

# **Adoption of ARCADIA and Capella to Develop an Elimination Process of Radioactive Waste by Melting**

A beginner's experience

Luca Bruno



HSE  
Occupational Health & Safety  
and Environmental Protection unit

# Outline

## 1. Introduction

- CERN context & facts
- Managing CERN radioactive waste

## 2. Process specification

- Limitations of current practices
- Causes, approaches
- Proposed solution by ARCADIA and Capella
- Examples of diagrams in use:  
operational architecture, capabilities, scenario
- M2Doc

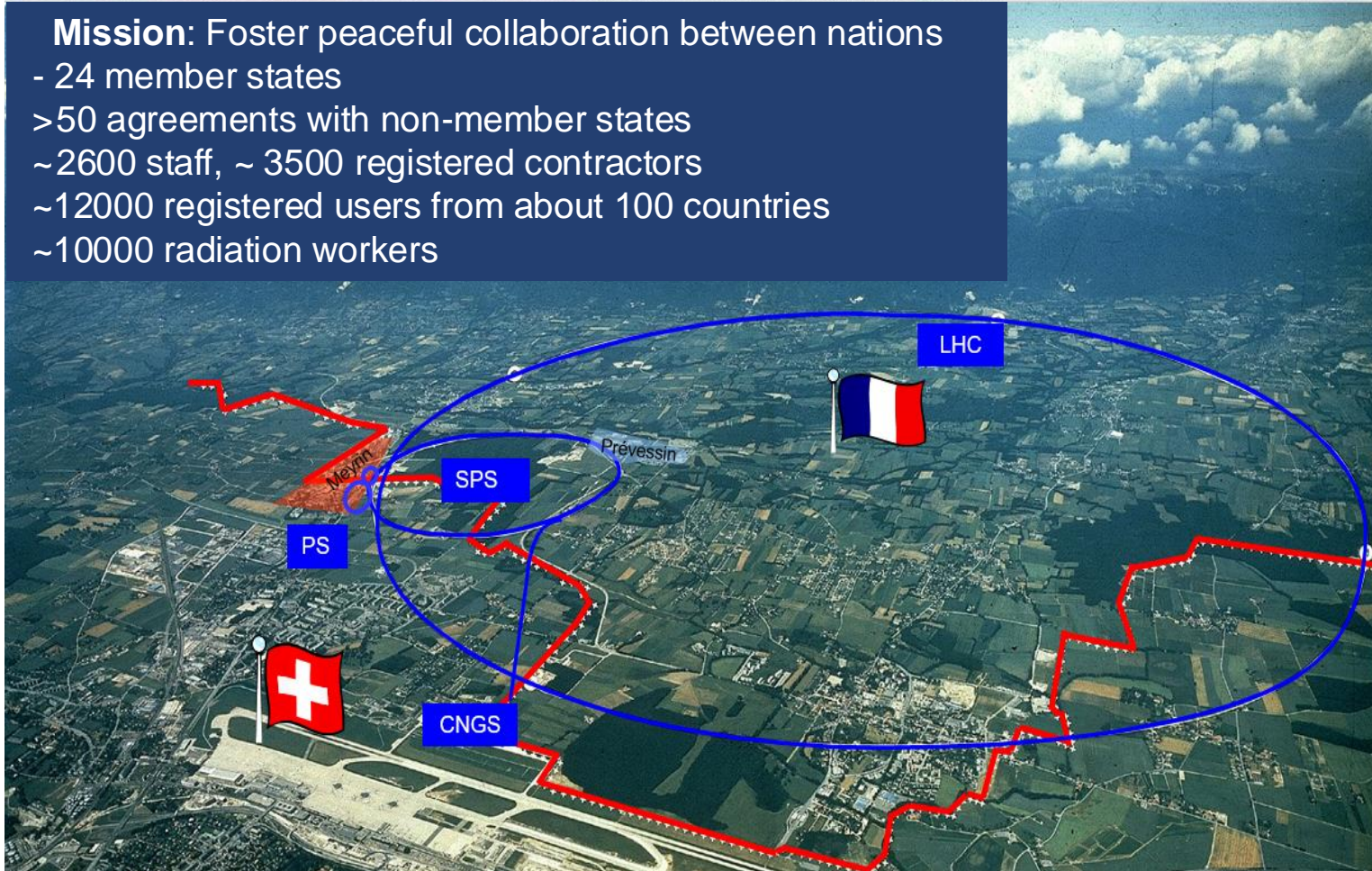
## 3. Conclusion



# CERN – The European Organization for Nuclear Research

**Mission:** Foster peaceful collaboration between nations

- 24 member states
- >50 agreements with non-member states
- ~2600 staff, ~ 3500 registered contractors
- ~12000 registered users from about 100 countries
- ~10000 radiation workers



- CERN is an *intergovernmental Organization* subject not to national but international law.
- **Right to establish rules** as necessary for the proper functioning of the Organization:
  - CERN Staff Rules and Regulations;
  - CERN Safety Rules.
- A “**Tripartite Agreement** on Radiation Protection and Radiation Safety” between CERN and its host states provides the legal framework to discuss in a transparent and collaborative way with the host states authorities. The subjects covered are:
  - Export / import and handling of radioactive materials;
  - Transport of radioactive materials;
  - Radioactive waste;
  - Incident declaration;
  - Dosimetry;
  - Environmental monitoring.

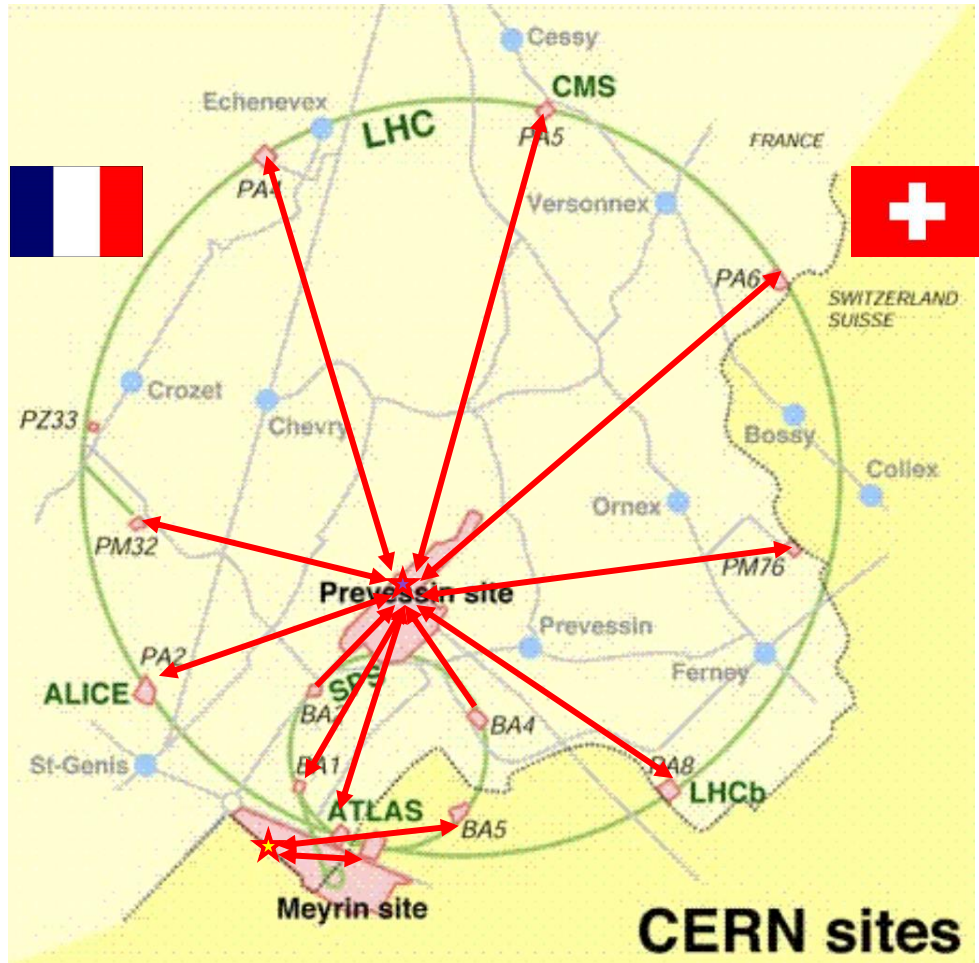


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# CERN Facts



- ~500 m<sup>3</sup>/year rad. waste
- ~1000 m<sup>3</sup>/year rad. waste processing facility
- 10.000 m<sup>3</sup> rad. waste interim storage facility.
- >160 experiments;
- ~1000 radiation areas
- ~50 km of accelerator infrastructures, mostly located underground (LHC up to 100m);
- Radioactive Ion Beam facility (ISOLDE);
- Spallation neutron source (n-TOF);
- <https://home.cern/resources/faqs>

In addition to **two main sites** (Meyrin and Pévessin), CERN has **13 remote sites** (11 in France and 2 in Switzerland).

