



**The COSMIC Functional Size Measurement Method**

**Version 4.0**

# **Measurement Manual**

**(The COSMIC Implementation Guide for ISO/IEC 19761: 2011)**

**April 2014**

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# Version Control

The following table gives the history of the versions of this document

DATE	REVIEWER(S)	Modifications / Additions
1999-03-31	Serge Oligny	First draft, issued for comments to reviewers.
1999-10-29	COSMIC Core team	Revised, final comments before publishing 'field trial' version 2.0.
2001-05-01	COSMIC Core Team	Revised for conformity to ISO/IEC 14143-1: 1998 + clarifications on measurement rules to version 2.1.
2003-01-31	COSMIC Measurement Practices Committee	Revised for conformity to ISO/IEC FDIS 19761: 2002 + further clarifications on measurement rules to version 2.2.
2007-09-01	COSMIC Measurement Practices Committee	Revised for further clarifications and additions to the measurement rules to version 3.0, particularly in the area of the Measurement Strategy phase. The method name was changed from the 'COSMIC-FFP method' to the 'COSMIC method'. In upgrading to v3.0 from v2.2, parts of the 'Measurement Manual' v2.2 were separated into other documents.
2009-05-01	COSMIC Measurement Practices Committee	Version 3.0 revised to v3.0.1 to make minor editorial improvements and clarifications, and to distinguish examples more clearly. This version also incorporates the changes proposed in Method Update Bulletins 3, 4 and 5.
2014-04-01	COSMIC Measurement Practices Committee et al	Version 4.0 revised to take into account of Method Update Bulletins 6 to 11, several editorial improvements and to incorporate the Glossary of terms. See Appendix E for details of these changes.

# Foreword

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The COSMIC method provides a standardized method of measuring a functional size of software from the domains commonly referred to as 'business application' (or 'MIS') software, 'real-time' software, 'infrastructure' software and some types of scientific/engineering software.

The COSMIC method was originally accepted by ISO/IEC JTC1 SC7 as an International Standard in December 2002. The current version is ISO/IEC 19761:2011 'Software Engineering – COSMIC – A functional size measurement method' [1] (hereafter referred to as 'ISO/IEC 19761').

The ISO/IEC 19761 standard contains only the fundamental normative definitions and rules of the method as at version 3.0 of the method. The purpose of the Measurement Manual is to provide these rules and definitions, and also to provide further explanation and many more examples in order to help Measurers to fully understand how to apply the method. The Measurement Manual is the principal standard description of the COSMIC method for practical use.

In addition to the 'Measurement Manual', the 'Introduction to the COSMIC method of measuring software' [2] gives a summary of version 4.0 of the method<sup>1</sup>. This 'Introduction' document should be read first by anyone who is new to functional size measurement ('FSM') or who is familiar with another FSM method and is thinking of converting, or who simply wants an overview of the COSMIC method, before reading this Measurement Manual. Much background information on FSM and the COSMIC method, as well as supporting Guidelines (e.g. on how to apply the method in various special circumstances, etc.), case studies, research papers, etc., can be found on [www.cosmicon.com](http://www.cosmicon.com).

## Main changes for version 4.0 of the COSMIC Method

The change in designation of the version of the COSMIC method from the previous 3.0.1 to this 4.0 indicates that this version aims to greatly improve the explanation of the method compared with the previous version but that the new version has no changes in the method's basic principles. In producing this version 4.0 of the COSMIC method, the main changes to the Measurement Manual from the previous version are as follows.

- The proposals to clarify the rules for access to persistent storage of Method Update Bulletin 7 v2 ('MUB 7 v2') (November 2012) have been incorporated.
- Limitations on the applicability of the COSMIC method have been relaxed as proposed in MUB 8 (September 2010). COSMIC now claims that the method may be successfully applied to size some software that might be considered as 'data manipulation-rich', e.g. some scientific/engineering software.
- The COSMIC definition of a 'layer' is much simplified and brought into line with common industry usage, as proposed in MUB 9 (November 2012).
- The concept of a Measurement Strategy Pattern<sup>1</sup> has been added.
- A section on 'non-functional requirements' has been added as per MUB 10 (December 2012). The COSMIC method may be used to measure many requirements that initially appear as non-functional but which evolve into functional requirements as a project progresses.
- The definition and rules for a 'functional process' and several related topics have been revised as per MUB 11 (December 2013).
- New rules for measuring error and confirmation messages have been introduced.
- The glossary of terms has been updated and included in the Measurement Manual.

The reasons for changes that have been published previously in a Method Update Bulletin are discussed fully in each MUB respectively. (Method Update Bulletins are published on

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<sup>1</sup> Publication of this v4.0 of the Measurement Manual, incorporating the Glossary of Terms, means that the 'Documentation Overview and Glossary of Terms', v3.0.1 document is now obsolete. Also the 'Advanced & Related Topics' v3.0 document will be replaced by two Guidelines on 'Approximate COSMIC Functional Size Measurement' [6] and on 'Convertibility' [13] which are currently under development.

[www.cosmicon.com](http://www.cosmicon.com) between versions of the Measurement Manual to describe significant proposed changes to the method.)

The basic structure of this Measurement Manual is identical to that of version 3.0.1 except that section 4.1 of the version 3.0.1 has been moved from the Chapter 4 'Measurement Phase' to section 3.5 of Chapter 3 'Mapping Phase' where it more logically belongs.

Finally, many editorial improvements have been made to improve understanding, including more use of diagrams. Some rules that are now considered unnecessary have been removed or their wording simplified.

All these changes are summarized in Appendix E. Users of the COSMIC method familiar with versions 3.0.1 or with earlier versions who intend to move to v4 are recommended to first read Appendix E to get an overview of the changes to the method. COSMIC envisages that the refinements introduced in this version 4.0 of the method will be submitted to ISO for inclusion in ISO/IEC 19761 when it is next due for revision.

**This Measurement Manual for version 4.0 of the method becomes the current standard definition of the method from April 2014. The Measurement Practices Committee has worked hard to eliminate defects and to improve the document so that it is easier to understand but it is possible that defects remain and/or that certain text is still difficult to understand. We strongly urge readers and translators to contact the MPC to report any defects and/or text that is unclear, using the process of Appendix F. If any significant changes are needed, the MPC will issue a version 4.0.1 document early in 2015 with any corrections (as was done after publishing version 3.0 of the method).**

#### **Consequences of the main changes to v4.0 on existing size measurements, etc.**

The original basic principles of the COSMIC method have remained unchanged since they were first published in the first draft of the Measurement Manual in 1999. This is in spite of the various refinements and additions needed to produce the International Standard and to produce all versions of the method up to this latest version 4.0.

Functional sizes measured according to the principles and rules of version 4.0 of the Measurement Manual may differ from sizes measured using earlier versions only because the new rules intend to be more precise and complete. Hence Measurers have less discretion for personal interpretation of the rules than was possible with earlier versions.

As a further indication of the continuity of the method, those who passed the Foundation level certification examination for version 3.0/3.0.1 of the method will be considered to be still certified for v4.0 of the method at the Foundation level.

#### **Note on terminology**

This Measurement Manual uses standard ISO terminology, namely

- 'shall' indicates a rule is mandatory; 'should' indicates a rule is advisory. (If neither term is present assume 'shall'.)
- 'may' indicates 'is allowed to'; 'can' indicates 'is able to'

#### **The contents of this Guideline**

Chapter 1 treats the types of software for which the COSMIC method may be used. The term 'Functional User Requirements' ('FUR'), is defined, together with the basic principles of the COSMIC method. The COSMIC method measurement process and the unit of measurement are also defined.

Chapter 2 describes the first Measurement Strategy phase of the measurement process in terms of its key parameters, such as the purpose of the measurement, the scope of measurement and the functional users of a piece of software. These parameters must be defined before starting to measure so that the meaning of the resulting measurements can be agreed and understood.

Chapter 3 discusses the second Mapping phase of the measurement process by defining how the FUR must be mapped onto functional processes and their data movements. A data movement moves

a data group, consisting of data attributes that all describe one 'object of interest'. The four types of data movements are defined: Entries and Exits move data to/from functional users and Reads and Writes move data to/from persistent storage.

Chapter 4 describes the final Measurement phase of the measurement process. It defines rules for assigning a size to the FUR of a piece of software and how to aggregate sizes of different pieces of software. This chapter also treats how to size changes to software and discusses the possibility of 'local extensions' to the standard COSMIC method.

Chapter 5 lists the parameters that should be considered for recording the measurement.

