Software Metrics & Software Metrology

Alain Abran

Chapter 12
COSMIC: Scaling Up & Industrialization

Agenda

This chapter covers:

- The objectives for scaling up the new measurement method
- The design decisions made by the COSMIC group
- The independent field trials in industry
- The design outcomes: The COSMIC measurement method
- The fit within the international infrastructure on software measurement

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Objectives of the Design Scale Up

- If the scale up from R&D does not occur, then most of the software measures proposed by researchers (or practitioners) will typically:
  - stay within the realm of their authors & that of a few researchers who use them for research purposes only, or
  - be identified by other researchers as having weaknesses, and partial solutions will be proposed by those researchers to address them,
  - And so on ...

- This leaves the industry with a continuously shifting foundation consisting of:
  - local optimizations (documented in a number of individual papers, but still suffering from other weaknesses), and
  - at times, very different designs put forward for the alternatives proposed.

Objectives of the Design Scale Up

- This chapter presents:
  - the steps deliberately taken to scale up the design of the COSMIC measurement method:
    - to make that design more robust from a measurement perspective, and
    - to broaden its consensual basis to bring it up to what should be considered as the ultimate reward for a measure in terms of recognition:
      - e.g. adoption as **an International Standard** by the ISO.

Objectives of the Design Scale Up

- Scaling up is very important for an organization & the industry:
  - An organization typically wishes to measure something with a measurement method already widely recognized in the industry:
    - It does not want to waste time & monies going through an evaluation of a large number of alternatives measurement methods.
      - & they typically do not have the skills and expertise to evaluate a number of distinct measurement methods.
  - An organization does not want to adopt a measurement method which could rapidly become obsolete:
    - through of a lack of support in industry or
    - through rapid successive improvements without due consideration to past investments in data collection & training.

Objectives of the Design Scale Up

- Scaling up Objectives (1/2)
  - The members of the COSMIC group defined the following objectives for scaling up the measurement prototype to ensure its robustness over time as a measurement method capable of meeting industry needs:
    - To meet the constraints of the many new & complex types of business and real-time software, as well as the business application software served by 1st generation functional sizing methods.
    - To be easy to train, understand & use with consistency
    - To fully meet the data collection rules of the established data repositories or software projects
    - To facilitate the development of approximate size estimation on the basis of requirements as they emerge early in a project's life.

Objectives of the Design Scale Up

- Scaling up Objectives (2/2)
  - To meet all <u>feasible metrology criteria</u> to ensure robustness for its use in industry;
  - To meet the requirements of correct application of numerical rules to facilitate its adoption by academia.
  - To fit into the international regulatory environment (as an ISO standard).
  - To facilitate automated sizing
    - e.g. to make it simple enough to define the interpretation rules for tool specifications, and for a variety of development paradigms.
  - To be independent of methodologies and technologies.
  - To be provided with free access through the Web.

Objectives of the Design Scale Up

- To meet these objectives, key decisions were taken to improve the design of the prototype:
  - The aspects of the IFPUG method that did not meet the metrology criteria were dropped:
    - This included dropping the assignment of weights and the corresponding ambiguous mix of numerical scales [1].
  - A more generic model of software functionality was designed to capture the key concepts of functionality that cut across most of the previous functional size measurement methods.
  - A number of the metrology concepts described in the ISO VIM (International Vocabulary on Metrology) were implemented [2].
  - Design in full conformity with the mandatory requirements of ISO 14143-1 on functional size measurement methods, including the key one:
    - What is to be measured is a ‘functional requirement’ of the software, independently of its quality and technical (non-functional) requirements.

- [1] See chapter 8. [2] See chapter 3.

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Design Decisions

- To meet the objectives of the COSMIC group, the R&D prototype (see chapter 11) was reviewed and a number of changes were made.
- Among the important changes:
  - Concepts generalized to a higher level of abstraction:
    - This meant that they could apply to all types of software, and not only to real-time software.
  - Adoption of a generic description of functionality in software, independently of its functional domain:
    - The key concept of functionality at the highest level of commonality that is present in all software was identified as the ‘data movement’.
    - This data movement concept was then assigned to the metrology concept of a size unit.