All remote sites are located in a semirural environment and have limited infrastructure and services.

**Over the last decades, the number of facilities has more than doubled**, while the demographic evolution in the region resulted in the construction of new long-stay buildings,

**Challenge:** how to manage the radiation-protection risks in accordance with the legislations of the two Host States, France and Switzerland.

**Example:** the management of radioactive waste: CERN's radioactive waste must be disposed of using the different pathways available in France and Switzerland through the most technically and economically advantageous pathways.



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Cables



Accelerating cavities



Pumps



Magnets

## CERN Radioactive Waste (RW)

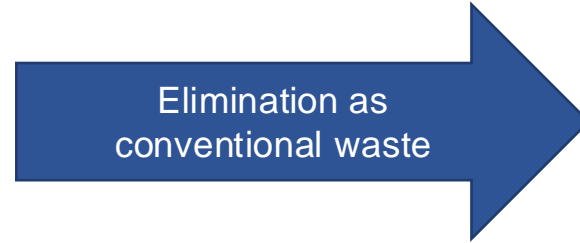
- Spallation, neutron capture...
- Very-low to intermediate-level rad. waste.
- Mainly  $\beta$ -,  $\gamma$ - emitters.
- Very limited contamination.
- Short to medium lived radionuclides (no long-lived radionuclides, apart from very specific experiments).
- Limited quantities of activated or contaminated liquids.
- Large variety of radionuclides.
- Possible mixed waste (waste presenting a chemical hazard linked to the radiological hazard).

# End-of-life stage of CERN radioactive equipment - 1/2

Classification



Candidates for "clearance"  
0 kCHF/m<sup>3</sup>, 30.5% of CERN radioactive waste



Switzerland



Very-Low-Level RW  
~0.9 kCHF/m<sup>3</sup>, 63.8% of CERN radioactive waste  
~25% of elimin. costs over the next 10 years



ANDRA (France)



# End-of-life stage of CERN radioactive equipment - 2/2

Classification



**Short-lived Intermediate- & Low-Level RW**  
~26 kCHF/m<sup>3</sup>, 5.5% of CERN radioactive waste  
~ 57% of elimin. costs over the next 10 years

Embed in reinf. concrete & 300y storage in a surface repository



ANDRA (France)



**Long-lived Intermediate- & Low-Level RW**  
~242 kCHF/m<sup>3</sup>, 0.2% of CERN radioactive waste,  
~18% of elimin. costs over the next 10 years

Dismantling in hot cell, packaging & geological disposal



PSI (Switzerland)

MA Team – EDMS 2726591



# Elimination of Radioactive Waste by Melting

## A long journey...

Setup phase

- 2017-11: **Start** of the **technical market survey** of available technologies and accredited European suppliers capable of processing FMA waste. Technical visits on selected companies in Germany, Sweden, France.
- 2018-06: **FMA elimination strategy** defined & presented at the 1<sup>st</sup> RWM St. Board.
- 2019-05: **FMA elimination program** defined & presented at the 2<sup>nd</sup> RWM St. Board.

Project phase

- 2020-05: **FMA elimination project** by melting: **mandate & milestone plan** defined.
- 2021-05: Primary waste batch: **first container filled** & available for characterisation.
- 2022-06: Primary waste batch **finalised**. **Audit** by the melting company
- 2022-11: **Melting**.
- 2023-06: **Elimination** of the pilot batch towards the French repository.
- 2023-10: **Project closure**.



Tube

Conditioned  
ashes in  
shielded drum

Ingots



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**List of the specifications  
applicable to the elimination  
of short-lived intermediate- &  
low-level waste**

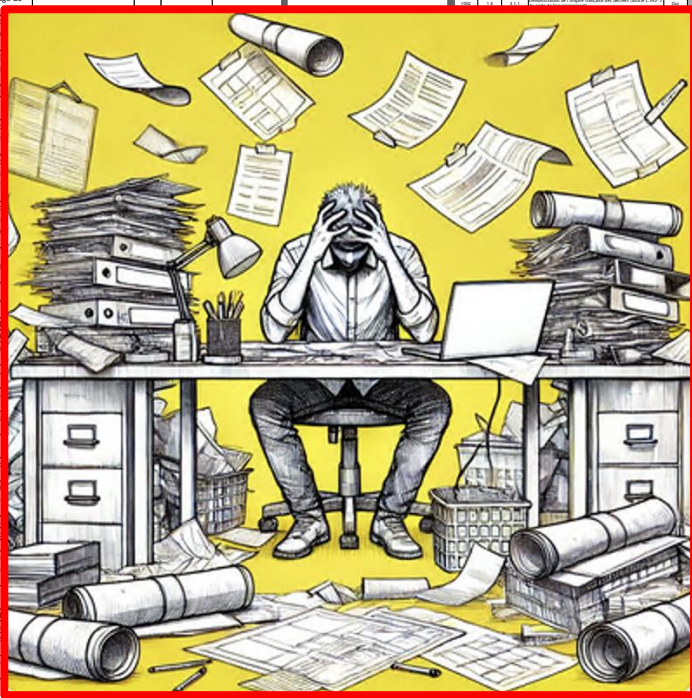
**List of high-level requirements  
extracted from the  
specifications**

**How to eliminate  
radioactive waste ?**

- Within the CERN framework, the knowledge associated with an engineering system is still entirely contained in text documents.
- Engineers use specific graphical notations to produce a set of standardized diagrams supporting the text descriptions.
- Actual drawing packages are used to create these diagrams that form part of the documentation.
- In the case of radioactive waste management, the high-level and hidden requirements approach the “painful” limit of 1000 (Roques & Hetherington 2024).