### **The Common Software Measurement International Consortium (COSMIC)**

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The COSMIC Measurement Practices Committee

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## INTRODUCTION

### 1.0 Chapter summary

This chapter has four purposes:

- To explain the types of software ('applicable domains') for which the COSMIC method may be used, and the limitations on its use.
- To define 'Functional User Requirements' ('FUR'), i.e. the requirements for software functionality that the COSMIC method aims to measure. We explain in general terms how a Measurer can extract or derive the FUR from available software artifacts for a functional size measurement. Non-Functional Requirements ('NFR') are also defined, since requirements that are initially expressed as non-functional often evolve as a project progresses partly or wholly into FUR that may also be measured.
- To define the basic principles of the COSMIC method, as summarized in two models. The 'Software Context Model' is used to characterize a piece of software to be measured. The 'Generic Software Model' defines the key principles of the COSMIC model of the FUR whose functional size is to be measured.
- To define the COSMIC method measurement process and measurement principle (related to the method's unit of measurement).

### 1.1 Applicability of the COSMIC method

The COSMIC method is designed to be applicable to measure the functionality of software from the following domains:

- Business application software that is typically needed in support of business administration, such as banking, insurance, accounting, personnel, purchasing, distribution or manufacturing, etc. Such software is often characterized as 'data rich', as it is dominated largely by the need to manage large amounts of data about events and objects in the real world.
- Real-time software, the task of which is to keep up with or control events happening in the real world. Examples would be software for telephone exchanges and message switching, software embedded in devices to control machines such as domestic appliances, elevators, vehicles and aircraft, for process control and automatic data acquisition, and software within the operating system of computers.
- Infrastructure software in support of the above such as re-usable components, device drivers and such-like.
- Some types of scientific/engineering software.

### 1.2 Functional User Requirements

The COSMIC method involves applying a set of models, principles, rules and processes to measure the Functional User Requirements (or 'FUR') of a given piece of software. The result is a numerical 'value of a quantity' (as defined by ISO) representing the functional size of the piece of software according to the COSMIC method.

Functional User Requirements are defined by ISO [1] as follows.

<b>DEFINITION – Functional User Requirements (FUR)</b>
<p>A sub-set of the user requirements. Requirements that describe what the software shall do, in terms of tasks and services.</p> <p>NOTE: Functional User Requirements relate to but are not limited to:</p> <ul style="list-style-type: none"><li>• data transfer (for example Input customer data; Send control signal)</li><li>• data transformation (for example Calculate bank interest; Derive average temperature)</li><li>• data storage (for example Store customer order; Record ambient temperature over time)</li><li>• data retrieval (for example List current employees; Retrieve latest aircraft position)</li></ul> <p>Examples of user requirements that are not Functional User Requirements include but are not limited to:</p> <ul style="list-style-type: none"><li>• quality constraints (for example usability, reliability, efficiency and portability)</li><li>• organizational constraints (for example locations for operation, target hardware and compliance to standards)</li><li>• environmental constraints (for example interoperability, security, privacy and safety)</li><li>• implementation constraints (for example development language, delivery schedule)</li></ul>

Note that the COSMIC method recognizes that some types of requirements (e.g. quality and environmental constraints as mentioned above) may be expressed early in the life of a software project as 'Non-Functional' Requirements, as per this ISO definition, but may evolve as the project progresses into Functional User Requirements. See section 1.2.3 of this Measurement Manual.

NOTE: In this document we will only use the term 'FUR' to mean the functional user requirements that:

- are derived from the available software artifacts (requirements, designs, physical artifacts, etc),
- are adjusted, if necessary, by assumptions to overcome uncertainties in the available artifacts,
- contain all the information needed for a COSMIC Functional Size Measurement.

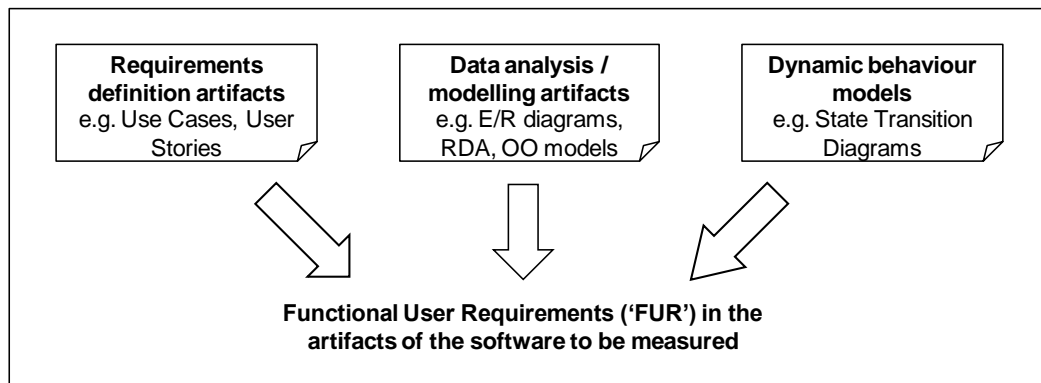
Otherwise we will use 'actual requirements' or 'physical artifacts', etc. as appropriate to the context.

Functional sizes measured by the COSMIC method are designed to depend only on the FUR of the software to be measured and to be independent of any requirements or constraints concerning the implementation of the FUR. 'Functionality' may be loosely defined as 'the information processing that the software must perform for its users'.

### **1.2.1 Extracting the Functional User Requirements from software artifacts in practice**

In the real world of software development it is rare to find artifacts for the software in which the FUR are clearly distinguished from other types of requirements and are expressed in a form suitable for direct measurement without any need for interpretation. This means that usually the Measurer will have to extract the FUR from the available artifacts of the software, before mapping them to the concepts of the COSMIC 'models of software'.

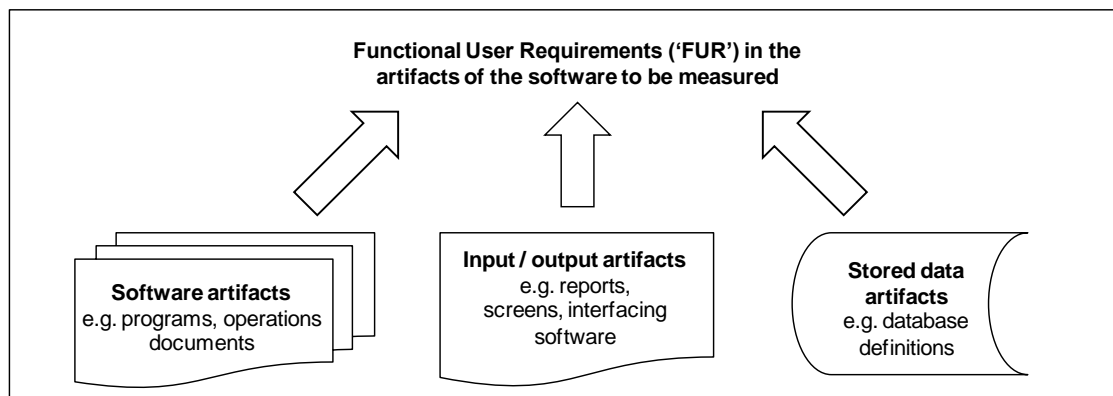
As illustrated in Figure 1.1, FUR can be derived from software engineering artifacts that are produced before the software exists. Thus, the functional size of software can be measured prior to its implementation in a computer system.



**Figure 1.1 – Pre-implementation sources of Functional User Requirements**

NOTE: Functional user requirements may be produced even before they are allocated to hardware or software. Since the COSMIC method is aimed at sizing the FUR of a piece of software, only the FUR allocated to the software are measured. However, in principle COSMIC can be applied to FUR before they are allocated to software or to hardware, regardless of the eventual allocation decision. For example, it is straightforward to size the functionality of a pocket calculator using the COSMIC method without any knowledge of what hardware or software (if any) is involved. However, the assertion that the COSMIC method can be used to size FUR allocated to hardware needs more testing in practice before it can be considered as fully validated without the need for further rules.

In other circumstances, some existing software may need to be measured without there being any, or with only a few, architecture or design artifacts available, and the FUR might not be documented (e.g. for legacy software). In such circumstances, it is still possible to derive the FUR from the artifacts of the computer system even after it has been implemented, as illustrated in Figure 1.2.



**Figure 1.2 – Post-implementation sources of Functional User Requirements**

### **1.2.2 The process of deriving Functional User Requirements from software artifacts**

The process to be used and hence the effort required to extract the FUR from different types of software engineering artifacts or to derive them from installed software will obviously vary enormously; these processes cannot be dealt with in the Measurement Manual. The method assumes that the Functional User Requirements of the software to be measured either exist or that they can be extracted or derived from its artifacts, in light of the purpose of the measurement.

