



# CONSIDERATIONS ON STANDARDISED DECOMMISSIONING COSTING



DECONTA, a.s.



The presentation include the review of experience with implementation of the cost structure as presented in the document **"A Proposed Standardised List of Items for Costing Purposes"** issued by OECD/NEA, IAEA and EC in 1999, further referred as "PSL" or "PSL structure".

Implementation of the PSL structure was performed in the company DECOM, a.s. in the frame of development and upgrading of the decommissioning computer code "OMEGA" (1999-2004).

The executive calculation structure of the code OMEGA fully implements the PSL structure. Management of waste from decommissioning is an integral part of the calculation structure. The code implements also the decay of radioactivity in the calculation process and impact of this on decommissioning parameters.

The code includes the system for optimisation of evaluated decommissioning options with application of the standard planning software MS Project.



- Decommissioning of nuclear facilities is in general a complex and expensive process of technical and non-technical activities covering the time scale of tens of years. Estimating of parameters of decommissioning is one of the main issues in preparatory phases of decommissioning.
- The main aim of these activities is to prepare files of qualified data like costs, exposure, manpower, personnel / equipment needed, amounts of waste, time schedules, time graphs etc. Based on this qualified data, the decommissioning process can be planned to be accomplished.
  - **safely** - with minimal actual and future influence on personnel/environment
  - **economically** - according to costs / resources optimized decommissioning option
  - **in due time** - according to optimised decommissioning time schedule
- The **decommissioning costs** should be known already in early stages before starting decommissioning and in the case of new nuclear facilities at the commissioning stage.
- The accuracy of costs estimates should be as best as possible **in total, in its fine structure and in time structure** in order to raise-up the relevant decommissioning fund.



- **Current costing methodologies were developed based on experience from decommissioning of nuclear facilities with standard shutdown properties. The methodologies could then be used for cost estimates for similar facilities.**
- **The unit factors, calculations formulas and other elements of cost methodologies could be applied after comparison of facilities and relevant corrections for the differences in size, inventory, local factors and other aspects. The quality of results depends on proper adjustment of the methodology for facility conditions.**
- **One of the general aspects of these traditional methodologies is the fact that the cost structures are in general different for various projects. The cost structure of the projects are then less comparable and also less transparent.**
- **When applying the above discussed cost estimating methodologies for a nuclear installation with is not typical or different from similar standard nuclear installation for example in radiological situation (accident during operation), the errors in final costs can arise.**



Decommissioning costs estimation methods, identified in major decommissioning projects are based on cost unit factors approach with following main steps [1]:

#### 1) Definition of Cost Categories

- Activity-dependent costs, related to the extent of “hands-on” work like dismantling
- Period-dependent costs, proportional to duration of individual activities/phases
- Collateral costs and costs for special items which can neither be assigned to hands-on work activity nor to period-dependent activity

#### 2) Identification of Decommissioning Activities and Inventories

- Identification of discrete elementary activities for which unit factors are defined
- Completion of the list of activities with a plant buildings/equipment inventory in order to define the overall extent of activities.

#### 3) Definition of Unit Factors

- Unit factors are defined in accordance to the details of the items considered in the plant inventory and in the decommissioning activities listing
- Unit factors are defined for ideal working conditions and correction factors are defined that reflect the specific working conditions (radiation, working height, etc.)

[1] L. Teunckens, Generalities about Costing, Thematic Network on Decommissioning, Document No. EC/TND/(2002)09, Sept 2002



#### 4) Project Scheduling and Staff Requirements

- Project time schedule construction based on calculated duration of individual hands-on work phases and based on the plant inventory data.
- Identification of critical path for decommissioning activities.
- Calculated duration of decommissioning activities / phases are used as a basis for definition of duration of period-dependent activities for which the staff is defined.

#### 5) Collateral Costs and Costs for Special Items

- Definition of collateral costs and costs for special items, like cost for heavy equipment for site support, health physics equipment and supplies, licenses and permits, costs for lighting, heating, cooling, income from sold equipment or scrap, etc.

#### 6) Total costs definition

- Total costs estimate are obtained as a sum of the costs three categories: activity-dependent costs, period-dependent costs, collateral costs
- The cost estimates may be adjusted to include a contingency that reflects the level of uncertainty in the estimates.
- A separate contingency expressed in some special cost items may be applied to the total cost estimate for the processes with high uncertainty.



**Based on experience and general trends in decommissioning costing, the traditional costing methodologies were enhanced at DECOM to an standardised generic decommissioning costing methodology with following main issues:**

#### **1) Standardisation**

Full implementation of standardised cost structure for decommissioning

#### **2) Algorithmization of material and radiological aspects of decommissioning**

Linking of calculation process for modelling the material and radioactivity flow in decommissioning based on real decommissioning infrastructure for enabling the on-line optimisation of the decommissioning activities and waste management processes.

#### **3) On-line optimisation and multi-option work**

Definition, calculation and evaluation of a set calculation options which cover all decommissioning scenarios considered

#### **4) Sensitivity analysis for decommissioning**

Supporting methodology for revealing the possible margins and trends of costs and other decommissioning parameters by varying selected input parameters like contamination, nuclide composition, start dates, etc.