CAT	Intitulé du document	référence	indice	Révision	consulter
	<b>Spécifications générales</b>				
	Spécifications d'apprêt pour la prise en charge des colis de déchets radioactifs au Centre de stockage de l'Aube	ACO.SP.ASRE.98.084	D	1-janv.-16	<a href="#">EDMS 1332400</a>
	Spécification technique générale d'acceptation des colis de déchets radioactifs au Centre de stockage de l'Aube	ACO.SP.ASRE.99.001	D	29-avr.-13	<a href="#">EDMS 1332408</a>
	Spécification d'évaluation et de déclaration des caractéristiques radioactives - Spécifications d'acceptation des colis de déchets radioactifs au Centre de stockage de l'Aube	ACO.SP.ASRE.99.002	D	29-avr.-13	<a href="#">EDMS 1332409</a>
	Plan guide de rédaction du descriptif d'évaluation l'activité pour les colis FA/MA destinés au Centre de stockage de l'Aube				
	Plan guide de rédaction du descriptif de projet d'acceptation des colis FA/MA destinés au Centre de stockage de l'Aube				
	<b>Spécifications techniques particulières (par type de colis)</b>				
	Spécification d'acceptation des colis contenant des déchets radioactifs scellés hors d'usage				
	Spécification technique d'acceptation des colis de déchets radioactifs conditionnés dans des conteneurs béton durables au Centre de Stockage l'Aube				
	Spécification technique d'acceptation des colis de déchets radioactifs conditionnés dans des conteneurs métalliques à enveloppe interne confinante au Centre de Stockage de l'Aube				
	Spécification technique d'acceptation des colis de déchets radioactifs conditionnés dans des conteneurs métalliques à matrice confinante au Centre de Stockage de l'Aube				
	Spécification technique d'acceptation des déchets radioactifs en fûts métalliques à compacter au Centre de Stockage de l'Aube				
	Spécification technique d'acceptation des déchets radioactifs en caissons à injecter au Centre de Stockage de l'Aube				
	<b>Epreuves techniques</b>				
	<b>ENSELU</b>				
	Évaluation du degré d'homogénéité d'un bloc de déchets homogènes				
	Évaluation de l'homogénéité et de la continuité d'enveloppe				
	Évaluation de la tenue aux cycles gel-dégel de colis de déchets				
	Évaluation du dégagement en tritium et carbone 14 de déchets				
	Détermination de la résistance à la lixiviation d'échantillons de blocs de déchets homogènes				
	Détermination du coefficient de diffusion effectif tritié dans un matériau				
	Évaluation de la tenue à l'irradiation gamma de colis de déchets radioactifs conditionnés dans un matériau de lants hydrauliques				
	Évaluation de la résistance à la chute de colis de déchets radioactifs				
	Évaluation du comportement au feu de colis de déchets radioactifs				
	Évaluation d'eau sous effort de compression				
	Évaluation de la perméabilité aux gaz, de la porosité accessible à l'eau et de la masse volumique de matrice de lants hydrauliques				
	Epreuve technique d'étanchéité de la liaison contre le bouchon				
	<b>EPRELUV</b>				
	Évaluation de la tenue sous charge de colis de déchets radioactifs				
	Caractérisation de la production de gaz par le décimilleu alcalin				
	Évaluation de la stabilité mécanique d'un bloc de déchets radioactifs dans un lant hydraulique alcalin				
	Évaluation du caractère agressif du bloc de déchets homogènes vis-à-vis de l'enveloppe				
	<b>Plans guides (pour la manutention des colis)</b>				
	Plan spécifique pour les coques béton C1, C2, C3 et C4 directement stockables	SAR.80.PG.A.0001	A	31-juil.-00	<a href="#">EDMS 1332452</a>
	Plan spécifique pour les coques béton Fibre CBFK directement stockables	SAR.80.PG.A.0002	C	7-août-15	<a href="#">EDMS 1332454</a>
	Plan spécifique pour les coques béton Fibre CBFCT et CBFCT directement stockables	SAR.80.PG.A.0003	B	1-août-01	<a href="#">EDMS 1332455</a>
	Plan spécifique pour les fûts de 450 litres stockables directement ou indirectement en ouvrage béton	SAR.80.PG.A.0004	A	31-juil.-00	<a href="#">EDMS 1332456</a>
	Plan spécifique pour les fûts de 300 litres à compacter	SAR.80.BG.A.0005	B	10-Fév.-08	<a href="#">EDMS 1332457</a>

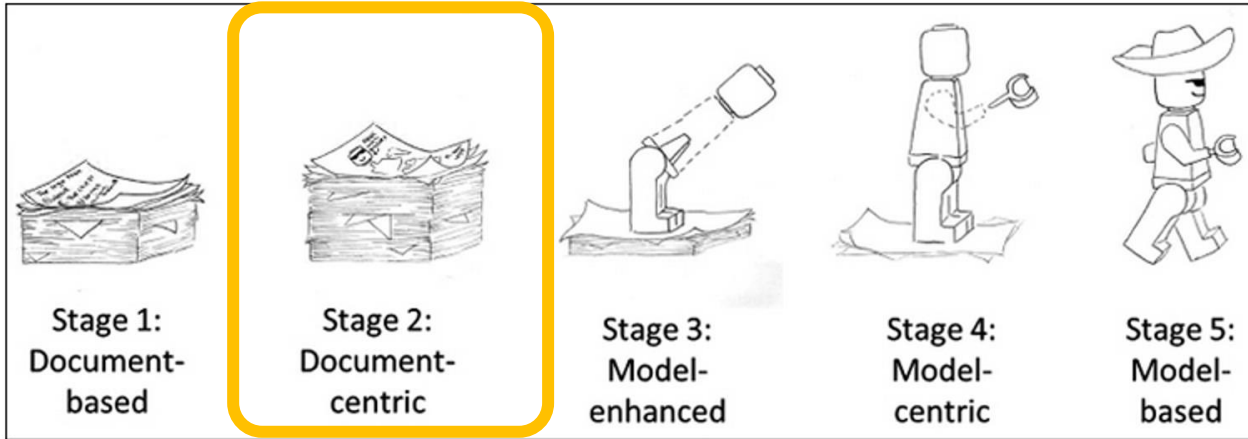
CERTEC		EXIGENCES	EXIGENCES	EXIGENCES	EXIGENCES		
N°	Libellé	Libellé	Libellé	Libellé	Libellé		
1.1	1.1.1	Présence de la colonne d'attente des déchets (colonne A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AM, AN, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AX, AY, AZ, BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BL, BM, BN, BO, BP, BQ, BR, BS, BT, BU, BV, BW, BX, BY, BZ, CA, CB, CC, CD, CE, CF, CG, CH, CI, CJ, CK, CL, CM, CN, CO, CP, CQ, CR, CS, CT, CU, CV, CW, CX, CY, CZ, DA, DB, DC, DD, DE, DF, DG, DH, DI, DJ, DK, DL, DM, DN, DO, DP, DQ, DR, DS, DT, DU, DV, DW, DX, DY, DZ, EA, EB, EC, ED, EE, EF, EG, EH, EI, EJ, EK, EL, EM, EN, EO, EP, EQ, ER, ES, ET, EU, EV, EW, EX, EY, EZ, FA, FB, FC, FD, FE, FF, FG, FH, FI, FJ, FK, FL, FM, FN, FO, FP, FQ, FR, FS, FT, FU, FV, FW, FX, FY, FZ, GA, GB, GC, GD, GE, GF, GG, GH, GI, GJ, GK, GL, GM, GN, GO, GP, GQ, GR, GS, GT, GU, GV, GW, GX, GY, GZ, HA, HB, HC, HD, HE, HF, HG, HH, HI, HJ, HK, HL, HM, HN, HO, HP, HQ, HR, HS, HT, HU, HV, HW, HX, HY, HZ, IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN, IO, IP, IQ, IR, IS, IT, IU, IV, IW, IX, IY, IZ, JA, JB, JC, JD, JE, JF, JG, JH, JI, JJ, JK, JL, JM, JN, JO, JP, JQ, JR, JS, JT, JU, JV, JW, JX, JY, JZ, KA, KB, KC, KD, KE, KF, KG, KH, KI, KJ, KK, KL, KM, KN, KO, KP, KQ, KR, KS, KT, KU, KV, KW, KX, KY, KZ, LA, LB, LC, LD, LE, LF, LG, LH, LI, LJ, LK, LL, LM, LN, LO, LP, LQ, LR, LS, LT, LU, LV, LW, LX, LY, LZ, MA, MB, MC, MD, ME, MF, MG, MH, MI, MJ, MK, ML, MM, MN, MO, MP, MQ, MR, MS, MT, MU, MV, MW, MX, MY, MZ, NA, NB, NC, ND, NE, NF, NG, NH, NI, NJ, NK, NL, NM, NN, NO, NP, NQ, NR, NS, NT, NU, NV, NW, NX, NY, NZ, OA, OB, OC, OD, OE, OF, OG, OH, OI, OJ, OK, OL, OM, ON, OO, OP, OQ, OR, OS, OT, OU, OV, OW, OX, OY, OZ, PA, PB, PC, PD, PE, PF, PG, PH, PI, PJ, PK, PL, PM, PN, PO, PP, PQ, PR, PS, PT, PU, PV, PW, PX, PY, PZ, QA, QB, QC, QD, QE, QF, QG, QH, QI, QJ, QK, QL, QM, QN, QO, QP, QQ, QR, QS, QT, QU, QV, QW, QX, QY, QZ, RA, RB, RC, RD, RE, RF, RG, RH, RI, RJ, RK, RL, RM, RN, RO, RP, RQ, RR, RS, RT, RU, RV, RW, RX, RY, RZ, SA, SB, SC, SD, SE, SF, SG, SH, SI, SJ, SK, SL, SM, SN, SO, SP, SQ, SR, SS, ST, SU, SV, SW, SX, SY, SZ, TA, TB, TC, TD, TE, TF, TG, TH, TI, TJ, TK, TL, TM, TN, TO, TP, TQ, TR, TS, TT, TU, TV, TW, TX, TY, TZ, UA, UB, UC, UD, UE, UF, UG, UH, UI, UJ, UK, UL, UM, UN, UO, UP, UQ, UR, US, UT, UU, UV, UW, UX, UY, UZ, VA, VB, VC, VD, VE, VF, VG, VH, VI, VJ, VK, VL, VM, VN, VO, VP, VQ, VR, VS, VT, VU, VV, VW, VX, VY, VZ, WA, WB, WC, WD, WE, WF, WG, WH, WI, WJ, WK, WL, WM, WN, WO, WP, WQ, WR, WS, WT, WU, WV, WW, WX, WY, WZ, XA, XB, XC, XD, XE, XF, XG, XH, XI, XJ, XK, XL, XM, XN, XO, XP, XQ, XR, XS, XT, XU, XV, XW, XX, XY, XZ, YA, YB, YC, YD, YE, YF, YG, YH, YI, YJ, YK, YL, YM, YN, YO, YP, YQ, YR, YS, YT, YU, YV, YW, YX, YZ, ZA, ZB, ZC, ZD, ZE, ZF, ZG, ZH, ZI, ZJ, ZK, ZL, ZM, ZN, ZO, ZP, ZQ, ZR, ZS, ZT, ZU, ZV, ZW, ZX, ZY, ZZ					