Design Decisions

- The Function Points transaction types were dropped, for the following reasons:
  - The data movement concept was more generic and superceded the Function Points transaction types.
  - The data movement concept was simpler and required less intricate rules to specify a measurement method.
  - The assignment of 1 unit to a data movement did not require recourse to arbitrarily (or somewhat arbitrarily) weights.
    - The absence of weights and the use of a single unit ensured a proper use of measurement scale type and, correspondingly, correct additivity of measurement results.

- The adoption of a generic description of a level of granularity for the measurement of this functionality in software:
  - **at the data movement level**,
    - without taking into account data manipulation with the simplifying assumption of an average number of data manipulations for each data movement).
- The recognition of distinct phases for quantifying the functionality of software:
  - a **strategy phase**, where the purpose and scope of measurement are determined
  - a **mapping phase**, where the documentation of the piece of software to be measured is analyzed and modeled and described by the COSMIC generic model of that software
  - A **measurement phase** for the application of the numerical assignment rules of the COSMIC method.
- The recognition of **layers of functionality**:
  - the adoption of the same model of functionality for each layer, as well as the same size unit.

Design Decisions

- The design was scaled up in an iterative manner and benefited from the vast expertise of the participants, many of whom were long-time contributors to ISO working groups for the development of international standards in systems and software engineering.
  - For instance, in ISO standards, the set of concepts (and the interrelationships across these concepts) that constitute the foundation of standards is embedded in the set of definitions adopted for any specific ISO document.
    - Of course, the establishment of a consensus on these definitions is a very difficult exercise, since the participants in the design of a standard invariably come from different individual backgrounds and levels of expertise, and many of them from very different cultural backgrounds.
    - Ensuring common understanding on terms, and on relationships across terms, is, on the one hand, a very time consuming effort, but,
    - on the other hand, it leads to a very robust, unambiguous, and coherent set of definitions.

Design Decisions

- Once agreement had been reached on these definitions, the measurement principles were developed to provide for a measurement method which would lead to reproducibility, repeatability, and reproducibility.
    - These are criteria that reflect the metrological strengths expected from a measurement method.

- Again, this was a highly iterative process with a large number of back and forth discussions and clarifications, and re-documentation whenever a team member had interpreted a concept and a rule differently.

Design Decisions

- Overall, close to 40 experts from 8 countries participated in the design of the prototype and of the scale up of this measurement method.

Implicit/explicit testing of a design by a group of experts

Throughout the scale up process, the contributing experts tested the application of the measurement rules based on their own expertise at working with requirements from different functional domains and verifying what the measurement results would be if the rules were applied:

– to software they had measured with previous measurement methods, or

– to requirements which could not have been measured adequately before such methods were used.

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Independent Industrial Field Trials

- A 12-month period was allocated for conducting industrial field trials of the COSMIC measurement method in a significant number of organizations around the world from multiple and varied contexts.
  - During this period, each participating organization received training on the application of the measurement method.
  - Multiple software projects were selected from each organization's portfolio and their functional size was measured.

Independent Industrial Field Trials

- Once the data analyzed, a specific report was prepared for each participating organization, offering:
  - guidelines for applying the method based on that organization's software engineering standards, and
  - some preliminary benchmarking information allowing the organization to leverage its investment in the new data and put it to use immediately.

  - From the perspective of the participants in the field trials, another benefit of this approach is in the availability, at the end of the field trial period, of a database of historical data useful for jumpstarting the implementation of the measurement method within their own organizations while respecting the confidentiality of the sources