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- **OECD/NEA, IAEA and EU issued in 1999 the document “A Proposed Standardised List of Costs Items for Decommissioning Purposes” (PSL), which defines the structure of decommissioning activities for which the costs are to be presented.**
  
- **The reason for issuing the document were inconsistencies in presented costs of various decommissioning projects caused by different extent of activities, technical / local / financial factors, waste management systems, etc. The main purpose of the document is:**
  - **To facilitate communication**
  - **To promote uniformity**
  - **To encourage common usage**
  - **To avoid inconsistency or contradiction of results of costs evaluations**
  - **To be of world wide interests to all decommissioners**
  
- **The principles of standardised list of decommissioning cost items were fully implemented into the costing methodology of DECOM, a.s.**
  
- **Standardisation of other aspects like fine costs structure, structure of inventory data, etc. are under consideration for extended standardisation**



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- Character and level of radioactivity can have in general an essential influence on choice of decommissioning activities (manual/remote, etc.), on amount of waste and its processing, on demand of volume in repositories, etc. and finally on decommissioning costs, exposure, manpower and other decommissioning parameters.
- These impacts are especially important in the case of a facility with non-standard radiological situation, for example after an accident
- Material and radiological aspects in developed standardised decommissioning costing refer to following issues:
  - **Algorithmization of the entire material flow in decommissioning by calculation modeling in order to on-line optimise the decommissioning and waste management**
  - **Algorithmization of radiological aspects in order to manage the flow of radioactivity linked to the material flow and to manage the effect of time in decommissioning (to implement the impacts of radioactive decay)**
- These principles enable to increase the accuracy of calculation of decommissioning parameters related to material flow in decommissioning, to optimise the waste management and to perform the sensitivity analysis



- **On-line optimization** represents the work with the Gantt chart of the decommissioning option in the standard MS Project software. The Gantt chart is generated automatically based on the decommissioning work breakdown structure defined in OMEGA code by grouping the items of the calculation structure. Parallel projects can be **co-optimised** using the joint Gantt chart of the projects involved.
- The **on-line data link** between the standardised calculation structure and the Gantt chart in MS Project enables the recalculation of decommissioning parameters with optimised starting dates of individual decommissioning activities (to include the effect of radioactivity decay)
- The developed advanced costing methodology has **multiple options** character, it means that a set of decommissioning options is defined for a decommissioning project in order to evaluate all possible scenarios of decommissioning in the frame of the project.
- Each decommissioning option is calculated, optimised and evaluated individually and the option optimal for the project is selected based on **multi-attribute analysis**.



Additional aspects of the advanced costing methodology due to internal linking of the calculation process is the possibility to perform the sensitivity analysis which can reveal the hypothetical **margins and trends of decommissioning costs** and other decommissioning parameters by varying for example the levels of contamination, nuclide composition (effects of alphas), by application of various decommissioning technologies or by varying the durations of deferred decommissioning phases, etc.

Complex graphs, tables, time scans of selected decommissioning parameters , etc., can be developed for supporting the decision making processes



The computer code Omega [2] is the generic tool for applications in decommissioning decision making processes for nuclear facilities of various types and radiological properties with following purposes and for development of data for decommissioning planning:

- Definition of the **set of decommissioning calculation options** for facilities with various building and technology inventory structure and with various radiological parameters
- **Calculation** of standardised costs and other parameters of decommissioning for individual calculation options, for processing and evaluation of calculated data
- **Optimisation** of individual calculation options and waste management within the individual options
- Comparison of decommissioning options and selection of the most suitable one based on **multi-attribute analysis**
- Optimisation of **parallel decommissioning projects** which use common equipment or other resources

[2] V. Daniška et.al., Decommissioning Cost Calculation Code Based on Proposed Standardised List of Items For Costing Purposes with Integrated Material and Radioactivity Flow Control and Integrated Costs Allocating System, The 9th International Conference on Radioactive Waste Management and Environmental Remediation, September 21 – 25, 2003, Oxford,



**Basic properties of the calculation code OMEGA for applications on the level of the calculation options:**

- **Activity based costing** was implemented based on the Proposed Standardised List of Costs Items (PSL) which enables to use the code for various types of nuclear facilities
- **Automatic generation** of the standardised calculation structure based on template calculation structures, conditions defined by the user and based on inventory data. Structures with approx. 60 000 items were generated and used.
- A new concept of calculation modelling of **material and radioactivity flow control** in the entire decommissioning process was implemented in order to increase the accuracy of calculation and for optimisation of RW management (**the code was developed for A1 costing with complicated radiological situation**).
- The calculation process is **nuclide-resolved**. This enables the use of limits on the nuclide level for treatment / conditioning / disposal / release of materials and to study the effect of time in decommissioning (options with deferred dismantling)
- **On-line optimisation** of decommissioning options in a **standard planning software** using the work breakdown structure, constructed as the upper layer over the standardised calculation structure



For achieving the above discussed properties, following principles of algorithmisation of costs calculation in Omega are applied:

**1) What to do -**

management of the standardised calculation structure. Definition of decommissioning activities and extent of calculation



**2) How to do -**

management of calculation conditions. Definition of calculation procedures, definition of local calculation input data and correction factors



Standard methodologies

Advanced methodology

**3) In what sequence -**

management of material / radioactivity flow in decommissioning by definition of calculation sequence and by data linking of calculation procedures (calculation modelling of decommissioning process)



**4) At what time -**

management of time in decommissioning by on-line optimisation of decommissioning time schedule with feed-back to the calculation structure supported by dynamical recovery of radiological parameters



#### 1) **What to do:** Definition of decommissioning activities/extent of option

**The tools for implementation of the Proposed Standardised List of Costs Items (PSL) were developed in following levels:**