49 specifications...

241 high-level requirements...

# CERN MBSE maturity

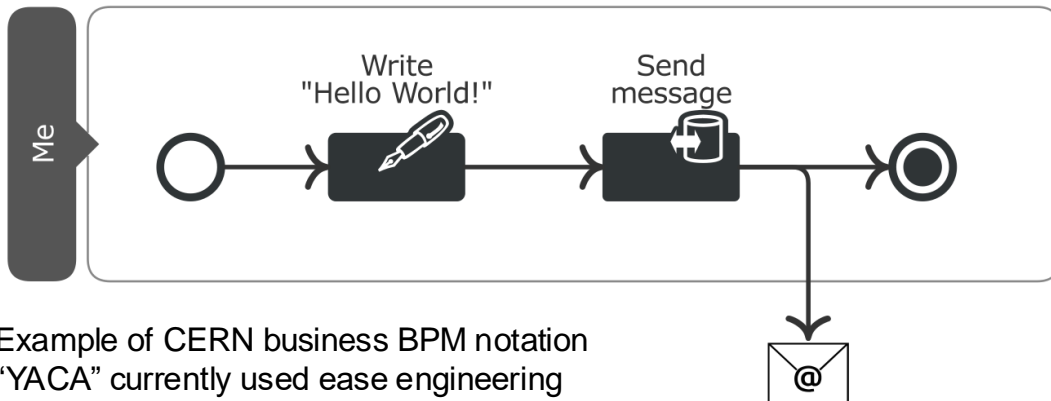


CERN today



Holt, J.D. & Perry, S.A. (2020) *Implementing MBSE – the Trinity Approach*. INCOSE UK Publishing, Ilminster, UK

- CERN has built and manages some of the most complex engineering systems.
- The knowledge associated with these engineering systems is still entirely contained in text documents.
- Since 2015 CERN uses a specific **business process modeling (BPM)** notation to produce a set of standardized diagrams supporting the text descriptions:
  - ➔ YACA (“Yet Another Charting Approach”)
- Drawing packages are used to create these diagrams that form part of the documentation.
  - ➔ Draw.IO



Example of CERN business BPM notation “YACA” currently used ease engineering documentation



Date : 202X-XX-XX

PROJECT MANAGEMENT DOCUMENT

**PROCESS MAST**  
(Melting of Activated STEel)

**Functional specification**

ABSTRACT:

Lorem ipsum dolor sit amet. Est quod omnis aut corporis saepe et recusandae Quis aut voluptatem consectetur ut tempora quidem et numquam aperiam, Et dolores aspernatur et pariatur consectetur aut eligendi molestias non tempore inventore et expedita accusantium.

DOCUMENT PREPARED BY:

...

DOCUMENT CHECKED BY:

...

DOCUMENT APPROVED BY:

...

DISTRIBUTION :

CERN internal distribution.

# Process specification

## Current practices and limitations

**Text documents are today the main vector to gather technical information** and convey it to the approval/validation bodies and to the development teams.

### Text documents have limitations:

- Complex consistency checks across the document(s);
- Loss of consistency as the specification evolves;
- Fuzzy separation between stakeholders' expectations, requirements, choices of implementation.

### Consequences:

- Time-consuming validation;
- Difficulty to assess and control change requests;
- Poor control of versioning;
- Definition of suppliers' delivery is weak and not sufficient (addendum to contracts / rework).

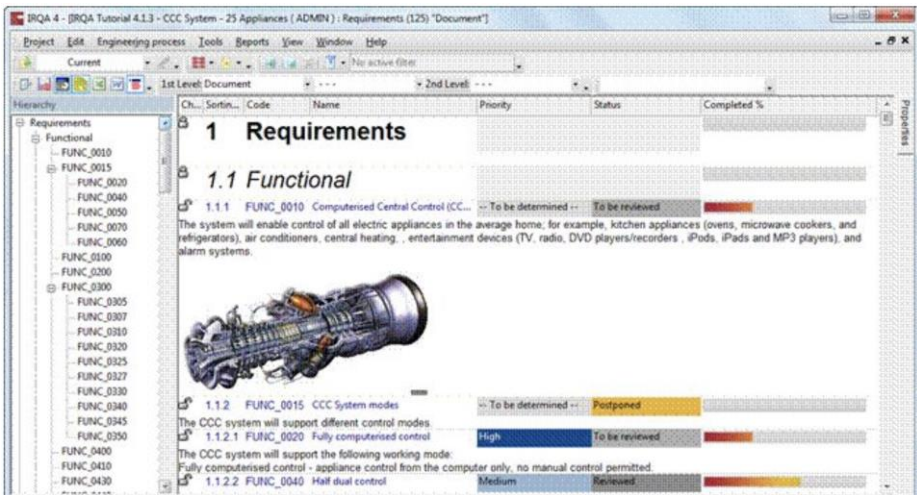
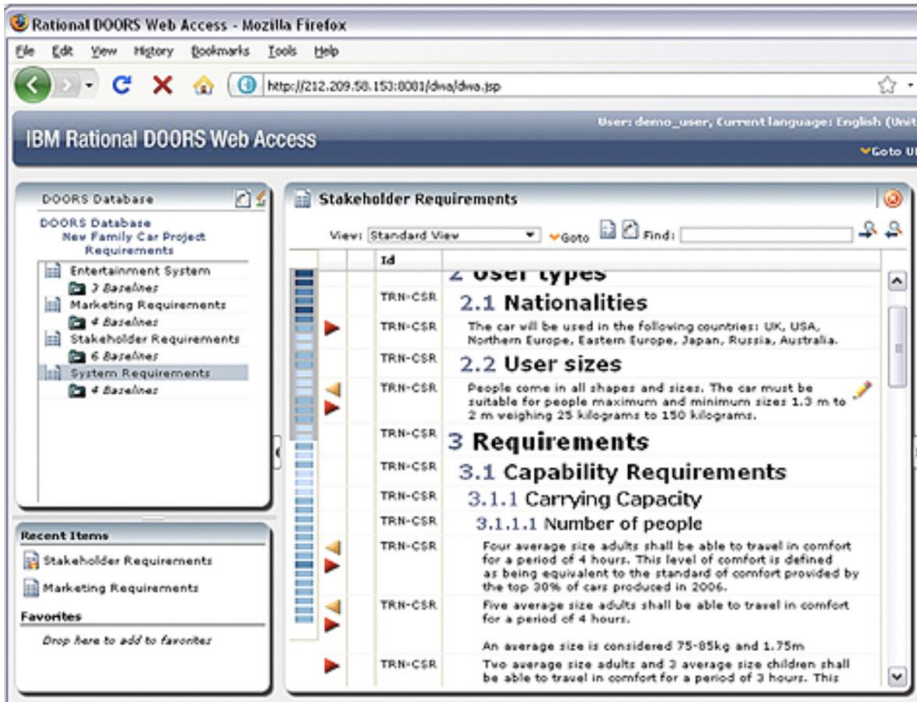
*Engineers have tried to pinpoint the cause of the limitations...*