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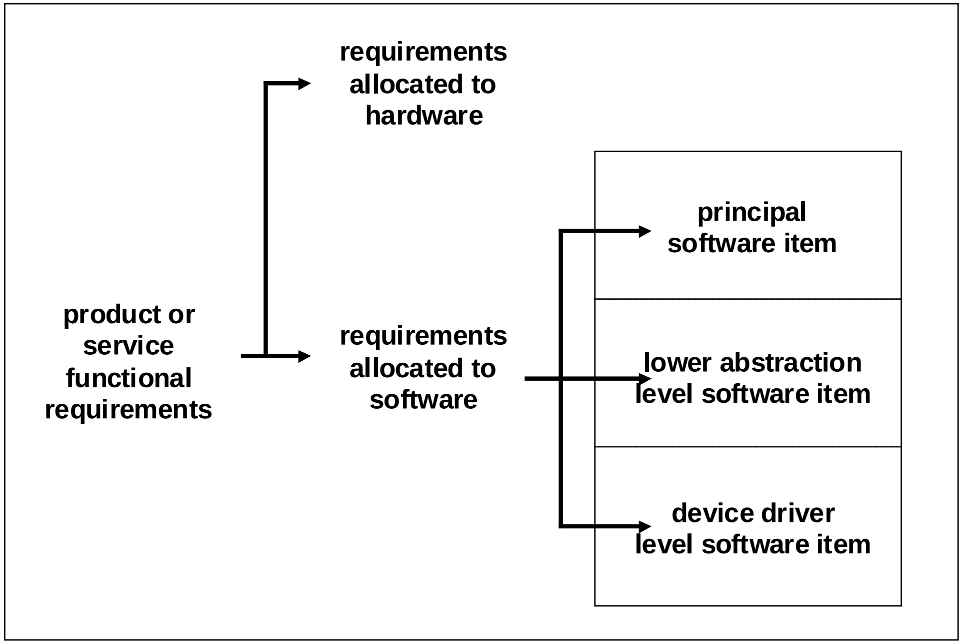
Outcome: The Design of the COSMIC Measurement Method

- **Allocation of functional user requirements**
  - From the perspective proposed by COSMIC, software is part of a product or service designed to satisfy functional user requirements. From this high-level perspective, functional user requirements can be allocated:
    - to hardware,
    - to software, or
    - to a combination of the two.
  - The functional user requirements allocated to software are not necessarily allocated to a single unit of software:
    - Often these requirements are allocated to pieces of software operating at different levels of abstraction and cooperating to supply the required functionality to the product or service in which they are included.
  - This is illustrated in next Slide.

Outcome: The Design of the COSMIC Measurement Method

Figure: Allocation of functional user requirements [COSMIC2009]



Outcome: The Design of the COSMIC Measurement Method

- In the context of the COSMIC measurement method, <u>only those functional user requirements allocated to software</u> are considered.

  - As illustrated in the next slide, the functional user requirements in this example are allocated to 3 distinct pieces of software, each of which exchanges data with another through a specific organization:
    - One piece of the software lies at the application level and exchanges data with the software's users and with a 2^{nd} piece lying at the operating system level.
    - In turn, this 2^{nd} piece of software exchanges data with a 3^{rd} piece lying at the device driver level.
    - This last piece then exchanges data directly with the hardware

Outcome: The Design of the COSMIC Measurement Method

- The COSMIC measurement method associates each level with a specific layer:
  - Each layer possesses an intrinsic boundary for which specific functional users are identified.
- The functional size of the software described through the functional user requirements is thus broken down into 3 pieces, each piece receiving some of the functional user requirements.

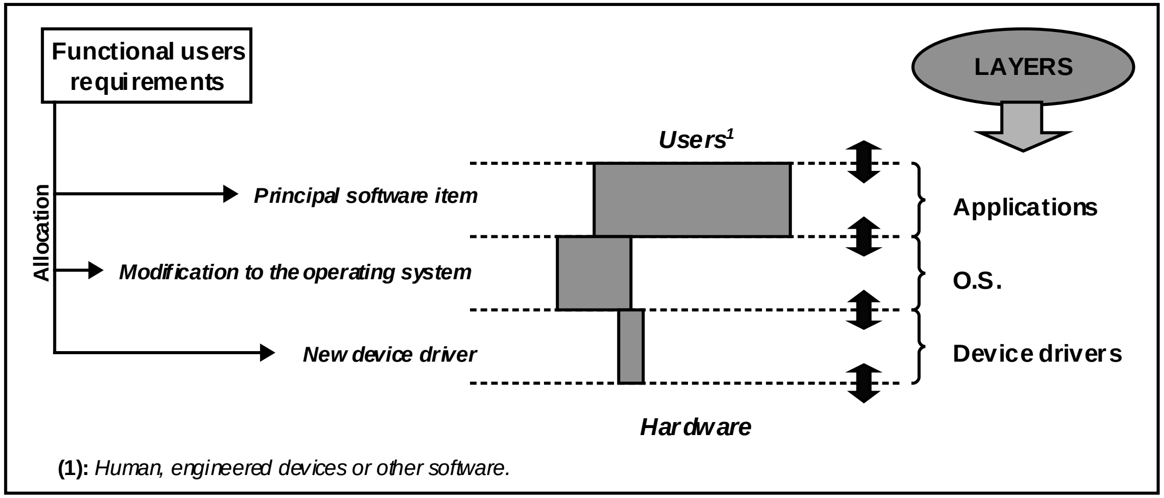


Figure 2: Example of functional user requirements allocation to different layers [COSMIC 2009]

Outcome: The Design of the COSMIC Measurement Method

- **Representation of functional user requirements in software**

  - The functional user requirements in the subset allocated to 1 or more pieces of software are represented by functional processes.