- **The standardised PSL structure**
  - ↓  
Categorised up to the third numbered level
  - List of decommissioning activities defined for the lowest level
- **Omega template PSL structures**
  - ↓  
Extended PSL structure with lower numbered levels were developed for decommissioning activities and for waste management
- **Option specific PSL calculation structure**
  - ↓  
User defined specific PSL structure based on a selected template structure.
  - At lowest levels, where applicable, modes for automatic generating of lower calculation levels are defined, e.g. object - floor - room - equipment structure
- **Executive PSL calculation structure (dynamic PSL structure)**
  - Generated based on static PSL structure and facility inventory data with general structure: building objects - floor - room - inventory item
  - Extent of calculation is defined by the user by switching decommissioning activities in generated dynamic PSL structure



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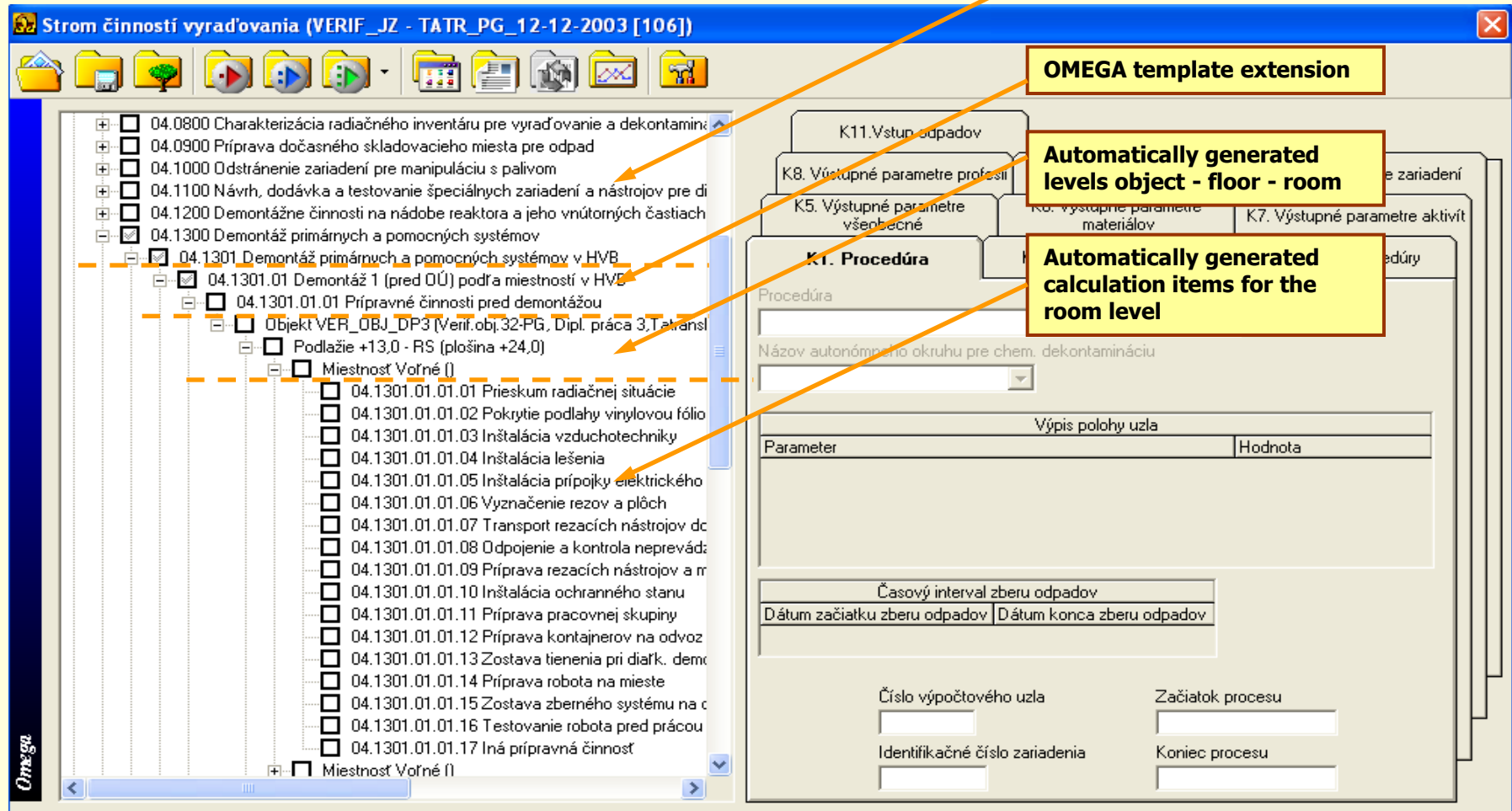
### Example of a standardised cost calculation structure