The Measurement Manual is therefore confined to defining and describing the concepts of the COSMIC models (the ‘Software Context Model’ and the ‘Generic Software Model’ – see section 1.3) and how to apply them to measure the FUR of a given piece of software.<sup>2</sup>

<sup>2</sup> Various COSMIC Guidelines, e.g. for sizing business application software [7] and for sizing real-time software [4] give guidance on the mapping from various data analysis and requirements determination methods and from software artifacts to the concepts of COSMIC.

If the Measurer really understands these two models, it will always be possible to derive the FUR of a piece of software to be measured from its available artifacts, though the Measurer may well have to make some assumptions due to missing or unclear information.

### 1.2.3 Non-Functional Requirements

The ISO standard definition of Functional User Requirements (or 'FUR', see above) lists various types of 'user requirements' that are not FUR. By implication these are Non-Functional Requirements (NFR).

NFR can be very significant for a software project. In extreme cases, a statement of requirements for a software-intensive system can require as much documentation for the NFR as for the FUR. But the distinction between NFR and FUR is not as simple as it appears from the ISO definition of FUR. The COSMIC method can be used to measure some requirements that may be first expressed as non-functional. First we need to define NFR:

DEFINITION – Non-Functional Requirement
Any requirement for or constraint on a hardware/software system or software product, or on a project to develop or maintain such a system or product, except a functional user requirement for software.
NOTE: System or software requirements that are initially expressed as non-functional often evolve as a project progresses wholly or partly into FUR for software.

Several studies [3] have shown that some requirements that initially appear as *system* NFR evolve as a project progresses into a mixture of requirements that can be implemented in software functions, and other requirements or constraints that are truly 'non-functional'. See Figure 1.3. This is true for many quality and environmental constraints. Once identified, these software functions that have been 'hidden' in NFR at the beginning of a project can be sized using the COSMIC method just as any other software functions. Not recognizing this 'hidden' functional size is one reason why software sizes can appear to grow as a project progresses.

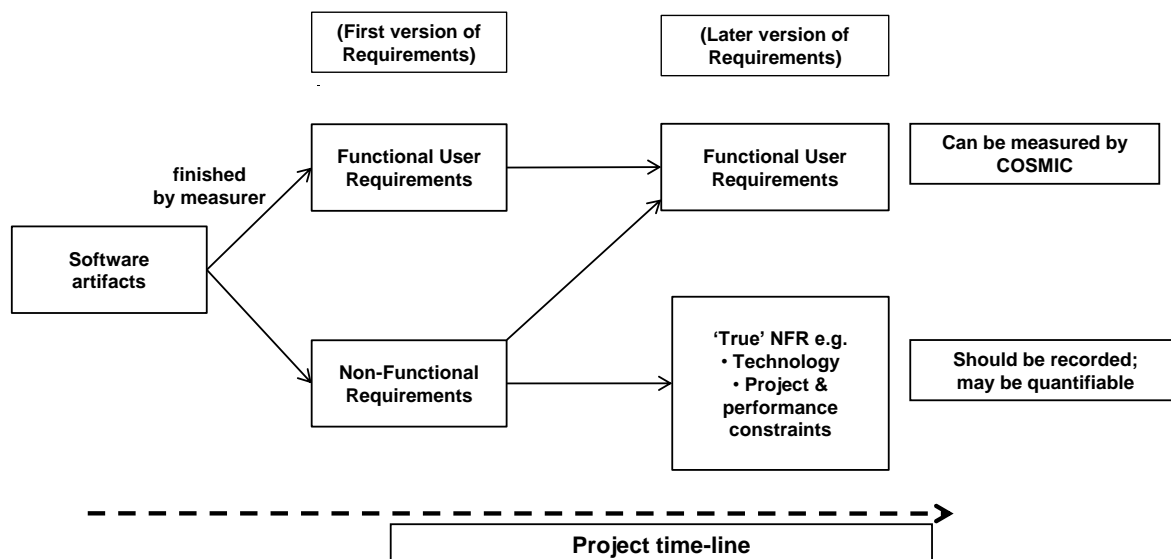


Figure 1.3 - Many requirements initially appearing as NFR evolve into FUR as a project progresses

*BUSINESS EXAMPLE: The requirements for a new software system include the statement 'the user shall have the option to secure files by encryption'. The project to develop the system is at the stage of estimating effort and cost. Two options are considered:*

- Develop some proprietary encryption software. For project estimating purposes it may be necessary to measure the size of the FUR for the encryption software.*
- Purchase an existing Commercial Off-The-Shelf (COTS) package. For project estimating purposes it may be necessary to measure only the size of the software function needed to integrate the COTS package. The cost of the package and the effort to integrate and test the file encryption package will also need to be considered in the project cost estimate.*

*REAL-TIME EXAMPLE: Fault tolerance on aerospace systems is achieved mostly through a combination of redundancy and backup of the physical systems. A function such as engine monitoring is copied on three or four separate embedded computers. This function has a strict timing constraint stated as a NFR: 'each separate computer must respond within a specific time. If any one of the computers repeatedly responds later than the required time, or its results disagree with the others, it must be out-voted' (by a mechanism specified as a functional requirement). A requirement that is initially stated as non-functional therefore evolves into FUR that can be measured. The timing mechanism can also be partly implemented in software and this functionality can also be measured (see for example the 'Guideline for sizing real-time software' [4], section 3.2).*

For more examples, see Appendix B. All these examples demonstrate that when there is a requirement to measure a size of some software early in the life of a project, it is important to consider whether some NFR could evolve into software FUR and whether the size of these software FUR should also be measured.

### **1.3 The fundamental principles of the COSMIC method**

The COSMIC method is based on fundamental software engineering principles. These principles are summarized in two models.

In the same way that a house can have many sizes depending on what you want to measure, the size of a piece of software can be measured in many ways, even using the same unit of measurement. The principles of the 'Software Context Model' enable a Measurer to define the software to be measured and the size measurement. These ensure that the results can be understood and interpreted consistently by future users.

The principles of the 'Generic Software Model' define how the FUR of the software to be measured are modeled so that they can be measured.

The main reason for including these two models at this stage in the Measurement Manual is to show how the COSMIC method is fundamentally very simple. We will also need to refer to the two models later in the Manual. However, a novice Measurer should not expect to be able to read these two models and then go away and measure accurately. To apply the models to a particular measurement situation, the Measurer will need the definitions of the various concepts and the additional principles, rules, explanations and examples given in this Manual.

N.B. Terms that are given in bold when first used in the following sections 1.3.1 and 1.3.2 are used with meanings that may be specific to the COSMIC method. For the formal definitions, see the glossary at the end of this Measurement Manual. The references given with each principle are to the sections of this Manual where the subject is dealt with in detail.

### 1.3.1 The COSMIC Software Context Model

PRINCIPLES – The COSMIC Software Context Model	Section
a) Software is bounded by hardware.	-
b) Software is typically structured into <b>layers</b> .	2.2.2
c) A layer may contain one or more separate ' <b>peer</b> ' pieces of software.	2.2.2
d) Any piece of software to be measured, shall be defined by its measurement <b>scope</b> , which shall be confined wholly within a single layer.	2.2
e) The scope of a piece of software to be measured shall depend on the <b>purpose</b> of the measurement.	2.1
f) The <b>functional users</b> of a piece of software to be measured shall be identified from its Functional User Requirements (FUR) as the senders and/or intended recipients of data to/from the software respectively.	2.3
g) The FUR of software may be expressed at different <b>levels of granularity</b> .	2.4
h) A precise COSMIC size measurement of a piece of software requires that its FUR are known at a level of granularity at which its <b>functional processes</b> and sub-processes may be identified.	2.4.3
i) An approximate COSMIC size measurement of a piece of software is possible if its FUR are measured at a high level of granularity by an approximation approach and scaled to the level of granularity of the functional processes and sub-processes.	2.4.3

### 1.3.2 The Generic Software Model

Having identified and defined the FUR of the software to be measured in terms of the Software Context Model, we now apply the Generic Software Model to the FUR to identify the components of the functionality that will be measured. This Generic Software Model assumes that the following general principles hold true for any software that can be measured with the method. (As noted in the glossary, any functional size measurement method aims to identify 'types' and not 'occurrences' of data or functions. In the Measurement Manual, the suffix 'type' will therefore be omitted when mentioning COSMIC basic concepts unless it is essential to distinguish 'types' from 'occurrences'.)