# Process specification Limitation 1

## HUMAN MIND

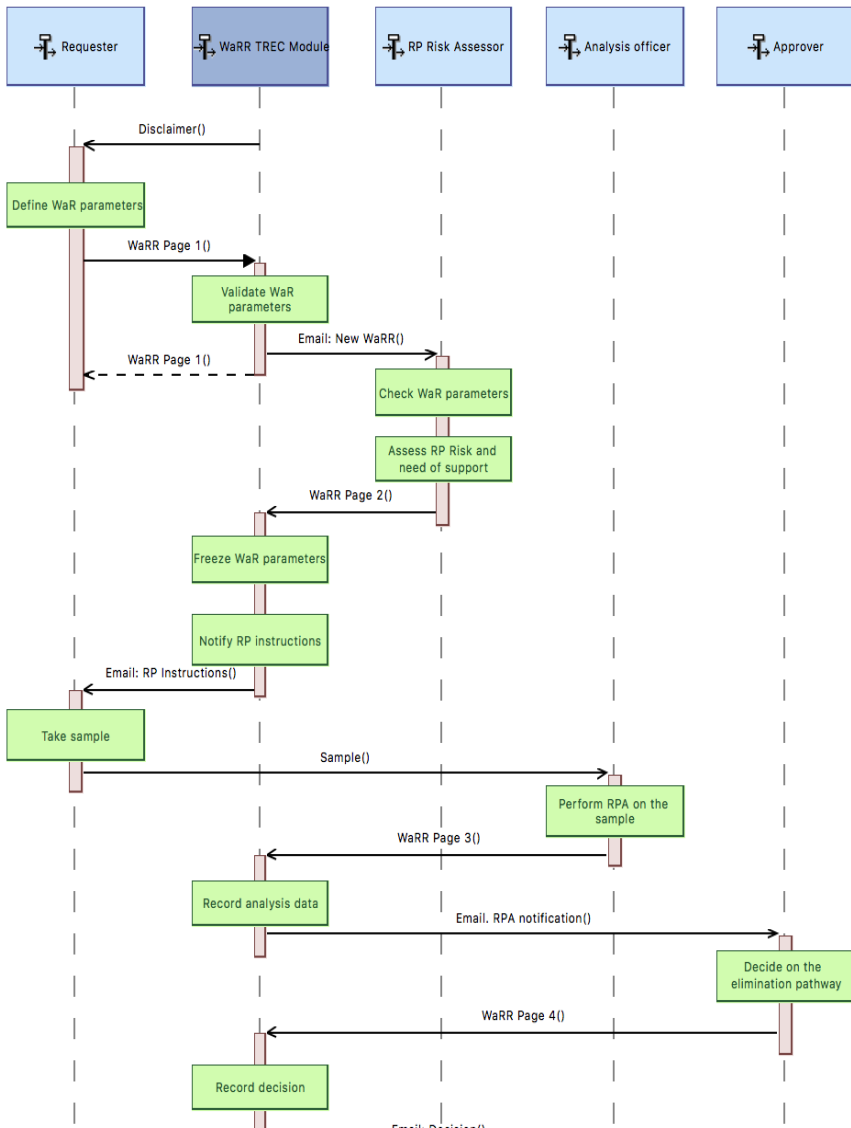
- **Cause:** beyond a given limit, human mind alone is unable to master complex information.
- **Approach:** break down the specification into elementary sentences and thoroughly manage *each one* of them (“requirements engineering” approach).  
Ideally, we should tell which requirements are fulfilled by which part of our system and how to test them. A link should show which test covers which requirement.
- **Solution:** use specific software tools to collect, link, share the sentences and manage their lifecycle.  
Examples: “IBM® Rational® DOORS®”, “ProR®”, “Innoslate®”.



# Process specification Limitation 2

## LANGUAGE

- **Cause:** Natural language is inadequate to clearly specify an engineering system.
- **Approach:** use ad hoc artificial notations.
- **Solution:** use a graphical language to capture and communicate engineering requirements.  
Examples: “Universal Modeling Language” (UML), “System Modeling Language” (SysML), “Architecture Analysis Design Language” (AADL).



# Process specification

## Limitation 3

### Operational Analysis

#### Define Stakeholder Needs and Environment

Capture and consolidate operational needs from stakeholders  
Define what the users of the system have to accomplish  
Identify entities, actors, roles, activities, concepts

### System Analysis

#### Formalize System Requirements

Identify the boundary of the system, consolidate requirements  
Define what the system has to accomplish for the users  
Model functional dataflows and dynamic behaviour

### Logical Architecture

#### Develop System Logical Architecture

See the system as a white box  
Define how the system will work so as to fulfill expectations  
Perform a first trade-off analysis

### Physical Architecture

#### Develop System Physical Architecture

How the system will be developed and built  
Software vs. hardware allocation, specification of interfaces,  
deployment configurations, trade-off analysis

### EPBS

#### Formalize Component Requirements

Manage industrial criteria and integration strategy; what is expected from each designer/sub-contractor  
Specify requirements and interfaces of all configuration items

“Activity explorer” of Capella

## METHOD

- **Cause:** A specification must describe both the problem that the designed system solves (the need), and the designed system itself (the solution). Unless a rigorous method is followed, these aspects are often muddled up.
- **Approach:** Separate the aspects of the specification to manage a system's complexity; tackle progressively operational, system, logical and physical aspects.
- **Solution:** develop a design method.  
Examples: ARCADIA (ARChitecture, Analysis and Design Integrated Approach).  
Theory textbook : ISBN 978-1-78405-413-7  
Software textbook : ISBN 978-1-78548-168-0  
ISBN 978-1-937468-14-9



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# Too Busy for Improvements?



