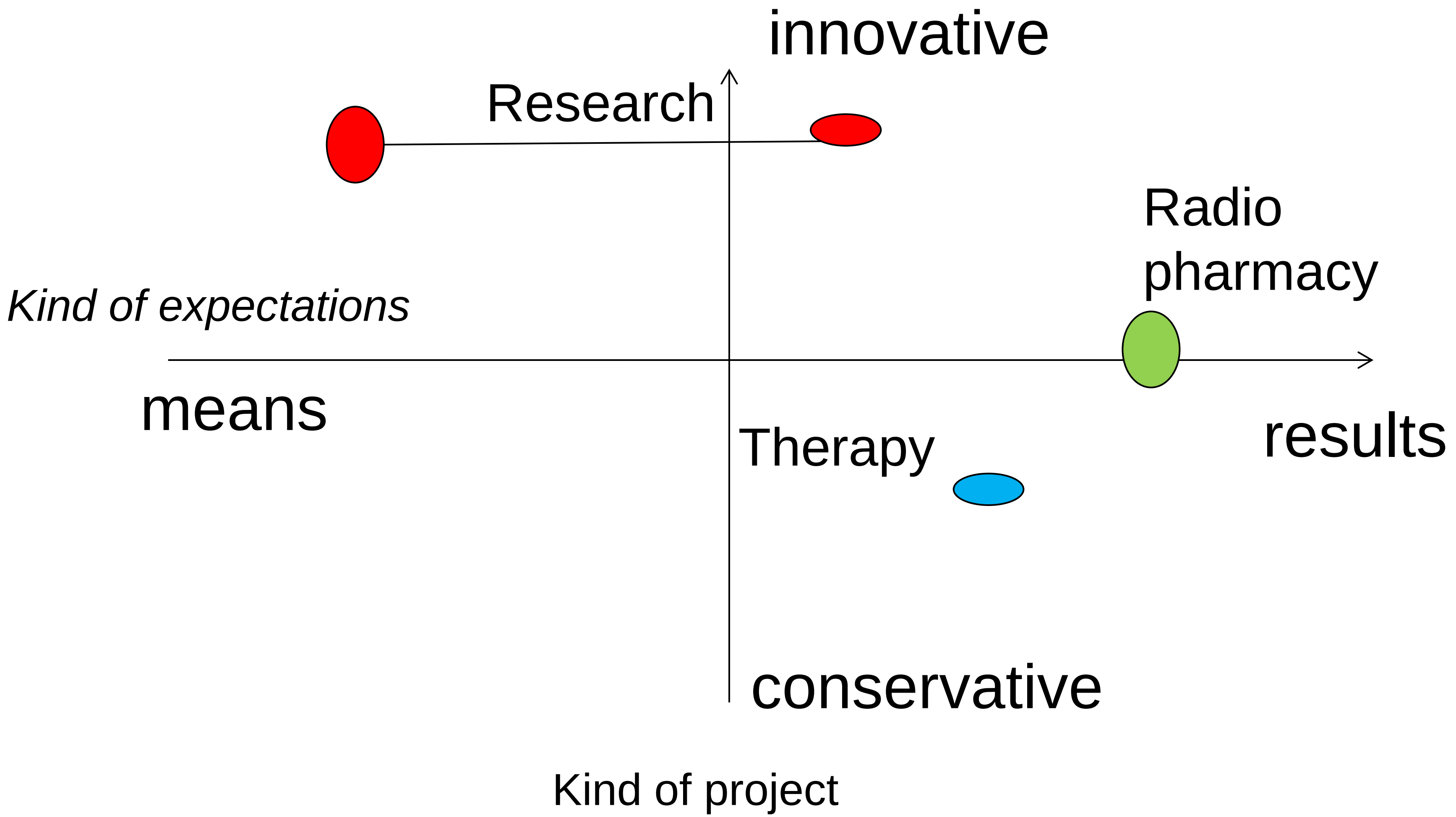
Science of Organisations

Henry Mintzberg: different kinds of coordination

- **Mutual adjustment**
- **Direct supervision**
- **Standardization of work processes**
- **Standardization of outputs**
- **Standardization of skills**
- **Standardization of norms**

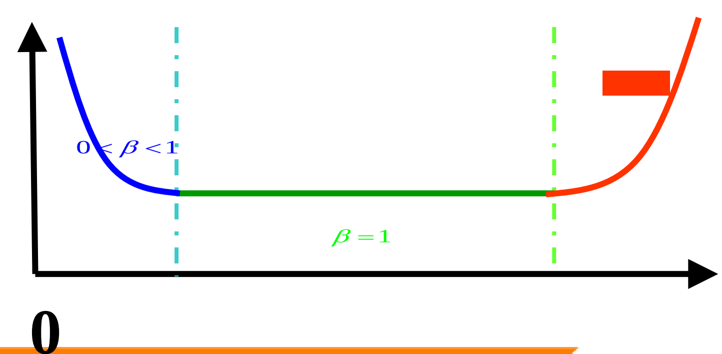

innovative
Research
Radio
pharmacy
Kind of expectations
means
results
Therapy
conservative
Kind of project