  - Each functional user requirement is thus represented, within the piece of software to which it has been allocated, by 1 or more functional processes. In turn, each functional process is represented by sub processes:
    - A sub process can either be a data movement type or a data transform type.
    - By convention, the COSMIC measurement method <u>recognizes only data movement type</u> sub processes in its numerical assignment rules.

Outcome: The Design of the COSMIC Measurement Method

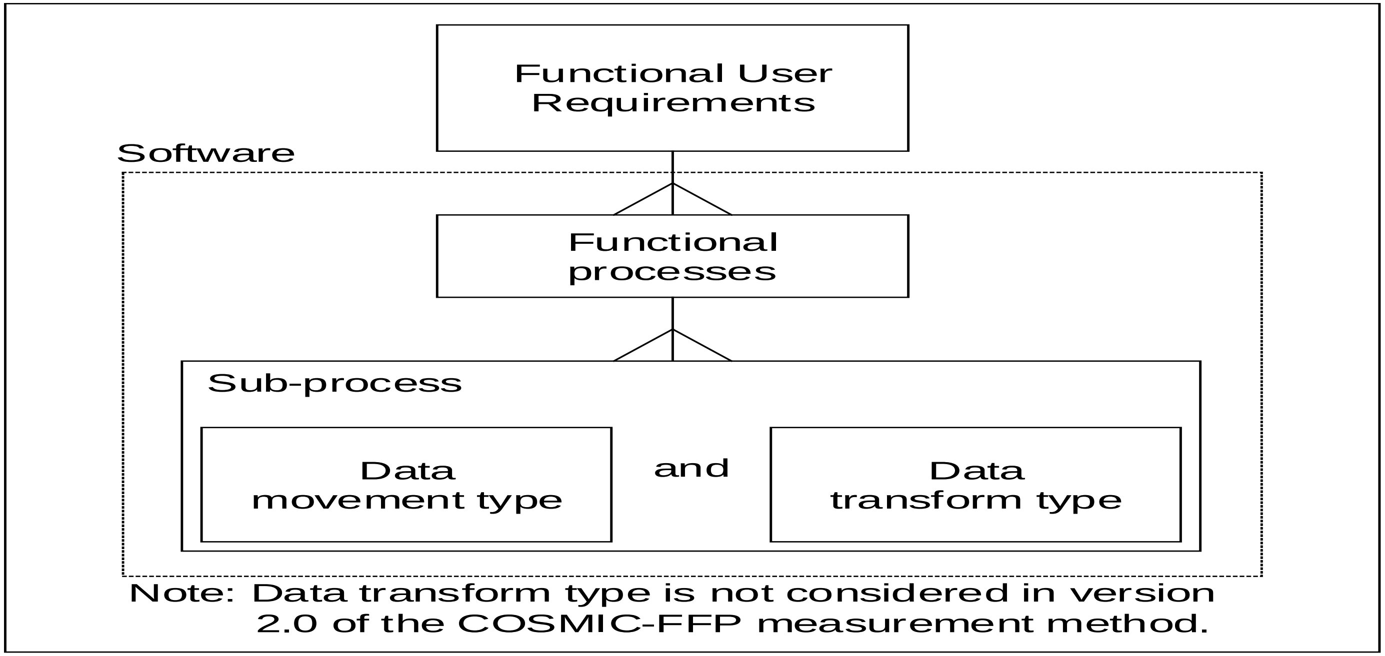


Figure 3: COSMIC representation of functional user requirements [COSMIC 2009]

Outcome: The Design of the COSMIC Measurement Method

The common concept: A data movement

Taking into account data movements is a common feature of many previous methods of measuring functional size, on which there is quite broad consensus that it is a fair representation of the concept of the functional size of software.

Of course, each method will have its own way of assigning a number to such a concept, leading to variations in that respect.