## Remarks

### Difficulty

Take the initiative, with limited or no assistance of others, in diagnosing the needs, formulating goals, identifying human and material resources, and evaluating outcomes

### Challenges

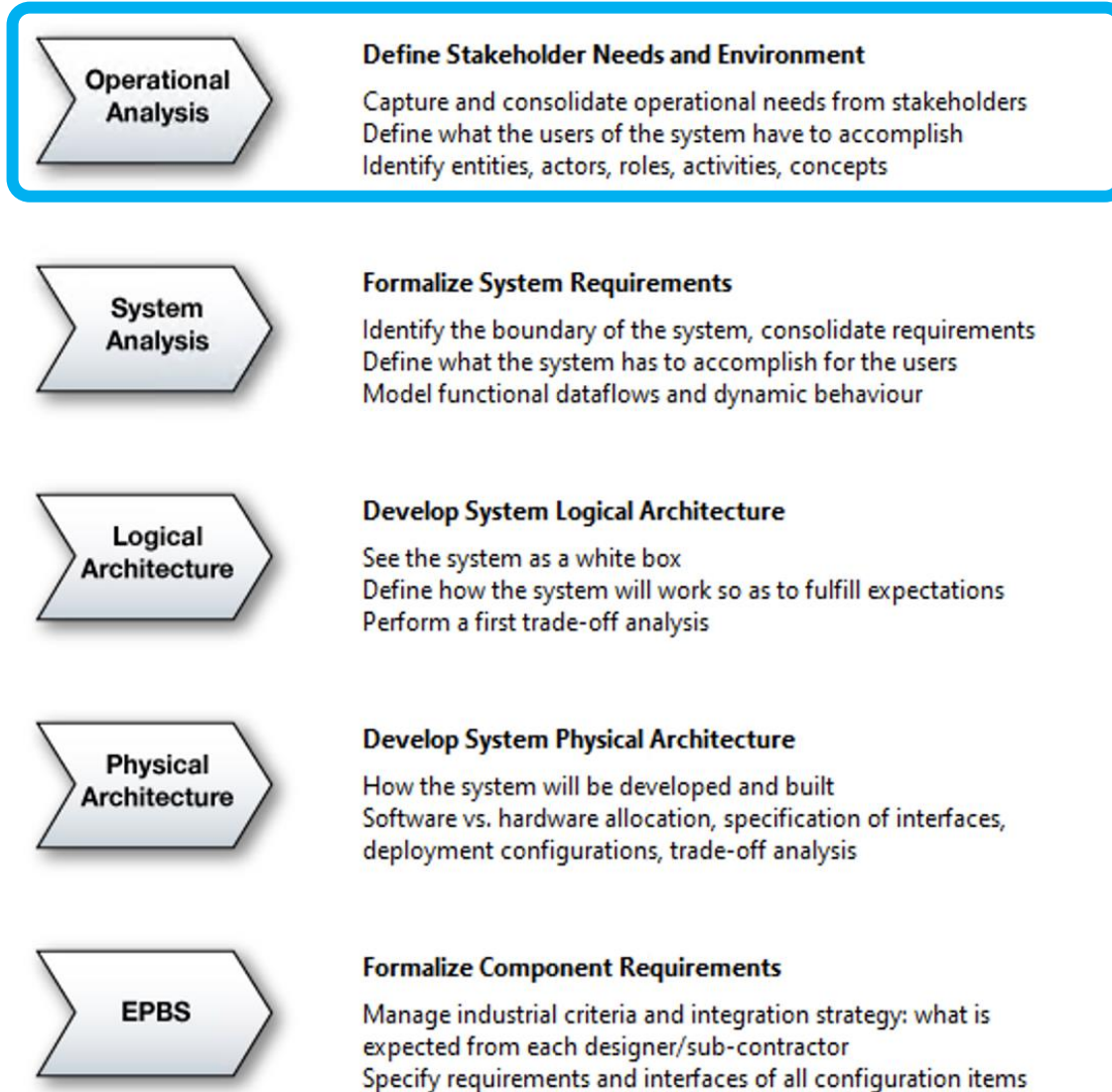
- Barriers: Financial (software cost).
- Personal: Learn a new language, method, software.
- Team: Introduce these tools to the colleagues.

### Selected approach

- Barriers: Open-source software → **Capella**
- Personal: Self learning and training/coaching → **ARCADIA**
- Team: Identify a use case → Development of a new
  - **RW elimination pathway by melting**
  - **Application to all other pathways**
  - **Feedback from external stakeholders**

# Selected approach

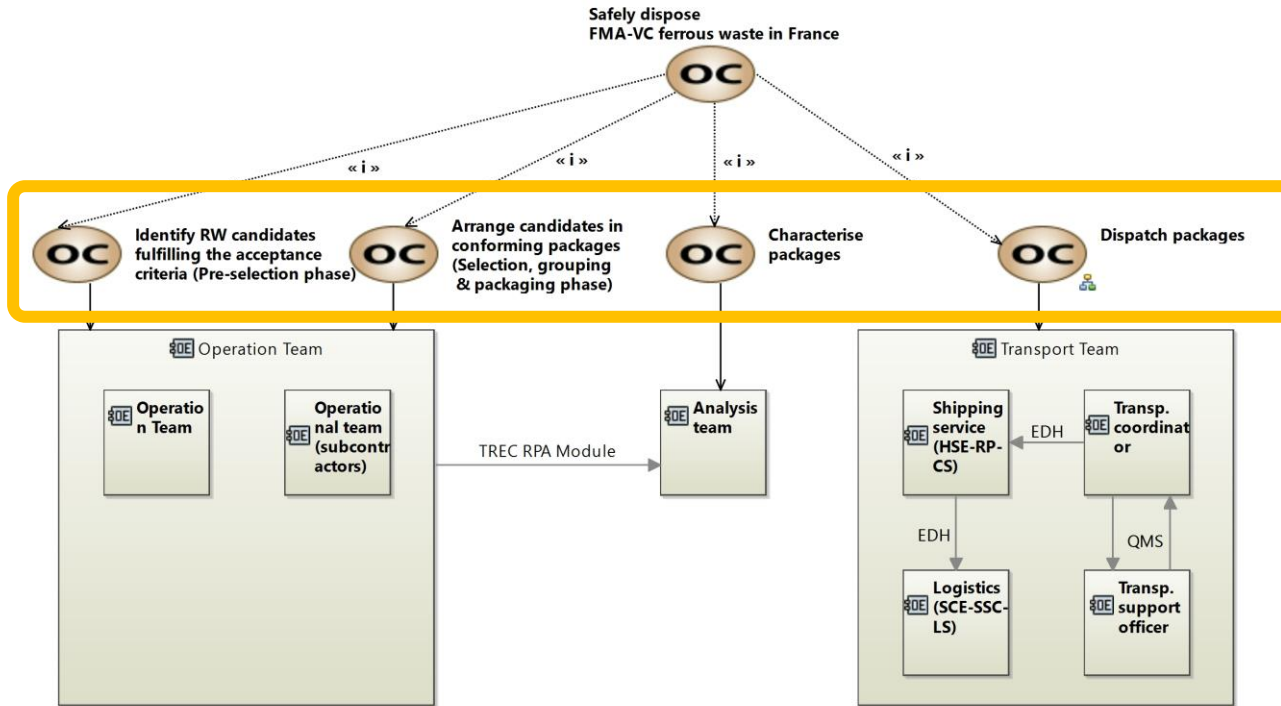
## A “tiny bit” of ARCADIA & Capella



- **“Waste” is not a product.** It is the end-of-life stage of any equipment.
- **“Waste management” is not a system.** It is a (complex) operational process.
- **ARCADIA and Capella seemed unsuitable** to develop the melting process, as they seemed to support the step-wise development only of equipment and systems.
- **However, the operational analysis has similarities with YACA**, the business process modeling in use at CERN, with the advantage that it is more rich and, in addition to a syntax, it has a semantics.
- Although only this “tiny bit” seemed applicable, **an attempt was made** to conceive and document the process by ARCADIA and Capella.