**Transformed PSL definition**

**OMEGA template extension**

**Automatically generated levels object - floor - room**

**Automatically generated calculation items for the room level**



**Strom činností vyradovania (VERIF\_JZ - TATR\_PG\_12-12-2003 [106])**

- 04.0800 Charakterizácia radiáčného inventáru pre vyradovanie a dekontamináciu
- 04.0900 Príprava dočasného skladovacieho miesta pre odpad
- 04.1000 Odstránenie zariadení pre manipuláciu s palivom
- 04.1100 Návrh, dodávka a testovanie špeciálnych zariadení a nástrojov pre di...
- 04.1200 Demontážne činnosti na nádobe reaktora a jeho vnútorných častiach
- 04.1300 Demontáž primárných a pomocných systémov
- 04.1301 Demontáž primárných a pomocných systémov v HVB
  - 04.1301.01 Demontáž 1 (pred OÚ) podľa miestností v HVB
    - 04.1301.01.01 Prípravné činnosti pred demontážou
      - Objekt VER\_OBJ\_DP3 [Venf.obj.32-PG, Dipl. práca 3, Tatránst...
      - Podlažie +13,0 - RS (plošina +24,0)
        - Miestnosť Voľné ()
          - 04.1301.01.01.01 Prieskum radiáčnej situácie
          - 04.1301.01.01.02 Pokrytie podlahy vinylovou fóliou
          - 04.1301.01.01.03 Inštalácia vzduchotechniky
          - 04.1301.01.01.04 Inštalácia lešenia
          - 04.1301.01.01.05 Inštalácia prípojky elektrického
          - 04.1301.01.01.06 Vyznačenie rezov a plôch
          - 04.1301.01.01.07 Transport rezacích nástrojov dc
          - 04.1301.01.01.08 Odpojenie a kontrola neprevádz...
          - 04.1301.01.01.09 Príprava rezacích nástrojov a r...
          - 04.1301.01.01.10 Inštalácia ochranného stanu
          - 04.1301.01.01.11 Príprava pracovnej skupiny
          - 04.1301.01.01.12 Príprava kontajnerov na odvoz
          - 04.1301.01.01.13 Zostava tienenia pri diaľk. demc...
          - 04.1301.01.01.14 Príprava robota na mieste
          - 04.1301.01.01.15 Zostava zberného systému na c...
          - 04.1301.01.01.16 Testovanie robota pred prácou
          - 04.1301.01.01.17 Iná prípravná činnosť
          - Miestnosť Voľné ()

**K1. Procedúra**

Procedúra

Názov autonómneho okruhu pre chem. dekontamináciu

Výpis polohy uzla	
Parameter	Hodnota

Časový interval zberu odpadov

Dátum začiatku zberu odpadov | Dátum konca zberu odpadov

Číslo výpočtového uzla

Začiatok procesu

Identifikačné číslo zariadenia

Koniec procesu



## 2) How to do: Definition of calculation procedures and conditions for calculation

Automatic allocation of calculation procedures, generation of default calculation data and user friendly tools for calculation data editing / entry were developed

- Calculation procedures for the individual calculation items or formulas for generation of the calculation procedures are **pre-defined** in the PSL calculation templates
- The **executive calculation procedures** are allocated automatically during the generation of the executive PSL calculation structure as one default procedure and set of supplement calculation procedures for editing by the user.
- The **remote controlled / manual** procedures are selected automatically based on actualised radiological inventory data and acceptance limits for manual work.
- The **correction factors** (work in radiation fields, on scaffolding) are **calculated** during generation of the executive calculation PSL structure based on inventory data and can be edited by the user.
- The local input **data entry points** (e.g. working group parameters / duration of period dependent activities, fixed costs, contingency, etc.) are generated as default values or empty data entry points during generation of the executive calculation PSL structure. The user enter or edit the input calculation data.



### 3) In what sequence: Definition of material / radioactivity flow in decommissioning

The concept of material / radioactivity flow control in decommissioning developed at DECOM, a.s. represents an original generic methodology and tools implemented into the standardised OMEGA code for on-line optimisation of decommissioning and waste management processes

- The modelling of the processes is based on mathematical **material partitioning** of inventory items into **one-material elements** which enter into the pre-defined **sequence** of calculation / sorting procedures linked each other by unambiguous material links
- To each one-material calculation element are **linked radiological parameters** which are generated during the material partitioning. The generation is based on the calculation category of the inventory items and distribution coefficients relevant for the item category
- The generation of **secondary waste** is considered
- The **concept of nuclide vectors** is used for definition of radiological parameters of inventory items (normalised participation of individual radio-nuclides on radiological inventory data)
- The linked radiological parameters are during the calculation dynamically recovered to the start dates of individual decommissioning activities. The **decay of radioactivity** of individual radio-nuclides is respected through the entire decommissioning process.



- The calculation procedures implement the parameters of individual processes of the **decommissioning infrastructure** (actually available or planned) for the decommissioning project
- The **sorting procedures** implement the limits for releasing of materials, acceptance limits for disposal of materials, acceptance limits for individual process (if they are defined) and parameters of individual processes which affect the material / radiological parameters of evaluated items
- Both types of procedures can be linked to pre-defined **scenarios of waste management** for decommissioning starting from pre-dismantling decontamination up the release of materials or disposal of materials on the surface repository or deep geological repository
- **Multi-stream** material calculation structures can be defined by appropriate sequence definition combined with selected sections of PSL calculation structure and by definition of dates for waste entry into individual material streams.
- **Keyboard data entry** of waste items for general application in waste management modelling and optimisation is feasible
- The waste streams are optimised in a standard **Microsoft Project** software



### 4) **When to do:** Management of time in decommissioning

The new concept of decommissioning time schedule in the form of the **Gantt chart** in Microsoft Project with bi-directional data link to the calculation structure enables the on-line optimisation of the decommissioning time schedule. The concept implement directly the impact of time on radio-logically dependent decommissioning parameters

- The real sequence and structure of activities in the work breakdown structure (WBS) of a decommissioning project is specific and different from the PSL structure. The WBS in Omega can be defined individually for each calculation option by tools for **specific grouping and linking** of items of the standardised calculation structure into the items of the WBS.
- The developed tools enable to transform the WBS, defined in OMEGA code by the user, into the **Gantt chart** in the standard Microsoft Project software and to generate the user defined resources data for the Gantt chart.
- The **grouping mode** (1 : N) of calculation items into the WBS item preserves the total duration of grouped calculation items.
- The **linking mode** (1:1) in definition of the WBS represents one to one linking of one calculation item to one WBS item. This mode is used for tasks where the duration is individually optimised in the Gantt chart.