Lack of consensus on the size of algorithms

By contrast, while it is often said that algorithms also contribute to functionality, there is **no consensus in the industry:**

– on how to represent such functionality, or

– on how to assign a quantitative value to it.

Although imperfect, most methods of functional size measurement do not take algorithms into account directly, and assume that, in general, this does not have a significant impact on size.

Of course, there are exceptions when there are many algorithms in a piece of software: any organization can easily recognize these exceptions and treat them as exceptions for whatever purpose they are measuring, be it for productivity analysis or estimation.

Outcome: The Design of the COSMIC Measurement Method

- **COSMIC model of generic software**
  - The COSMIC measurement method defines an explicit model of software **functionality** derived from the functional user requirements.
    - Based on this explicit model of functionality, relevant functional attributes of software are identified, that is, the 4 data movement types recognized by the COSMIC measurement method (Entry, Exit, Read, Write) – see Table below.

Type	Definition
ENTRY	A data movement type that moves a data group from a functional user across the boundary into the functional process where it is required.
EXIT	A data movement that moves a data group from a functional process across the boundary to the functional user that requires it.
READ	A data movement that moves a data group from persistent storage within reach of the functional process that requires it.
WRITE	A data movement that moves a data group lying inside a functional process to persistent storage.

Table : Definitions of COSMIC data movement types

Outcome: The Design of the COSMIC Measurement Method

- The COSMIC model of generic software:

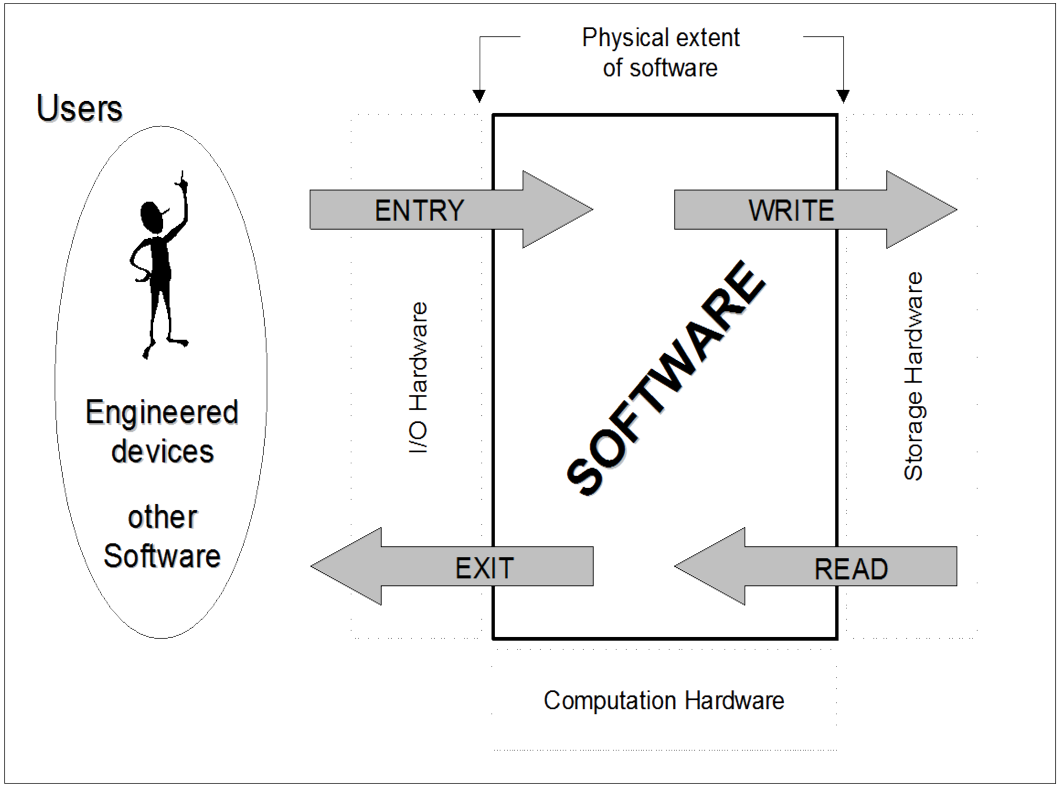


Figure : COSMIC model of generic software [COSMIC2009]

It is to be noted that each data movement type is considered to include a certain number of associated <u>data manipulations</u> – see the COSMIC Measurement Manual for details –www.cosmicon.com

Strengths of the COSMIC Design

- **Conformity with metrology design criteria**
  - The COSMIC measurement method has been designed to conform to the metrology design criteria embedded within the set of definitions in the VIM.
  - For instance, 2 elements characterize the COSMIC measurement rules and procedures:
    - the base functional components that constitute the arguments of the measurement function, and
    - the standard unit of measurement, which is the yardstick defining one unit of functional size.