# A simple model



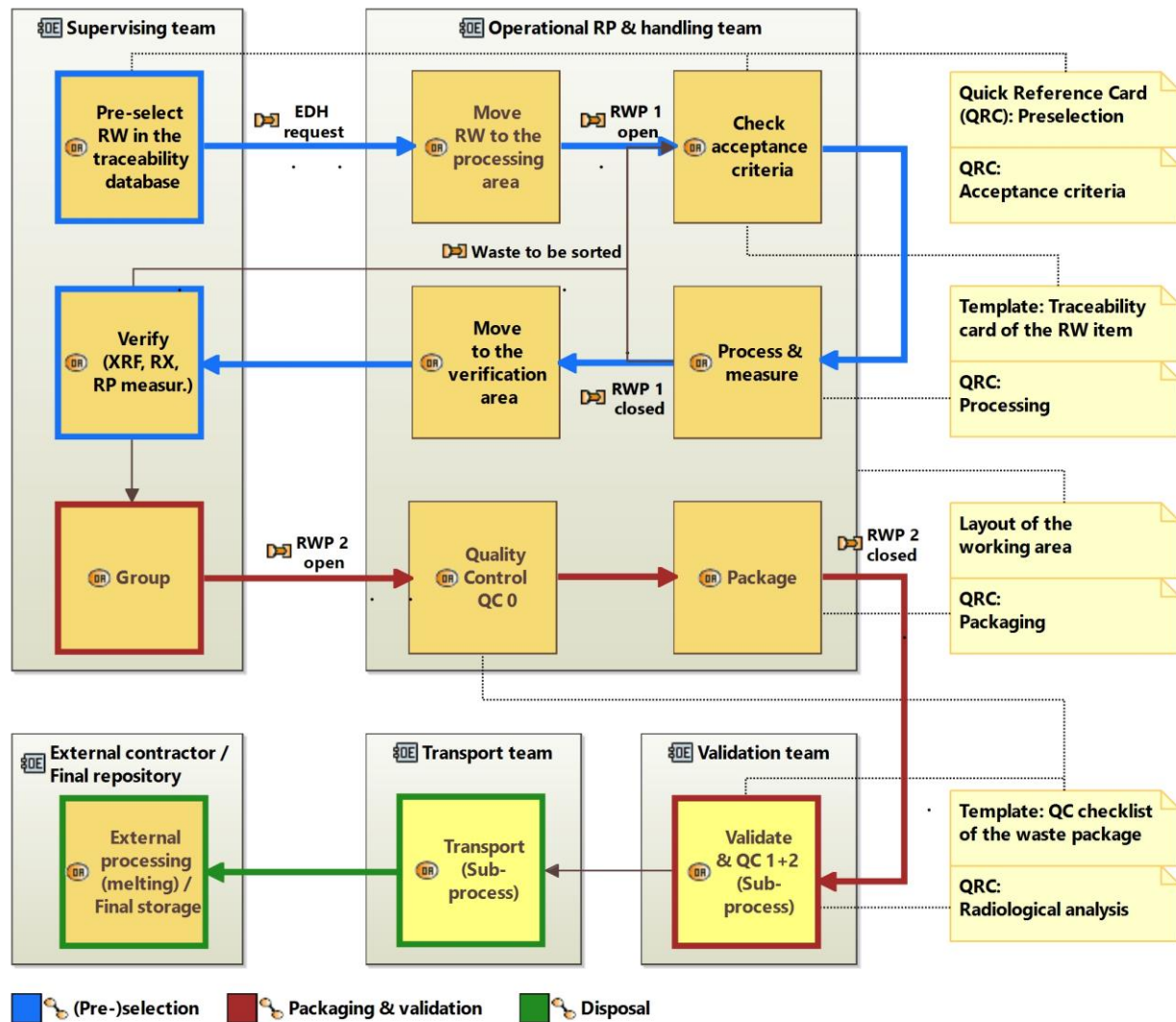
**Capabilities diagram of the waste process.**

(EDH: CERN Electronic Document Handling system;  
TREC: Traceability system of Radioactive Equipment at CERN)

- **The model was developed “by the book”** defining the goal and scope of the process by a capabilities diagram in Capella 5.1 (later upgraded to v.6.1).
- **It encompasses only the operational analysis**, including one main process and two sub-processes, totaling 69 activities.
- **Access to the model is provided by 11 diagrams**: 1+2 (simplified) architecture diagrams, 1+2 capabilities diagrams, 4 entity scenarios, and 1 state machine diagram.
- **Additional diagrams**, such as activity interaction diagrams and detailed operational architectures, were used during the model construction.
- **System analysis** and **logical architecture** steps were conducted to model the CERN quality management system. However, these steps **ultimately proved unnecessary** for demonstrating compliance with the Authorities’ requirements.

# The result

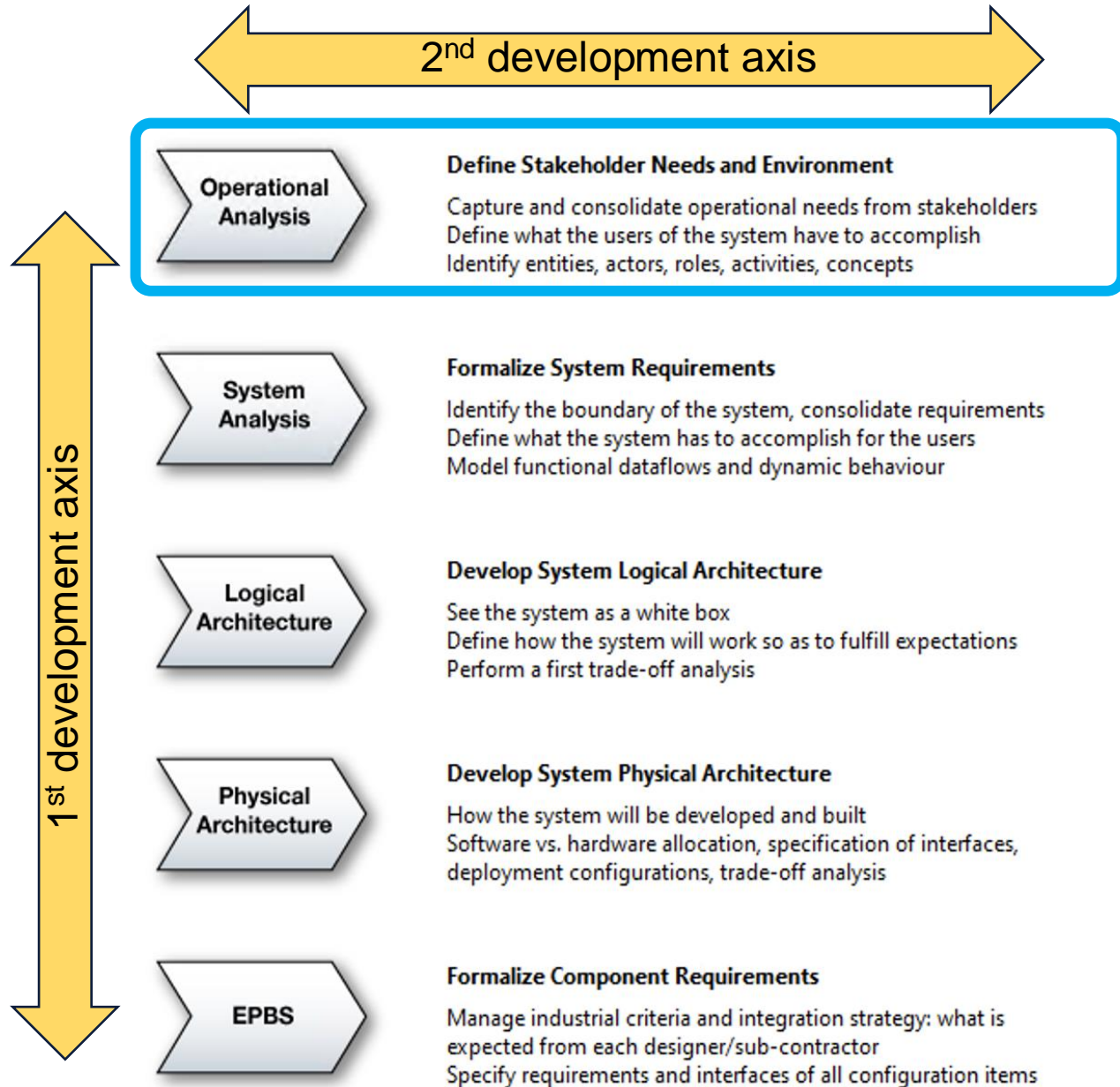
## A gain of six months



### Operational architecture of the waste process.

(EDH: CERN Electronic Document Handling system; QC: Quality Control; RWP: electronic RW Processing request; QRC: Quick reference Cards)