PRINCIPLES – The COSMIC Generic Software Model	Section
a) A piece of software interacts with its functional users across a <b>boundary</b> , and with <b>persistent storage</b> within this boundary.	2.3
b) Functional user requirements of a piece of software to be measured can be mapped into unique functional processes.	3.2
c) Each functional process consists of sub-processes.	3.2
d) A sub-process may be either a <b>data movement</b> or a <b>data manipulation</b> .	3.2
e) A data movement moves a single <b>data group</b> .	3.3
f) There are four data movement types, <b>Entry</b> , <b>Exit</b> , <b>Write</b> and <b>Read</b> . An Entry moves a data group into a functional process from a functional user. An Exit moves a data group out of a functional process to a functional user. A Write moves a data group from a functional process to persistent storage. A Read moves a data group from persistent storage to a functional process.	3.5
g) A data group consists of a unique set of <b>data attributes</b> that describe a single <b>object of interest</b> .	3.4
h) Each functional process is started by its <b>triggering Entry</b> data movement. The data group moved by the triggering Entry is generated by a functional user in response to a <b>triggering event</b> .	3.2

i) A functional process shall include at least one Entry data movement and either a Write or an Exit data movement, i.e. it shall include a minimum of two data movements. There is no upper limit to the number of data movements in a functional process  j) As an approximation for measurement purposes, data manipulation sub-processes are not separately measured; the functionality of any data manipulation is assumed to be accounted for by the data movement with which it is associated.	3.5
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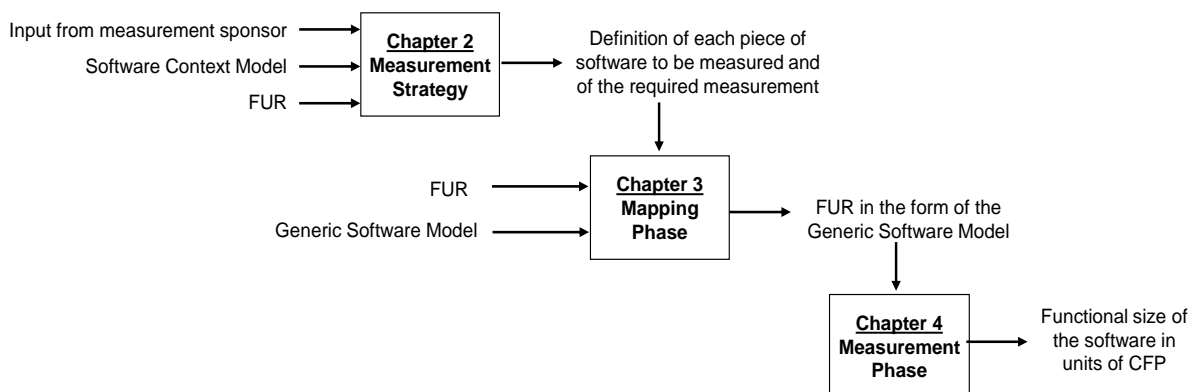
## 1.4 The COSMIC measurement process and the unit of measurement

The COSMIC measurement process consists of three phases:

- the Measurement Strategy phase, in which the purpose and scope of the measurement are defined. The Software Context Model is then applied so that the software to be measured and the required measurement are unambiguously defined. (Chapter 2)
- the Mapping Phase in which the Generic Software Model is applied to the FUR of the software to be measured to produce the COSMIC model of the software that can be measured. (Chapter 3)
- the Measurement Phase, in which actual sizes are measured. (Chapter 4)

Rules for how measurements should be recorded are given in Chapter 5.

The relationship of the three phases of the COSMIC method is shown in Figure 1.4.



**Figure 1.4 – The COSMIC method measurement process**

The COSMIC unit of measurement (the ‘CFP’) and the measurement principle are defined as follows.

### DEFINITION – COSMIC unit of measurement

1 CFP (Cosmic Function Point), which is the size of one data movement.

### PRINCIPLE – The COSMIC measurement principle

- The size of a functional process is equal to the number of its data movements.
- The functional size of a piece of software of defined scope is equal to the sum of the sizes of its functional processes.

Sizes of required changes to a piece of software are measured as follows:

- The size of any data movement impacted (i.e. that must be added, modified or deleted) by the required change is measured by convention as one CFP.
- The size of the required changes to a piece of software is equal to the number of data movements that are impacted by the required changes.
- The minimum size of a change to a piece of software is 1 CFP.

Further rules and guidance on measurement and aggregation of measurements are given in sections 4.1 to 4.4 of this Measurement Manual.

### **1.5 Limitations on the applicability of the COSMIC method**

See section 4.5 for possible limitations of the method and how it may be possible to extend the method locally to overcome the limitations.



## THE MEASUREMENT STRATEGY PHASE

### 2.0 Chapter summary

This chapter describes the key parameters that must be considered in the first ‘Measurement Strategy’ phase of the measurement process, before actually starting to measure. These are (*in italics*):

- The *purpose* of the measurement, i.e. what the result will be used for. The purpose determines the other parameters of a measurement.
- The *overall scope* of the software to be measured and, if the software consists of more than one part that should be measured separately (e.g. the components of a distributed software system), the *measurement scope(s)* of the individual parts. We also need to determine the *layer* in which each piece of software is situated and maybe the *level of decomposition* of the pieces of software to be measured.
- The *functional users* of each piece of software to be measured. These are the senders and intended recipients of data to/from the software to be measured; they may be humans, hardware devices or other pieces of software. As different functional users may ‘see’ different functionality, functional sizes vary with the choice of functional users.
- The *level of granularity* of the available artifacts of the software to be measured. For example, maybe the only available statement of requirements is not defined in all the detail needed for a precise COSMIC measurement. We must therefore decide how to derive the FUR to be measured and/or whether an approximate size variant should be used.

Determining these parameters helps answer the questions of ‘which size should be measured’, ‘how accurate do we want the measurement’, etc. Recording the parameters enables future users of a measurement to decide how to interpret the measurement.

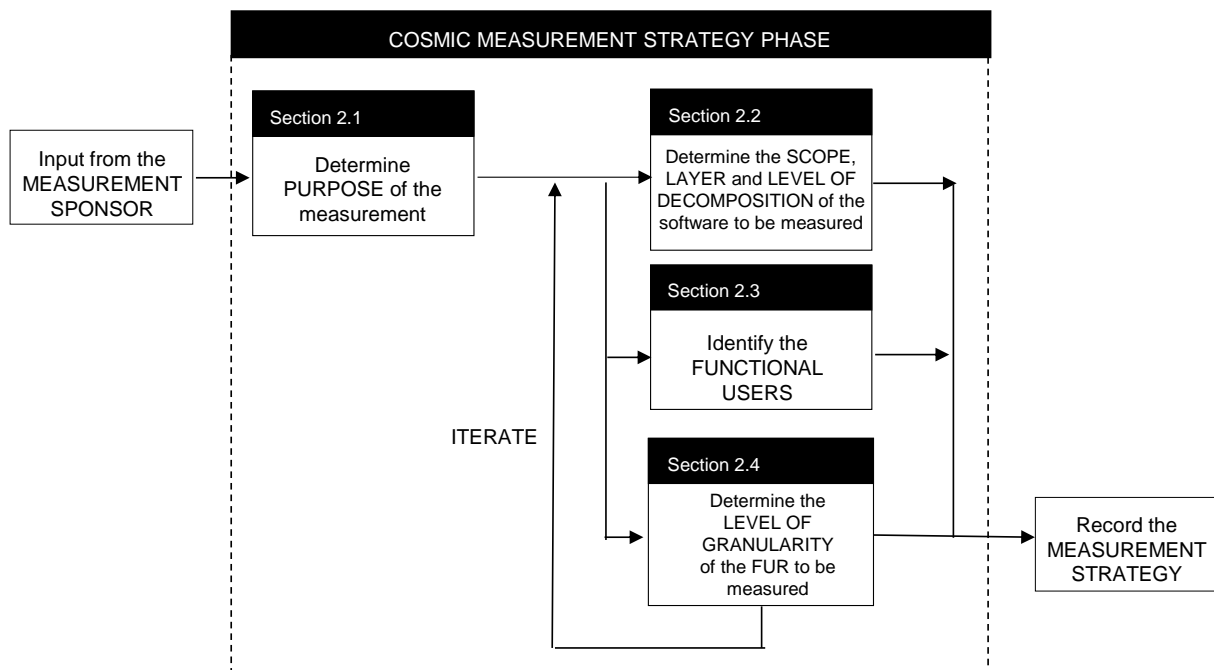
It is important to note that these parameters and related concepts are not specific to the COSMIC FSM method, but should be common to all FSM methods. Other FSM methods may not distinguish different types of functional users and may not discuss different levels of granularity, etc. It is only the broader applicability and flexibility of the COSMIC method that requires these parameters to be considered more carefully than with other FSM methods.

It is very important to record the data arising from this Measurement Strategy phase (as listed in section 5.2) when recording the result of any measurement. Failure to define and to record these parameters consistently will lead to measurements that cannot be interpreted reliably and compared, or be used reliably as input for processes such as estimating project effort.

The sections of this chapter give the formal definitions, principles and rules and some examples for each of the key parameters to help the Measurer through the process of determining a measurement strategy, as shown in Figure 2.0 below.