Strengths of the COSMIC Design

Base functional components

- The COSMIC measurement method uses only 4 base functional components: Entry, Exit, Read, and Write.

What about data manipulation?
Data manipulation sub processes are not used as base functional components. The method assumes, as an acceptable approximation for many types of software, that the functionality of this type of sub process is already embedded among the four types of sub process defined earlier.

Standard unit of measurement

- The standard unit of measurement, that is, 1 CFP (COSMIC Function Point) is defined by convention as equivalent to 1 data movement of 1 data group.

Standard unit of measurement in COSMIC
1 COSMIC Function Point unit or CFP, in version 3.0

Strengths of the COSMIC Design

- **Aggregation function**
  - Using the standard unit of measurement, base functional components are thus assigned size units.
  - The functional size of the base functional components can then be combined to obtain the size of higher-level functional structures like functional processes or layers.
    - This is done by <u>arithmetically adding</u> the functional sizes of the constituent functional structures using an aggregation function.

Strengths of the COSMIC Design

- **COSMIC measurement method**
  - According to ISO-14143-1, a functional size measurement method is based on the perspective provided by the functional user requirements of the software to be measured.
    - In practice, functional user requirements do not often exist in a "pure" form, as a stand-alone document.
      - Therefore, very often, functional user requirements constitute a relatively abstract view of the software which needs to be extracted from other documents generated by the software engineering process.

Strengths of the COSMIC Design

- Functional user requirements can be extracted:
  - from software engineering documents which are produced before the software exists (typically from architecture and design artifacts), or
  - after the software has been created (typically from user documentation, physical programs, and storage structure layouts).
- Thus, the functional size of software can be measured:
  - prior to its creation, or
  - after its creation.