- Capella provided a comprehensive set of diagrams **that addressed all design needs**.
- Beyond the model and the low-level operational documents therein referenced, **no additional documentation was needed** for designing, auditing, and implementing the process.
- The diagrams served as a clear basis for discussion. Differences in the **educational backgrounds** of technicians, engineers or physicists **played little or no role at all**.
- **Communicating with the auditors** was so **effective** that the process was approved the very same day of the audit.
- **The model was re-used** for the elimination of non-meltable radioactive waste. The development took ~12 months instead of 18. **About 6 months of work were saved...**



# Interpretation

## Why a gain of six months?

- **A picture is worth a thousand words:** the diagrams were extremely effective in conveying the information.
- **A 2<sup>nd</sup> development axis seems to exist:** the traditional text-based approach progresses “horizontally”, with documents addressed to the different stakeholders (physicists, engineers, technicians...). The model’s information is thus repeated and adapted for the reader.
- **The process was developed in one go** thanks to Capella, which streamlined information sharing and avoided repetition.
- **The semantics facilitated the impact analysis** of the changes requested by the stakeholders.
- **The stakeholders’ attention shifted** from the text documents to the process itself.





Date: { DATE \@ "yyyy-MM-dd" }

TECHNICAL NOTE

**{M:SELF.NAME.ASBOOKMARK(SELF.ID)}**  
{m:self.summary}

**Processing Plan**

ABSTRACT:

{m:self.description.fromHTMLBodyString()}

DOCUMENT PREPARED BY:  
L.BRUNO [HSE-RP]

DOCUMENT CHECKED BY:  
R.CHAROUSSET [HSE-RP]  
N.MENAA [HSE-RP]

DOCUMENT APPROVED BY:  
G.DUMONT [HSE-RP]

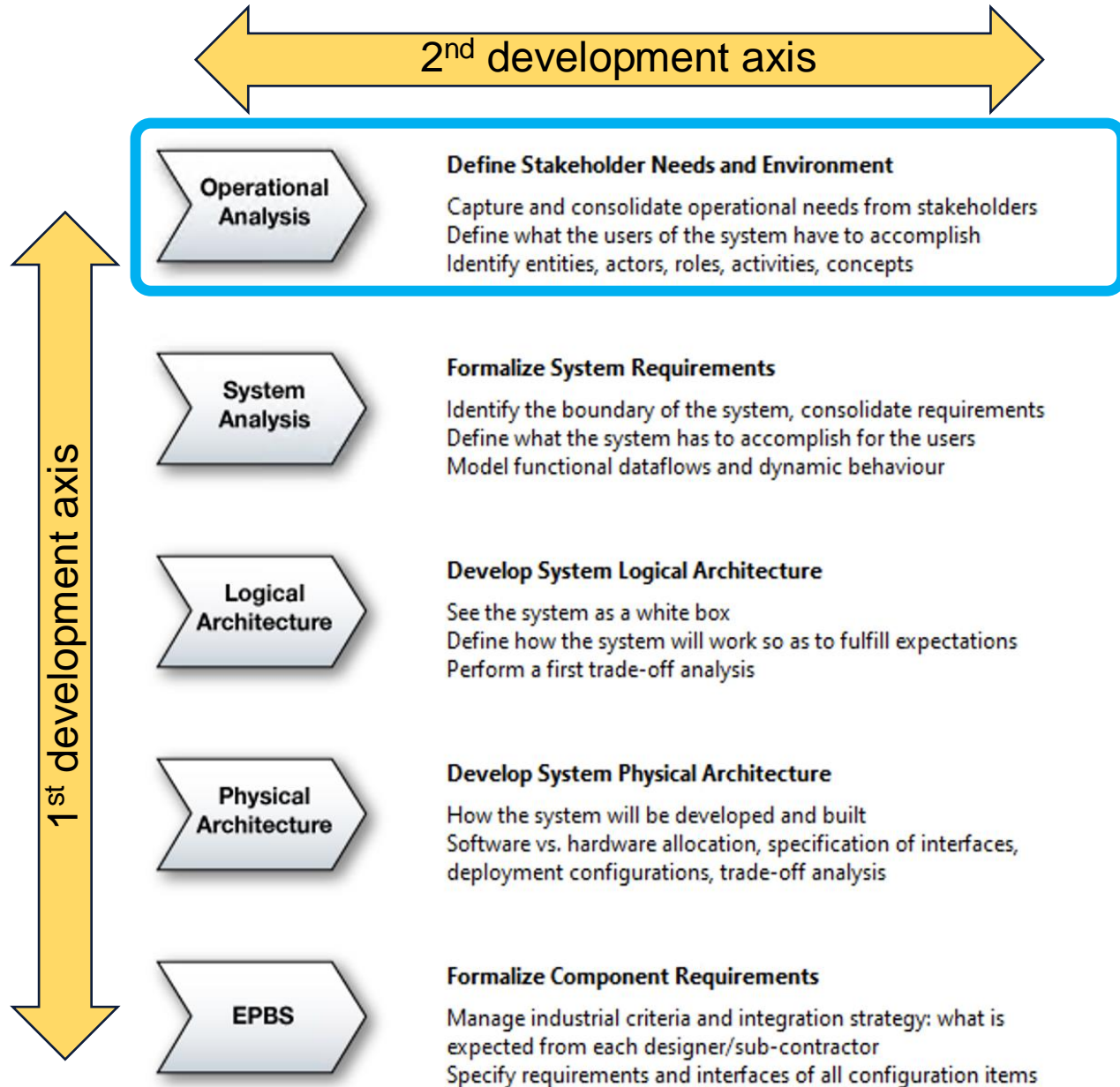
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*This document is automatically generated by Capella®, a Model-Based System Engineering tool [1].*

# The text documents

## A special “viewpoint”: M2Doc

- “**Text documents do not own any of the knowledge specific to the model** and, in fact, should be perceived as just another set of Views that make up the Model, albeit text-based Views” (J.Holt & T.Weilkiens, *Systems Engineering Demystified* 2<sup>nd</sup> ed.).
- Actually, only a set of contextual information common to all CERN RW elimination pathways is given in the template.
- **Indispensable** to interact with stakeholders that are not familiar with the MBSE approach or the Capella tool.
- The **text documentation boils down ~10 pages** containing diagrams and tables, possibly with the low-level “Quick Reference Cards” (QRC) as annexes.
- The Authorities accept referencing documents in the QRCs without version number. This gives **flexibility to disclose information** and avoids freezing the operational documentation in the context of a formal approval.



## Some final remarks...

- **The model was extended to all other elimination processes**, unifying and consolidating roles and operational activities.
- **The extended model was adopted**: its views are now the standard process reference.
- **Capella has not (yet) been adopted** by the team. Despite a user-friendly software and objective results, it is not straightforward for newcomers to “go from start to the finish line”.
- **The French auditing authority was surprised** by the fast results obtained, as they were unfamiliar with the approach.
- **Life Cycle Analysis could benefit from** a suitable implementation of **the “2<sup>nd</sup> axis”**: a “gate-to-gate” approach would then be possible, integrating information otherwise dispersed across the organisation.



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# Conclusions

- The **ARCADIA method** was used to conceive and specify efficiently a process for the elimination by melting of CERN ferrous low-level/intermediate-level metallic radioactive waste.
- **Capella** was instrumental in the transition from the traditional approach in use at CERN to the new MBSE mindset.
- **M2Doc** was indispensable to interact with stakeholders that are not familiar with the MBSE approach or the Capella tool, producing very concise text documentation.
- The method and tool ensured the **quality** requested by the French auditing authority to meet the acceptance criteria set by the foundry and the final radioactive waste repository.
- The model gave **insight** on all other elimination processes, unifying and consolidating roles and operational activities.
- The approach could have **potential benefits** in other domains, such as streamlining environmental life-cycle assessment.



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Thank you  
for  
your attention