Each section gives some background explanation of why the key parameter is important, using analogies to show why the parameter is taken for granted in other fields of measurement, and hence must also be considered in the field of software functional size measurement.

Note from Figure 2.0 that determining the parameters of the Measurement Strategy may need some iteration.



**Figure 2.0 - The process of determining a Measurement Strategy**

## Measurement Strategy Patterns

As an aid to determining a measurement strategy, the Guideline for 'Measurement Strategy Patterns' [5] describes, for each of several different types of software, a standard set of parameters for measuring software sizes, called a 'measurement strategy pattern' (abbreviated to 'measurement pattern').

### DEFINITION – Measurement (Strategy) Pattern

A standard template that may be applied when measuring a piece of software from a given software functional domain, that defines the types of functional user that may interact with the software, the level of decomposition of the software and the types of data movements that the software may handle.

Consistent use of the same measurement patterns should help Measurers to ensure that measurements made for the same purpose are made in a consistent way, may be safely compared with other measurements made using the same pattern and will be correctly interpreted for all future uses. A side benefit of using a standard pattern is that the effort to determine the Measurement Strategy parameters is much reduced. We do, however, strongly recommend that Measurers study and master the COSMIC method, especially the Measurement Strategy parameters, before using the standard patterns.

## 2.1 Defining the purpose of the measurement

The term 'purpose' is used in its normal English meaning.

### DEFINITION – Purpose of a measurement

A statement that defines why a measurement is required, and what the result will be used for.

### 2.1.1 The purpose of the measurement – an analogy

There are many reasons to measure the functional size of software, just as there are many reasons to measure, say, the surface areas of a house and in both cases the different reasons may result in different sizes. Starting with the analogy, the size of a house may well vary with:

- the reason for and timing of the measurement (e.g. depending on the need to measure the customer's outline specification for budgeting, or the architect's plans for a precise cost estimate, or the actual size on completion for planning floor coverings),
- the artifacts measured (e.g. the plans or the physical building).

Note, however, the same measurement principles and the unit of measurement are used for all the measurements. In exactly the same way, the measured size of a piece of software may well vary with:

- the reason for and timing of the measurement (e.g. depending on the need to measure prior to development for estimating purposes, or during development to track scope creep, or after installation to measure the developer's performance),
- the artifacts measured (e.g. a statement of requirements, or the physical software artifacts).

As with the analogy, however, the same measurement principles and the unit of measurement are used for all the measurements.

Clearly it is up to the Measurer of a piece of software to decide, depending on the purpose of the measurement, *when* to measure (before, during or after development), *what* to measure (e.g. all the software to be delivered by a project, or to exclude re-used software) and *which artifacts* to use to derive the FUR to be measured (e.g. a statement of requirements or the installed software).

*EXAMPLES: The following are typical measurement purposes*

- *To measure the size of the FUR as they evolve, as input to a process to estimate development effort.*
- *To measure the size of changes to the FUR after they have been initially agreed, in order to manage project 'scope creep'.*
- *To measure the size of the FUR of the delivered software as input to the measurement of the developer's performance.*
- *To measure the size of the FUR of the total software delivered, and also the size of the FUR of the software which was developed, in order to obtain a measure of functional re-use.*
- *To measure the size of the FUR of the existing software as input to the measurement of the performance of those responsible for maintaining and supporting the software.*
- *To measure the size of some changes to (the FUR of) an existing software system as a measure of the size of the work-output of an enhancement project team.*
- *To measure the size of the sub-set of functionality of the software provided to human functional users.*

### **2.1.2 The importance of the purpose**

The purpose helps the Measurer to determine:

- The scope to be measured and hence the artifacts which will be needed for the measurement.
- The functional users (as will be shown in section 2.3, the functional size changes depending on who or what is defined as the functional user).
- The point in time in the project life-cycle when the measurement will take place.
- The required accuracy of the measurement, and hence whether the standard COSMIC method should be used, or whether an approximation version of the standard COSMIC method should be used (e.g. early in a project's life-cycle, before the FUR are fully elaborated).

Both of these latter two points will determine the level of granularity at which the FUR will be measured.

## 2.2 Defining the scope of the measurement

### DEFINITION – Scope of a measurement

The set of Functional User Requirements to be included in a specific functional size measurement exercise.

NOTE: (specific to the COSMIC method) A distinction should be made between the 'overall scope', i.e. all the software that should be measured according to the purpose, and the 'scope' of any individual piece of software within the overall scope, whose size should be measured separately. In this Measurement Manual, the term 'scope' (or the expression 'measurement scope') will relate to an individual piece of software whose size must be measured separately.

### RULES – Measurement scope

- a) The scope of any piece of software to be measured shall be derived from the purpose of the measurement.
- b) The scope of any one measurement shall not extend over more than one layer of the software to be measured.

See the next section for examples of the overall scope and measurement scopes.

### 2.2.1 Deriving the scope from the purpose of a measurement

The software defined by an *overall scope* may be sub-divided into individual pieces of software each with their own defined *measurement scope* in many ways, depending on the purpose of the measurement. Suppose an overall scope is defined as 'the application portfolio of organization X' or as 'all the pieces of software to be delivered by project Y'. The sub-divisions could be made due to:

- software in different layers (due to rule b) above),
- different organizational responsibilities, e.g. by customer-group or sub-project team,
- the need to distinguish different deliverables for performance measurement, effort estimation or for software contract purposes.

The latter reason could be due to the need to distinguish separate measurement scopes for pieces of software that:

- are built using different technologies, i.e. hardware platform, programming language, etc,
- operate in different modes, i.e. on-line-versus batch modes,
- are developed as opposed to 'delivered' (the latter including. package-implemented or other re-used software),
- are at different levels of decomposition, e.g. a whole application or a major component or a minor component such as re-usable object,
- are the main deliverables as opposed to software that is used once, e.g. for data conversion, and then discarded; it might not be worth the effort of measuring the latter,
- are developed versus enhanced software,

and any combinations of these factors.

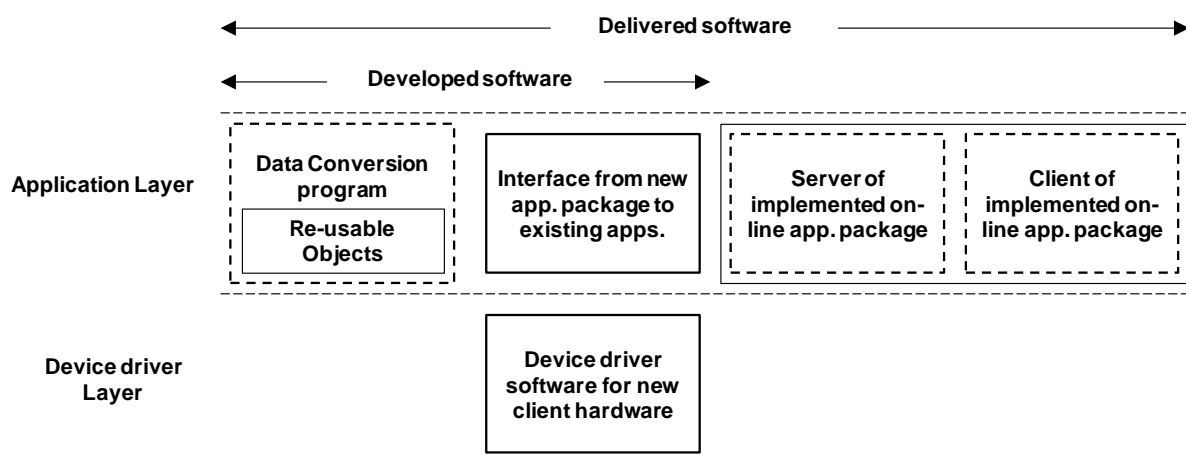
In summary, the purpose of the measurement must always be used to determine (a) what software is included or excluded from the overall scope and (b) the way the included software may need to be divided up into separate pieces, each with its own scope, to be measured separately.

In practice a scope statement needs to be explicit rather than generic, e.g. the developed work-output of project team 'A', or application 'B', or the portfolio of enterprise 'C'. The scope statement may also, for clarity, need to state what is excluded.