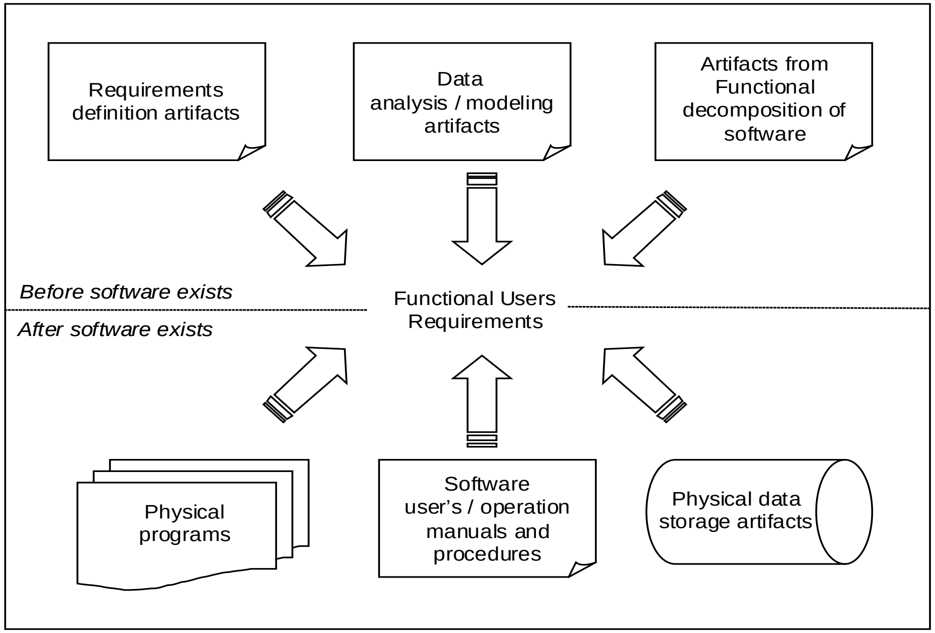
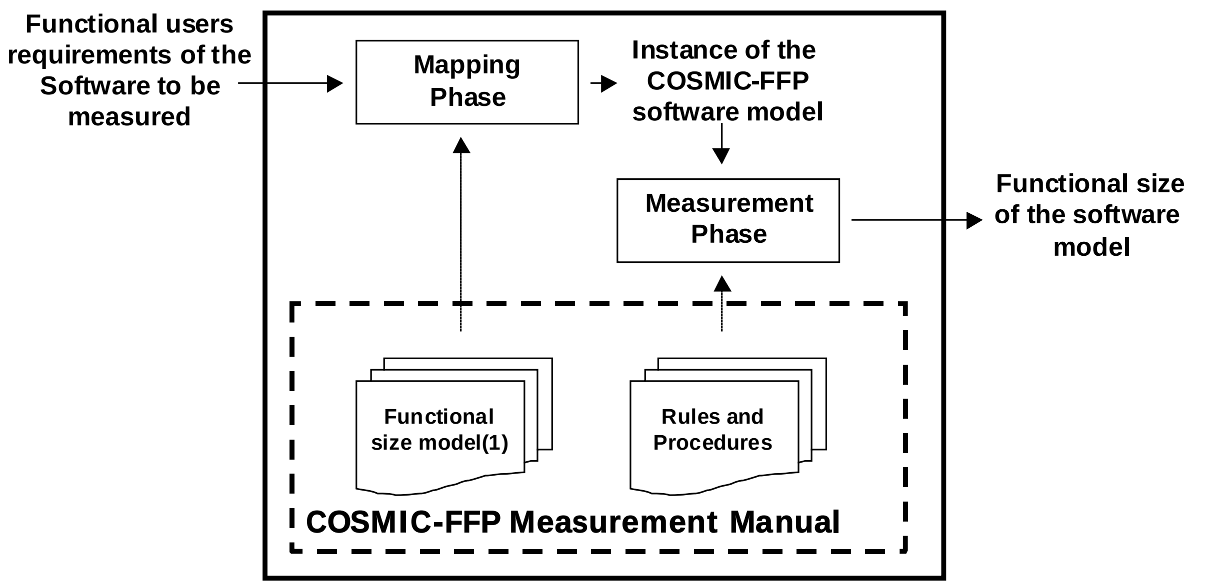


Figure 5: Extracting Functional User Requirements - COSMIC [2009]

Strengths of the COSMIC Design

Figure : COSMIC measurement procedure [COSMIC 2009]



(1): COSMIC-*FFP functional size model includes concepts, definitions and relationship structure of functional size attributes*

Strengths of the COSMIC Design

- **Applying the measurement function**
  - This step consists of applying the COSMIC measurement standard to each of the data movements identified in each functional process.
    - The COSMIC measurement standard, 1 CFP, is defined as the size of the data movement of a single data group.
  - According to this measurement function, each instance of a data movement of one data group (Entry, Exit, Read, or Write) is assigned a numerical size of 1 CFP.
  - The final step consists of aggregating the results of the measurement function, as applied to all the identified data movements, into a single functional size value.

Strengths of the COSMIC Design

- For each functional process, the functional sizes of individual data movements are arithmetically added:

$$Size_{CFP}(\text{functional process}_i) = \sum size(\text{entries}_i) + \sum size(\text{exits}_i) + \sum size(\text{reads}_i) + \sum size(\text{writes}_i)$$

- Note 1: the minimum size of a functional process is 2 CFP (there must always be one Entry and either a Write or an Exit)

- Note 2: there is no upper limit to the size of any functional process.

Strengths of the COSMIC Design

- For any functional process, the functional size of changes to the Functional User Requirements is aggregated from the sizes of the corresponding modified data movements according to the following formula:

$$Size_{CFP}\ (Change\ (functional\ process_i)) = \sum size\ (added\ data\ movements) + \sum size\ (modified\ data\ movements) + \sum size\ (deleted\ data\ movements)$$

Measuring a software enhancement

A requested change to a piece of software might be:

– add 1 new functional process of size 6 CFP, and

– add 1 data movement to another functional process, make changes to 3 other data movements, and delete 2 data movements.

The total size of the requested change is:

6 + (1 + 3) + 2 = 12 CFP.

Can you have a size of 1 CFP?

The minimum size of a functional process is 2 CFP:
– There must always be one Entry and either a Write or an Exit.