- The Gantt chart can be optimised using the standard tools of the Microsoft Project. The optimisation represents the linking of activities with calculated durations (activity dependent types of tasks, like dismantling) in order to define the **critical path** for the option, adjustment of **duration** of period dependent activities and modifying the **optimisation parameters** (number of working groups or shifts) where needed
- The optimised Gantt chart is used for **transfer of start dates** and durations back to the executive calculation structure. The start dates for the grouped items are sequenced for individual de-grouped items, for linked items are transferred directly. The duration is transferred for items defined in the calculation structure.
- The **start dates** of individual calculation items, derived from the Gant chart of the calculation option, determines the **actual values of radiological parameters** involved in the calculation item. There are two basic modes of calculation run in Omega:
  - **First calculation run** - all calculation items starts with the same date. This mode is used for the first generating the Gantt chart before its optimisation in Microsoft Project.
  - **Second / n<sup>th</sup> calculation run** - the start dates are derived from the optimised Gantt chart. Effects of time decay (e.g. in deferred dismantling) can then be evaluated directly.

# 4. Cost calculation code OMEGA Principles of on-line optimisation



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Principal scheme of work breakdown structure (WBS) definition, its transformation into the Gantt chart, optimisation of the Gantt chart and modes of calculation runs

**User defined WBS - a prescription for generating the Gantt chart of the option**

- Vyradovanie HVB
  - Predmontážna dekontaminácia v HVB pred OU
  - Okružná dekontaminácia
  - Neokružná dekontaminácia
  - Demontáž bežných zariadení v HVB pred OU
  - Demontáž reaktora
    - Pripravné práce pred demontážou reaktora
    - Demontáž reaktora
      - Demontáž prekážkových reaktora
      - Demontáž výparných častí reaktora
      - Demontáž veľka reaktora s prísúšením
      - Demontáž vnútroreaktorových častí
      - Demontáž tlakových nádob reaktora
      - Demontáž zariadení v šachte reaktora
    - Ukončovanie práce po demontáži reaktora
  - Podporné činnosti počas demontáže reaktora
  - Dekontaminácia stavebných častí HVB pred OU
    - Mechanická dekontaminácia
    - Chemická dekontaminácia
    - Radičná kontrola stavebných povrchov pred OU

**User definition of the option specific WBS:**  
Grouping / linking of calculation items into WBS items

**Executive PSL calculation structure**

- 04 0800 Charakteristika radiačného inventáru na vyradovanie a dekontamináciu
- 04 0900 Piprava dočasného skladovacieho miesta pre odpad
- 04 1000 Očistenie zariadení pre manipuláciu s palivom
- 04 1100 Návrh, dodávka a testovanie špeciálnych zariadení a nástrojov pre dekontamináciu
- 04 1200 Demontážne činnosti na nádobe reaktora a jeho vnútorných častiach
- 04 1300 Demontáž zimných a pomocných systémov
  - 04 1301 01 01 Pipravé činnosti pred demontážou
    - 04 1301 01 02 Práca na podlažnej úrovni v HVB
    - 04 1301 01 03 Práca na úrovni podlažia v HVB
    - 04 1301 01 04 Práca na úrovni stropu v HVB
    - 04 1301 01 05 Práca na úrovni podlažia v HVB
    - 04 1301 01 06 Práca na úrovni stropu v HVB
    - 04 1301 01 07 Práca na úrovni podlažia v HVB
    - 04 1301 01 08 Práca na úrovni stropu v HVB
    - 04 1301 01 09 Práca na úrovni podlažia v HVB
    - 04 1301 01 10 Práca na úrovni stropu v HVB
    - 04 1301 01 11 Práca na úrovni podlažia v HVB
    - 04 1301 01 12 Práca na úrovni stropu v HVB
    - 04 1301 01 13 Zostava terénu pri deči, zeme
    - 04 1301 01 14 Piprava robota na mieste
    - 04 1301 01 15 Zostava zberného systému na č...
    - 04 1301 01 16 Instalovanie robota pred prácou
    - 04 1301 01 17 Inštalácia činnosti

**Start**

**Calculated data: last calculation run**

**Facility inventory**

**On-line transformation of the WBS into the Gantt chart after the calculation run**

**On-line transformation of start dates / durations from the Gantt chart into the executive calculation structure before the 2<sup>nd</sup> / n<sup>th</sup> calculation run**