*BUSINESS EXAMPLE: Figure 2.1 shows all the separate pieces of software – the 'overall scope' - delivered by a project team:*

- the client and the server components of an implemented software package
- a program that provides an interface between the server component of the new package and existing applications
- a program that is used once to convert existing data to the new format required by the package. This program was built using a number of re-usable objects developed by the project team
- the device driver software for new hardware on which the package client component will execute

*(Each individual piece of software for which a measurement scope was defined is shown as a solid rectangular box.)*



**Figure 2.1 - The overall scope of the deliverables of a software project and the individual measurement scopes**

*The diagram shows that the 'delivered' pieces of software consisted of some that were newly developed and some that were implemented by the project team.*

*The size of the implemented package was measured as a 'whole', i.e. ignoring the client-server component structure. This size was added with that of the interface program to update the total size of the organization's application portfolio. The size of the data conversion program was not of interest as it was used once and thrown away. But the size of each of the re-usable objects was recorded in the organization's infrastructure software inventory, as well as that of the new device driver. Again these were classified separately.*

*Due to the diverse nature of the deliverables it made no sense when measuring the project team's performance to add together the sizes of all the delivered software. The performance of the teams that delivered each piece of software was measured separately.*

## 2.2.2 Layers

Since the scope of a piece of software to be measured must be confined to a single software layer, the process of defining the scope may require that the Measurer first has to decide what are the layers of the software architecture. In this section we will therefore define and discuss 'layers' of software as these terms are used in the COSMIC method. The reasons why we need these definitions and rules are as follows

- The Measurer may be faced with measuring some software in a 'legacy' environment of software that evolved over many years without ever having been designed according to an underlying

architecture (the software to be measured has a so-called 'spaghetti architecture'). The Measurer may therefore need guidance on how to distinguish layers according to the COSMIC terminology.

- The expressions 'layer' and 'layered architecture' are not used consistently in the software industry. If the Measurer must measure some software that is described as being in a 'layered architecture', it is advisable to check that 'layers' in this architecture are defined in a way that is compatible with the COSMIC method. To do this, the Measurer should establish the equivalence between specific architectural objects in the 'layered architecture' paradigm and the concept of layers as defined in this manual.

Layers may be identified according to the following definitions and principles.

<b>DEFINITION – Layer</b>
A functional partition of a software system architecture.

In a defined software architecture, each layer should comply with the following principles:

<b>PRINCIPLES – Layer</b>
<p>a) Software in one layer provides a set of services that is cohesive according to some defined criterion, and that software in other layers can utilize without knowing how those services are implemented.</p> <p>b) The relationship between software in any two layers is defined by a 'correspondence rule' which may be either</p> <ul style="list-style-type: none"> <li>• 'hierarchical', i.e. software in layer A is allowed to use the services provided by software in layer B but not vice versa (where the hierarchical relationship may be up, down or sideways), or</li> <li>• 'bi-directional', i.e. software in layer A is allowed to use software in layer B, and vice versa.</li> </ul> <p>c) Software in one layer exchanges data groups with software in another layer via their respective functional processes.</p> <p>d) Software in one layer does not necessarily use all the functional services supplied by software in another layer.</p> <p>e) Software in one layer of a defined software architecture may be partitioned into other layers according to a different defined software architecture.</p>

Often, a measurement relates to two or more 'peer' pieces of software, defined as follows:

<b>DEFINITION – Peer pieces of software</b>
Two pieces of software are peers of each other if they reside in the same layer.

*EXAMPLE: The pieces of software in the application layer of Figure 2.1 are all peers of each other.*

If the software to be measured exists within an established architecture of layers that can be mapped to the COSMIC layering principles as defined above, then that architecture should be used to identify the layers for measurement purposes.

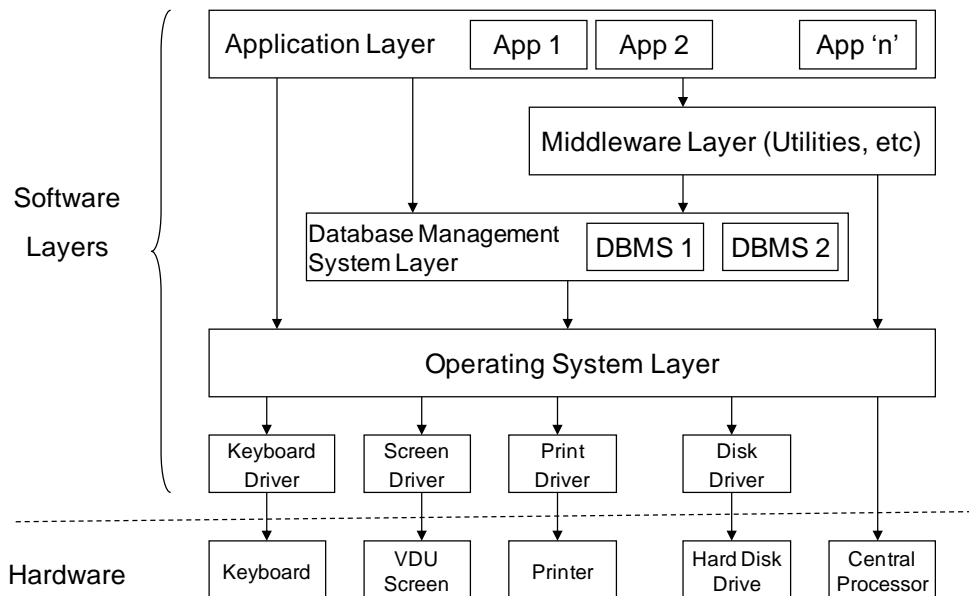
If however, the purpose requires that some software is measured that is not structured according to the COSMIC layering principles, the Measurer should try to partition the software into layers by applying the principles defined above. Conventionally, infrastructure software packages such as database management systems, operating systems or device drivers, that provide services that can be used by other software in other layers, are each located in separate layers.

Normally in software architectures, the 'top' layer, i.e. the layer that is not a subordinate to any other layer in a hierarchy of layers, is referred to as the 'application' layer. Software in this application layer relies on the services of software in all the other layers for it to perform properly. Software in this 'top'

layer may itself be layered, e.g. as in a 'three-layer architecture' of User Interface, Business Rules and Data Services components (see Example 5 below).

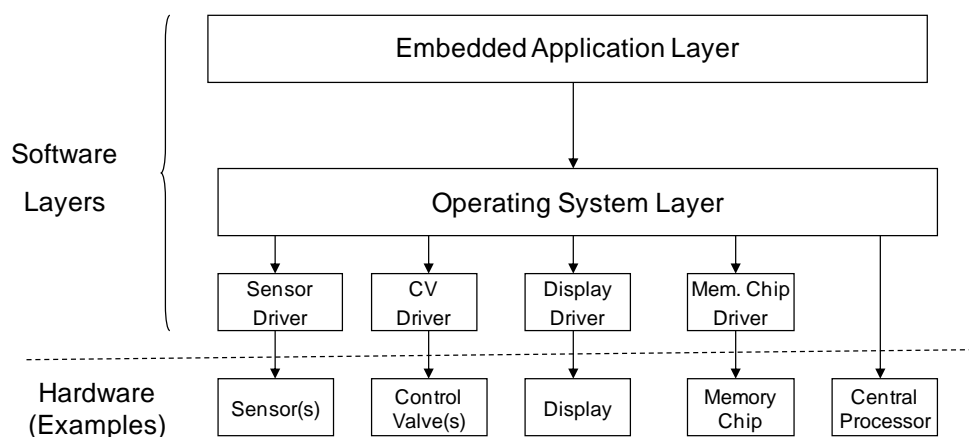
Once identified, each layer can be registered in the Generic Software Model matrix (Appendix A), with the corresponding label.

*BUSINESS EXAMPLE 1: The physical structure of a typical layered software architecture (using the term 'layer' as defined here) supporting business applications software is given in Figure 2.2:*



**Figure 2.2- Typical layered software architecture for a Business/MIS computer system**

*REAL-TIME EXAMPLE 2: The physical structure of a typical layered software architecture (again using the term 'layer' as defined here) supporting a piece of embedded real-time software is given in Figure 2.3:*



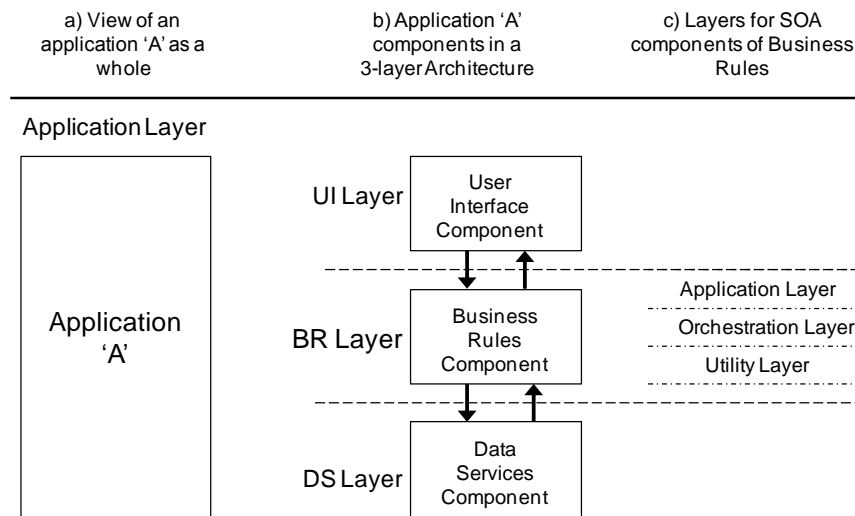
**Figure 2.3 - Typical layered architecture for a real-time embedded-software computer system**

*REAL-TIME EXAMPLE 3: The ISO 7-layer (OSI) model for telecommunications. This defines a layered architecture for which the hierarchical correspondence rules for the layers of the message-receiving software are the inverse of the rules for the layers of the message-transmitting software.*

*REAL-TIME EXAMPLE 4: The 'Autosar' architecture of the auto industry which exhibits all the different types of correspondence rules between layers now described in the principles for a layer. See [www.autosar.org/download/AUTOSAR\\_LayeredSoftwareArchitecture.pdf](http://www.autosar.org/download/AUTOSAR_LayeredSoftwareArchitecture.pdf).*

A software architecture may exhibit different layers depending on the 'view' of the architecture.