+

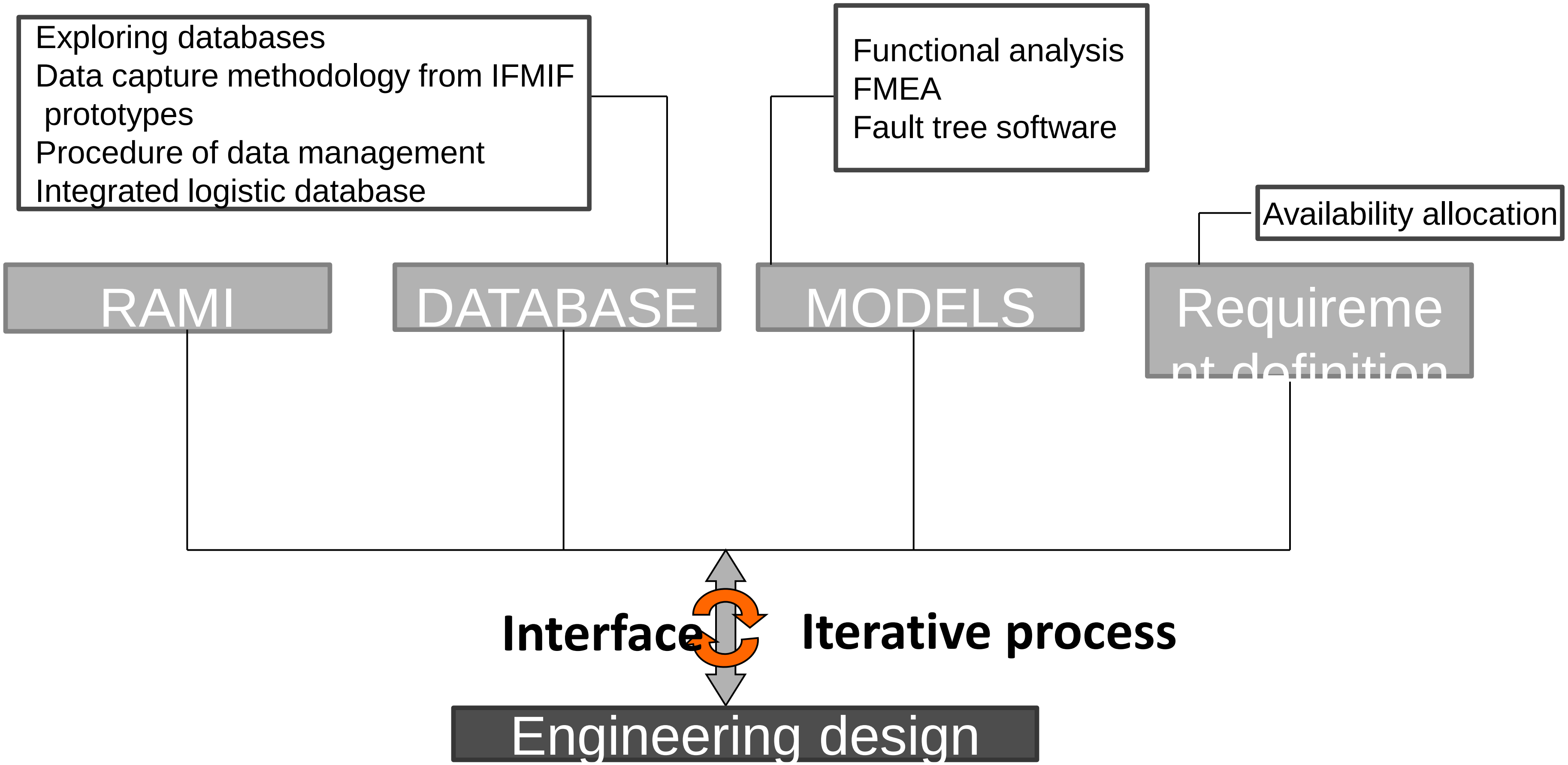
Quality Assurance

Desire-Need | Preliminary design | Detailed design | Construction-Installation | Tests Com. | Operations Maintenances | Stop

contract



RAMI approach (Reliability, Availability, Maintainability, Inspectability) for project IFMIF



Concepts and reliability

Principles to increase reliability:

- **Redundancy**
- **accessibility**
- **over -engineering**
- **maintainability**
- **…**

Parameters increasing risks on reliability

- **Technological innovations**
- **Lonely experience**
- **Number of specific interfaces**
- **pressure on quality, budget, delay**
- **…**

The (wellknown) recipes for a good reliability

A system (hardware & software) well designed

- specifications, model of developpement, tests
- principles of reliability, a lot of diagnosis

A well-maintained system

- Preventive, real, adaptative, reactivity for corrective
- Spare parts (a lot, ready for use)
- time dedicated for operations

Human resources and good organization

- people trained, skilled, enough, here when required
- efficient and clean organization, data-base, Knowledge Management

Briefly: resources (men, budget), consistency, willingness…

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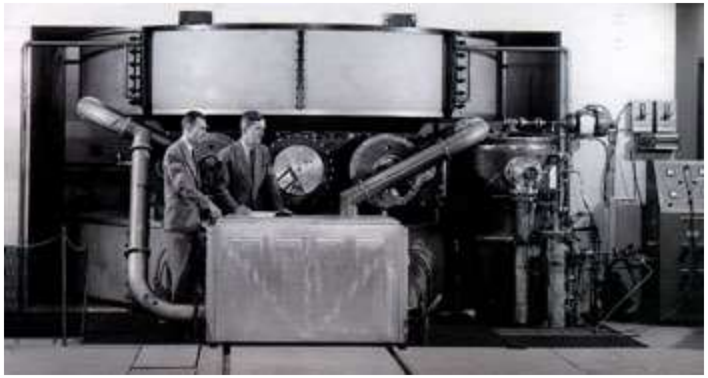
Synchro-cyclotron - HCL
Harvard (1949-2003)



Cyclotron 88 inch - LBL
Berkeley (1961 - …)

Cyclotron PSI (590 MeV)- CH
designed for 100 µA (1974)
an now at 2,2 mA (2012)

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