**Sample of MS Project output before optimisation**

Task Name	Duration	Start	Finish	Resource Names
WBS "Option 1 - Object 41"	556,38 days	Fri 14.2.02	Fri 2.4.04	
Preliminary activities	116 days	Fri 15.2.02	Fri 26.7.02	
Decommissioning study	928 hrs	Fri 15.2.02	Fri 26.7.02	
Dekontamination	51,75 days	Fri 15.2.02	Tue 30.4.02	
Level -0,00	28,88 days	Fri 15.2.02	Thu 28.3.02	
Room 101	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 102	80 hrs	Fri 15.2.02	Fri 1.3.02	Costs[179 559,84 Sk]Work[391,81 manhrs]I...
Room 103	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 104	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 105	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 106	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 107	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 108	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 11	369,62 manhrs			Costs[369,62 manhrs]D...
Room 12	414 hrs	Fri 15.2.02	Thu 28.2.02	Costs[2 375 544,54 Sk]Work[5 008,84 manhrs]I...
Room 13	73 hrs	Fri 15.2.02	Thu 28.2.02	Costs[166 146,51 Sk]Work[362,54 manhrs]I...
Room 14	124 hrs	Fri 15.2.02	Fri 8.3.02	Costs[395 093,49 Sk]Work[849,04 manhrs]I...
Room 15	69 hrs	Fri 15.2.02	Thu 28.2.02	Costs[156 366,41 Sk]Work[341,3 manhrs]D...
Dismantling	146,25 days	Thu 14.2.02	Fri 6.3.02	
Level -0,00	144,75 days	Fri 15.2.02	Fri 6.3.02	
Room 101	39 hrs	Fri 15.2.02	Fri 22.2.02	Costs[57 767,93 Sk]Work[134,7 manhrs]I...
Room 102	46 hrs	Fri 15.2.02	Mon 25.2.02	Costs[65 708,04 Sk]Work[149,52 manhrs]I...

**Gantt chart after the first calculation run**

**2<sup>nd</sup> / n<sup>th</sup> run (start dates preserved):**  
Tasks re-editing and optimisation

**First run (equal start dates):**  
Tasks linking, critical path definition, editing of durations for period dependent activities

**Sample of MS Project output after optimisation**

Task Name	Duration	Start	Finish	Resource Names
WBS "Option 1 - Object 41"	556,38 days	Fri 15.2.02	Fri 2.4.04	
Preliminary activities	116 days	Fri 15.2.02	Fri 26.7.02	
Decommissioning study	928 hrs	Fri 15.2.02	Fri 26.7.02	
Dekontamination	194,13 days	Fri 15.2.02	Thu 14.11.02	
Level -0,00	115,5 days	Fri 15.2.02	Fri 26.7.02	
Room 101	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 102	80 hrs	Fri 15.2.02	Fri 1.3.02	Costs[179 559,84 Sk]Work[391,81 manhrs]I...
Room 103	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 104	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 105	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 106	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 107	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 108	74 hrs	Fri 15.2.02	Thu 28.2.02	Costs[167 226,62 Sk]Work[364,9 manhrs]D...
Room 11	369,62 manhrs			Costs[369,62 manhrs]D...
Room 12	414 hrs	Mon 15.7.02	Tue 24.9.02	Costs[2 375 544,54 Sk]Work[5 008,84 manhrs]I...
Room 13	73 hrs	Mon 16.9.02	Fri 27.9.02	Costs[166 146,51 Sk]Work[362,54 manhrs]I...
Room 14	124 hrs	Mon 7.10.02	Mon 28.10.02	Costs[395 093,49 Sk]Work[849,04 manhrs]I...
Room 15	69 hrs	Mon 4.11.02	Thu 14.11.02	Costs[156 366,41 Sk]Work[341,3 manhrs]D...
Dismantling	146,25 days	Mon 6.7.02	Wed 9.10.02	Costs[340 590,63 Sk]Work[1 369,62 manhrs]I...
Level -3,9	93,6 days	Mon 6.7.02	Wed 9.10.02	Costs[340 590,63 Sk]Work[1 369,62 manhrs]I...

**Gantt chart ready for the second / n<sup>th</sup> calculation run**



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The computer code OMEGA produce following groups of calculated parameters:

- **General decommissioning parameters**
  - **Costs, manpower, exposure, duration, amount of workers, consumption items.**
  - **An extended numbered fine costs structure of chapter 12 of the PSL was prepared.**
- **Material parameters**
  - **Parameters of interim / output materials (weight, inner / outer surface, volume, etc.) including all interim waste forms, final waste form (overpacs), released materials, gaseous and liquid effluents**
- **Nuclide parameters**
  - **Radioactivity of interim / output material items evaluated for individual radio-nuclides linked to each material item**
- **Profession resolved parameters**
  - **Manpower / exposure items resolved for individual professions of the working group**
- **Time parameters**
  - **Start, duration of individual decommissioning activities**
- **Equipment**
  - **Equipment needed for performing of individual decommissioning activities**



Following data formats of calculated parameters are available:

- **Detailed data review**
  - **Detailed review of all calculated parameters on the level of the calculation item**
  
- **Summary format for user selected general calculated decommissioning parameters**
  - **Costs, manpower, exposure, duration, amount of workers, consumption items, etc.**
  - **The data are used also for multi-attribute analysis for selection of the optimal option**
  
- **Standardised PSL formats**
  - **Table of user selected calculated parameters assembled in standardised format of PSL**
  
- **Time graphs**
  - **Time graphs with pre-selected time scale for any user selected calculated parameter**
  
- **Gantt chart**
  - **Decommissioning Gantt charts in the standard software for project planning with user selected resource parameters from the list of calculated parameters**