**BUSINESS EXAMPLE 5:** Consider an application A situated in a layered software architecture, as in Figure 2.4 below, which shows three possible layer structures a), b) and c) according to different architecture 'views'



**Figure 2.4 - Three views of the layers of an application**

*Purpose 1 is to measure the functional size of application A 'as a whole', as in View a). The measurement scope is the whole of application A, which exists entirely within the one 'application' layer*

*Purpose 2. Application A has been built according to a 'three-layer' architecture comprising a User Interface, Business Rules and Data Services components. Purpose 2 is to measure the three components separately as in View b). Each component is situated in its own layer of the architecture and the measurement scope must be defined separately for each component.*

*Purpose 3. The Business Rules component of the application has been built using re-usable components of a Service-Oriented Architecture, which has its own layer structure. Purpose 3 is to measure an SOA component of the Business Rules component as in View c). Each SOA component is situated in a layer of the SOA architecture and the measurement scope must be defined separately for each SOA component. (Note that SOA terminology also uses 'application layer' within its own architecture.)*

### 2.2.3 Levels of decomposition

The 'level of decomposition' of a piece of software is defined as follows:

#### DEFINITION – Level of decomposition

Any level resulting from dividing a piece of software into components (named 'Level 1', for example), then from dividing components into sub-components ('Level 2'), then from dividing sub-components into sub-sub components ('Level 3'), etc.

NOTE 1: Not to be confused with 'level of granularity'.

NOTE 2: Size measurements of the components of a piece of software may only be directly comparable for components at the same level of decomposition.

**EXAMPLE:** The Guideline for 'Measurement Strategy Patterns' [5] recognizes three standard levels of decomposition: 'Whole application', 'Major Component' and 'Minor component'. See business example 5 in section 2.2.2 of this Measurement Manual, where the three levels are shown in Figure 2.4.



Defining the measurement scope summary: Determining a measurement scope may therefore be more than just a question of simply deciding what functionality should be included in the measurement. The decision may also involve consideration of the layer(s) in which the software to be measured resides and the level of decomposition of software at which the measurement(s) will be made, all dependent on the purpose of the measurement.

## 2.3 Identifying the functional users and persistent storage

### 2.3.1 Functional size may vary with the functional users

Different types of users of a 'thing' may 'see' different functionality and hence may measure different sizes of the 'thing'. In the case of software, different (types of) functional users may require (via their FUR) different functionality and therefore functional sizes will vary with the choice of functional users.

A 'user' is defined, in effect<sup>3</sup>, as 'any thing that interacts with the software being measured'. This definition is too broad for the needs of the COSMIC method. For the COSMIC method, the choice of user (or users) is determined by the Functional 'User' Requirements that must be measured. This (type of) user, known as the 'functional user', is defined as follows.

DEFINITION – Functional user
A (type of) user that is a sender and/or an intended recipient of data in the Functional User Requirements of a piece of software.

In the COSMIC method it is essential to distinguish the functional users of a piece of software that must be measured from all of its possible users.

*EXAMPLE 1: Consider a business application, its functional users would normally include humans and other peer applications with which the application interfaces. For a real-time application, the functional users would normally be engineered hardware devices or other interfacing peer software. The FUR of such software normally identify the functional users that are the senders of data and/or the intended recipients of data to and from the software, respectively.*

However, the total set of 'users', i.e. including 'any thing that interacts with the software', must include the operating system. But the FUR of any application would never include the operating system as a user. Any constraints that the operating system may impose on an application will be common to all applications, will normally be handled by the compiler or interpreter, are invisible to the real functional users of the application and therefore do not appear in the FUR. In practical functional size measurement, an operating system never normally needs to be considered as a functional user of an application. But it is not always the case that the functional users are obvious.

*EXAMPLE 2: Consider the application software of a mobile phone. Having excluded the operating system of the mobile phone as a possible functional user of the application, the 'users' could still be either (a) humans who press the keys, or (b) hardware devices (e.g. the screen, keys, etc) and peer applications that interact directly with the phone application. The human user, for example, will see only a sub-set of all the functionality that must be provided to enable the mobile phone application to work. So these two types of users will 'see' different functionality, the size of the FUR for the human user will be smaller than the size of the FUR that must be developed to make the phone application work.<sup>4</sup>*

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<sup>3</sup> See the glossary for the definition, taken from ISO/IEC 14143/1:2007

<sup>4</sup> Toivonen, for example, compared the functionality of mobile phones available to human users in 'Defining measures for memory efficiency of the software in mobile terminals', International Workshop on Software Measurement, Magdeburg, Germany, October 2002.

<b>RULES – Functional users</b>
<p>a) The functional users of a piece of software to be measured shall be derived from the purpose of the measurement.</p> <p>b) When the purpose of a measurement of a piece of software is related to the effort to develop or modify the piece of software, then the functional users should be all the senders and/or intended recipients of data to/from the new or modified functionality, as required by its FUR.</p>

Having identified the functional users, it is then straightforward to identify the boundary. The boundary lies between the piece of software being measured and its functional users. We ignore any other hardware or software in that intervening space<sup>5</sup>.

<b>DEFINITION – Boundary</b>
<p>A conceptual interface between the software being measured and its functional users.</p> <p>NOTE: It follows from the definition that there is a boundary between any two pieces of software in the same or different layers that exchange data where one piece of software is a functional user of the other, and/or vice versa.</p>

NOTE: This definition of ‘boundary’ is taken from ISO/IEC 14143/1:2007, modified by the addition of ‘functional’ to qualify ‘user’. To avoid ambiguity, note that the boundary should not be confused with any line that might be drawn around some software to be measured to define the measurement scope. The boundary is not used to define the scope of a measurement.

### **2.3.2 Persistent storage**

<b>DEFINITION – Persistent storage</b>
<p>Storage which enables a functional process to store a data group beyond the life of the functional process and/or from which a functional process can retrieve a data group stored by another functional process, or stored by an earlier occurrence of the same functional process, or stored by some other process.</p> <p>NOTE 1: In the COSMIC model, persistent storage is a concept that exists only within the boundary of the software being measured, it cannot therefore be considered as a functional user of the software being measured.</p> <p>NOTE 2: An example of ‘some other process’ would be the manufacture of read-only memory.</p>

(For the definition of a ‘functional process’, see section 3.2)


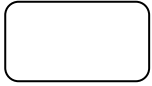
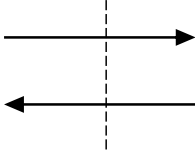
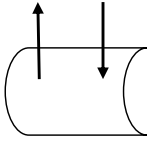
### **2.3.3 Context diagrams**

It can be very helpful when defining a measurement scope and the functional users to draw a ‘context diagram’ for the software being measured. In this and other COSMIC Guidelines, context diagrams are used to show the scope of a piece of software to be measured within its context of functional users (humans, other software, or hardware devices) and the movements of data between them. (Context diagrams usually also show persistent storage, if relevant.)