However, **an enhancement may be to a single data movement of size = 1 CFP**

The size of such an enhancement is then equal to 1 CFP.

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Scaling up – Metrology Infrastructure

- **International standards**
  - What is the ultimate recognition for a measurement method - and for its designer(s)?
    - Is it to be published in the most prestigious academic journal?
    - Is it to be extensively referenced by other researchers in the academic literature?
    - Is it to be copyrighted?
    - Is it to be assigned a patent?
  - In the field of measurement in the sciences and in engineering, the ultimate recognition is:
    - to be adopted by the largest community, and
    - to be adopted within an international recognized legal framework .
      - In practice, this is achieved by being recognized as an ISO standard.

Scaling up – Metrology Infrastructure

- In the COSMIC design process, one of the criteria had been that its design meet all the criteria specified in the ISO meta standard on functional size measurement – ISO 14143-1. Therefore, the COSMIC design and its measurement manual had to:
  - meet all the technical and editorial requirements of ISO standards; and
  - have its content widely accessible (that is, understandable) across the many cultures and languages of the national standards organizations with voting rights at the ISO international level.

- + the ISO guide to ISO 9001 for software organizations (e.g. ISO 90003) includes COSMIC as a recognized measurement method
  - see ISO 90003 – Guide to the implementation of quality system in software.

Scaling up – Metrology Infrastructure

- **International Data Collection Practices – ISBSG**
  - The International Software Benchmarking Standards Group (ISBSG) – see www.isbsg.org – maintains the largest publicly available repository of software projects:
    - This ISBSG repository included over 5,000 projects by mid 2009.
  - The COSMIC group has obtained recognition for COSMIC as one of the ISBSG's functional size standards for data collection. Since then:
    - The ISBSG has developed a tailored data collection questionnaire for projects measured using COSMIC.
    - COSMIC projects are now being collected and stored in this repository; similarly, COSMIC projects are being used in benchmarking studies.
  - This makes available to both industry and researchers a number of COSMIC measured projects for productivity studies and for the development of estimation models.
    - As of mid-2009, the Release 11 of the ISBSG repository contains over 300 projects measured with the COSMIC standard.

Competitive Advantages

- The competitive advantages of COSMIC can be summarized as follows:
  - It is in the public domain
    - as with any classic measure in the sciences and in engineering
  - It has full ISO recognition
  - Its design is simple
  - Its flexibility allows it to be applicable to a very wide range of software, and in multiple layers
  - Its underlying concepts are compatible with modern software engineering concepts
  - Translated into many languages, including: Japanese, Chinese, French, Arabic, Turkish, Dutch and Spanish.

Competitive Advantages

- COSMIC measurement method is designed to be applicable to:
  - <u>Business application software</u> which is typically needed to support business administration
    - Such software is often characterized as “data rich”, as its complexity is dominated largely by the need to manage large amounts of data about events in the real world.
  - <u>Real-time software</u>, the task of which is to keep up with or control events happening in the real world.
    - Examples: software for telephone exchanges and message switching, software embedded in devices to control machines such as domestic appliances, elevators, and car engines, for process control and automatic data acquisition, and in the computer operating systems.
  - It is possible to <u>define local extensions</u> to COSMIC for software which:
    - is characterized by complex mathematical algorithms or other specialized and complex rules, computer game software, musical instruments, and the like.

Competitive Advantages

- For further information about COSMIC, visit
  - www.cosmicon.com
- + for free downloads of:
  - COSMIC Implementation Guide to ISO 19761:2003
  - measurement bulletin updates
  - case studies
  - publications
  - certification information, etc.
- + Guidelines such as:
  - Local extensions for contexts not addressed in the initial design.
  - Derivation of an approximate size early on, when not all the functional requirements have been fully described.
  - Convertibility to other functional size measurement methods [1], etc.

Summary

- This chapter has described the process designed for scaling up the R&D prototype into the COSMIC measurement method which:
  - Was reviewed and improved at an internationally level,
  - Is now supported by an international users group, and
  - Has been endorsed by an international standards organization – ISO.

This chapter has presented more specifically:

- The objectives of the design scale up
- The design decisions taken by the COSMIC group
- The independent field trials in industry
- The design outcomes: The COSMIC measurement method
- Its fit within the international infrastructure of software measurement - ex: ISO & ISBSG