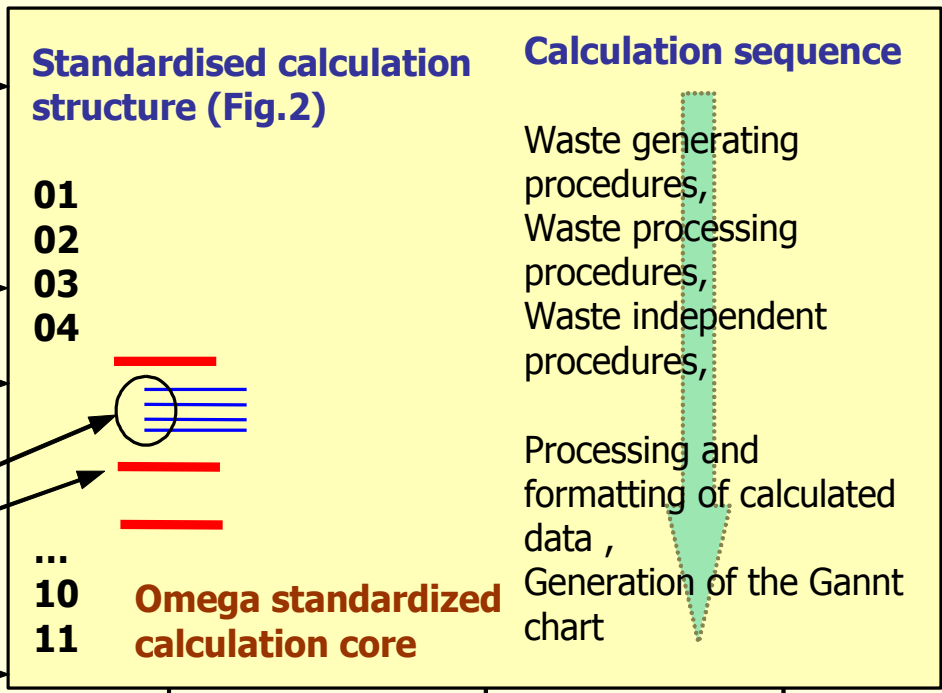
# 5. Cost calculation code OMEGA Process review scheme



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**Mode 1:** equal start dates for all items

**Mode 2:** start dates according the Gantt chart of the option



Calculation database - unit factors, nuclide data

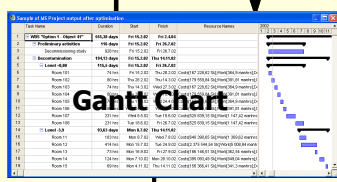
Local input calculation data

Waste management scenarios

Facility inventory database

WBS for the calculation option

WBS interface



Calculated data formatted in standardised structure

Time graphs

Overall data

Data post-processing

Multi-attribute analysis (MAA)

Experts

Criteria for MAA

Other optimised options



The pre-requisite for efficient work with the OMEGA code is the **inventory database** of the facility with relevant systems, buildings and radiological data and the **calculation database** with relevant data for processes, profession / work time data, material / nuclide data and other data

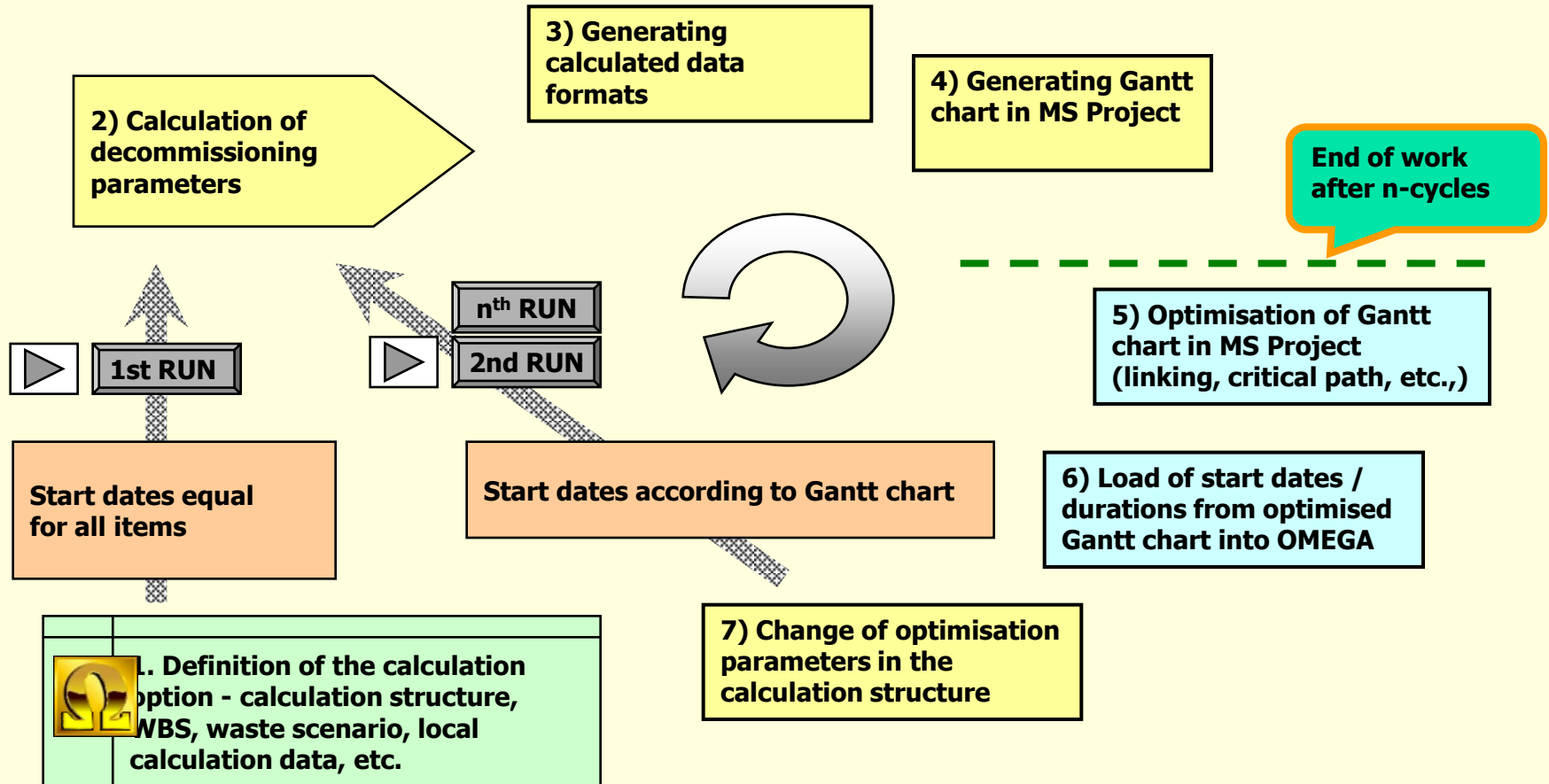
The work with OMEGA for management of the decommissioning calculation option has an **iterative** character with following main steps:

- Definition of the calculation option - calculation structure, WBS, waste scenario, local calculation data, extent of calculation, etc.
- Calculation of parameters in the first calculation run with equal start dates
- Generating calculated data formats and Gantt chart in MS Project
- Optimisation of Gantt chart in MS Project (linking, critical path, etc.,)
- Load of start dates / durations from optimised Gantt chart into OMEGA, change of optimisation parameters in the calculation structure
- Calculation of decommissioning parameters with start dates derived from the Gantt chart
- Repeated calculations with start dates derived from Gantt chart up to achieving the finally optimised decommissioning option ready for multi-attribute analysis.
- Multi-attribute analysis of individually calculated / optimised / evaluated projects



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## Graphical interpretation of main steps of the iterative work with Omega





The methodology for work with a group of calculation parameters for selection of the optimal decommissioning option and the methodology for co-optimisation of parallel projects was developed:

- **Multi-option** work represents definition of a set of calculation option which cover all aspects of decommissioning which should be considered in the decommissioning project.
- Each calculation option is calculated, optimised and evaluated **individually** in full extent of the work with a calculation option
- For selection of the most optimal option, the methods of **multi-attribute analysis** are used, for which tools were developed. The calculated data of options for the decommissioning project are evaluated based on **pre-defined criteria**, specific for the decommissioning project.
- The **objective criteria** are linked to selected calculated parameters, the values for **subjective criteria** are defined by the user. The evaluation experts define the weight of individual criteria.
- The result of the multi-attribute analysis are the evaluative numbers for each option which are used for selection of the optimal option for the decommissioning project



### Application of on-line optimisation in decommissioning waste management

- Special task in optimisation of the Gantt chart of the decommissioning option is the optimisation of decommissioning **waste management**. The implemented tools enable to create a multi-stream waste management system which can cover several periods of waste management linked to individual decommissioning phases.
- The waste streams are pre-defined in the form of **waste scenarios**. The user can include the selected scenario into the calculation option.
- The **amount of wastes** entering the individual streams is the **result of calculation** in relevant waste generating calculation items like dismantling, decontamination (wet and dry), demolition and this on-line data link increase the accuracy of calculation of the parameters for the waste management. The secondary waste items are calculated based on distribution coefficients
- **Keyboard data entry** of waste items is feasible for calculating the parameters for management of operational waste (not the result of previous calculation).
- The range of on-line waste management include all waste handling activities from the origin of the waste (or the keyboard entry) up to the **release** of materials or **disposal** of conditioned waste at surface or geological repository.



The Omega code use the bottom-up principle for evaluating the decommissioning parameters for all elementary decommissioning activities. The dose uptake for personal is also calculated on this level.

- The external exposure is calculated based on calculated manpower components (productive and non-productive) for three components:
  - Dose rate from the equipment at the working distance 0,5 m
  - Average dose rate in the room
  - Average dose rate in the background of the controlled area
  
- The internal exposure is calculated based on calculated manpower components (productive and non-productive) , breathing data, conversion factors data (Sv/Bq) and retention factors of protective clothing for three components:
  - Volume activity of aerosols at the working place
  - Average volume activity of aerosols in the room
  - Average volume activity of aerosols in the background of the controlled area
  
- The exposure items are calculated for individual professions of the working group using the coefficients of effective stay in above listed working points and summed over professions of the working group



The methodology of generating the calculation structure, as applied in the Omega code, enables to select automatically by the code the application of manual or remote dismantling technique based on:

- Actual dose rate at the equipment to be dismantled (recovered for the date of dismantling)
- Dose rate limit for application of the remote dismantling – defined by the user

This property of the code can be used for evaluation of the **optimal level for application of remote dismantling** and for cost benefit analysis of the type costs and manpower versus dose uptake during dismantling

Model calculations were performed for the primary circuit of the A1 NPP. The results show that the optimal level for application of remote dismantling is in the interval between 100 - 200 micro Sv/hour.