A context diagram is effectively an instance of a measurement pattern (see section 2.0) applied to the software being measured. The key to symbols used in context diagrams is as indicated in Figure 2.5:

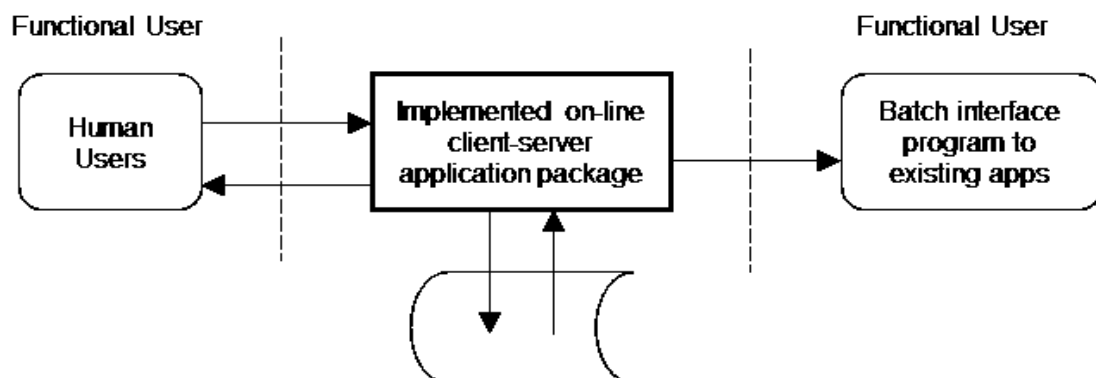
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<sup>5</sup> In fact, if the measurer has had to examine the FUR in order to identify the senders and intended recipients of data, the boundary will have already been identified.

Symbol	Interpretation
	The piece of software to be measured (box with thick outline) i.e. the definition of a measurement scope.
	Any functional user of the software being measured.
	The arrows represent <u>all</u> the movements of data crossing a boundary (the dotted line) between a functional user and the software being measured.
	The arrows represent <u>all</u> the movements of data between the software being measured and 'persistent storage'.  (The standard flowchart symbol for 'data storage' emphasizes that persistent storage is an abstract concept. Use of this symbol indicates that the software does not interact directly with physical hardware storage.)

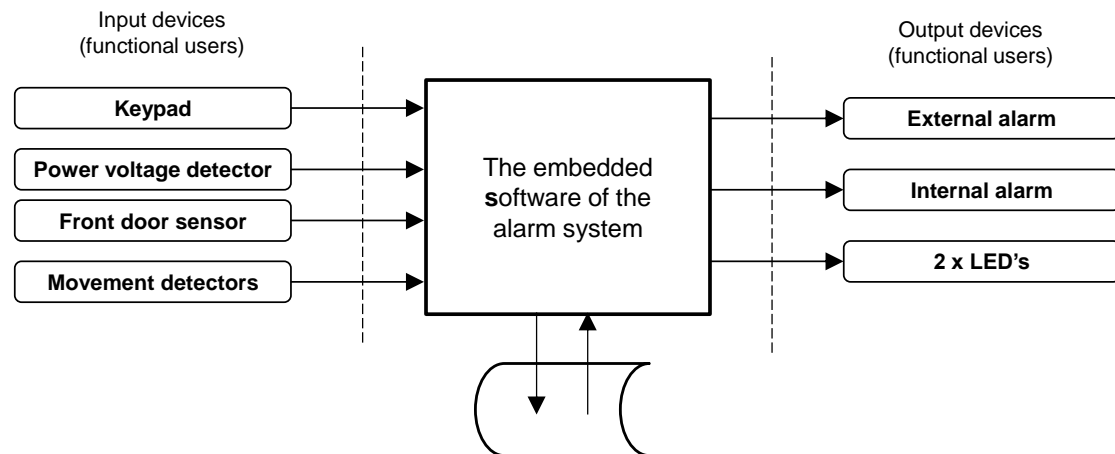
**Figure 2.5 - Key to the symbols of context diagrams**

*BUSINESS EXAMPLE:* Figure 2.6 shows the context diagram for the client/server software of the implemented application package as in the Example shown in Figure 2.1 of section 2.2.1, to be measured as a 'whole'.



**Figure 2.6 - Context diagram for the client-server application from section 2.2.1**

*REAL-TIME EXAMPLE:* Figure 2.7 shows the context diagram for a simple intruder alarm embedded software system (taken from the 'COSMIC Guideline for sizing real-time software' [4], version 1.0, section 4.2)



**Figure 2.7 - Context diagram for the embedded software of an intruder alarm system**

## 2.4 Identifying the level of granularity

### 2.4.1 The need for a standard level of granularity

In the initial stages of a software development project, actual requirements are specified 'at a high level', that is, in outline, or in little detail. As the project progresses, the actual requirements are refined, (e.g. through versions 1, 2, 3 etc.), revealing more detail 'at a lower level'. These different degrees of detail of the actual requirements (and hence of the derived FUR) are known as different 'levels of granularity'. (See also section 2.4.2 for other terms that may be confused with the concept of 'level of granularity' as defined here.)

#### **DEFINITION – Level of granularity**

Any level of expansion of the description of a single piece of software (e.g. a statement of its requirements, or a description of the structure of the piece of software) such that at each increased level of expansion, the description of the functionality of the piece of software is at an increased and uniform level of detail.

**NOTE:** Measurers should be aware that when requirements are evolving early in the life of a software project, at any moment different parts of the required software functionality will typically have been documented at different levels of granularity.

In most product development activities, plans are drawn to standard scales, and it is easy to translate dimensions measured on one drawing to those on another drawing with a different scale. In contrast there are no standard scales for the various levels of granularity at which software may be specified, so it may be difficult to be sure that two statements of FUR are at the same level of granularity. Without agreement on some standard level of granularity at which to measure (or to which measurements should be scaled) it is impossible to know for sure that two functional size measurements may be compared.

To illustrate the problems further, consider this analogy. A set of road maps reveals the details of a national road network at three levels of granularity:

- map A shows only motorways and main highways,
- map B shows all motorways, main and secondary roads (as in an atlas for motorists),
- map C shows all roads with their names (as in a set of local district road maps).

If we did not recognize the phenomenon of different levels of granularity, it would appear that these three maps revealed different sizes of the nation's road network. Of course, with road maps, everyone understands the different levels of detail shown and there are standard scales to interpret the size of the network revealed at any level. The abstract concept of 'level of granularity' lies behind the scales of these different maps.

For software measurement, there is only one standard level of granularity that it is possible to define unambiguously. That is the level of granularity at which individual functional processes and their data movements can be identified and defined. Measurements should be made at this level or scaled to this level whenever possible<sup>6</sup>.

## 2.4.2 Clarification of 'level of granularity'

Before proceeding further, it is important to ensure there is no misunderstanding about the meaning of 'level of granularity' in the COSMIC method. Zooming in on the FUR involves expanding the *description* of some software from a 'higher' to a 'lower' level of granularity and revealing more detail, *without changing its scope*. This process should NOT be confused with any of the following.

- Zooming in on some software in order to reveal its components, sub-components, etc (at different 'levels of decomposition' – see section 2.2.3 above). Such zooming in may be required if the measurement purpose requires the overall measurement scope to be sub-divided following the physical structure of the software.
- Evolving the description of some software as it progresses through its development cycle, e.g. from requirements to logical design, to physical design, etc. Whatever the stage in the development of some software, we are only interested in its FUR for measurement purposes.

The concept of 'level of granularity' is therefore intended to be interpreted as applying only to the Functional User Requirements of software.

## 2.4.3 The standard level of granularity

Precise COSMIC functional size measurements require that the FUR to be measured exist at a level of granularity at which functional processes and their data movements can be identified. The 'functional process level of granularity' is defined as follows<sup>7</sup>.

DEFINITION - Functional process level of granularity
<p>A level of granularity of the description of a piece of software at which:</p> <ul style="list-style-type: none"> <li>• its functional users are individual humans or engineered devices or pieces of software (and not any groups of these) AND</li> <li>• single events occur that the piece of software must respond to (and not any level at which groups of events are defined).</li> </ul> <p>NOTE 1: In practice, software documentation and hence Functional User Requirements often describe functionality at varying levels of granularity, especially when the documentation is still evolving.</p> <p>NOTE 2: 'Groups of these' (functional users) might, for example, be a 'department' whose members handle many types of functional processes; or a 'control panel' that has many types of instruments; or 'central systems'.</p> <p>NOTE 3: 'Groups of events' might, for example, be indicated in a statement of FUR at a high level of granularity by an input stream to an accounting software system labeled 'sales transactions'; or by an input stream to an avionics software system labeled 'pilot commands'.</p>

With this definition, we can now define the following rules and a recommendation.

<sup>6</sup> The topic of scaling measurements from one level of granularity to another is currently dealt with in the document 'Advanced and Related Topics' [6]. A 'Guideline for approximate COSMIC functional size measurement' [12] is under development which will eventually replace the existing document.

<sup>7</sup> The reason for the name 'functional process level of granularity' is that this is the level at which functional processes are identified – see section 3.2 for a more detailed discussion of functional processes.

## RULES - Functional process level of granularity

- a) Precise functional size measurement of a piece of software requires that its FUR are known at a level of granularity at which its functional processes and data movement sub-processes may be identified.
- b) If some requirements must be measured before they have been defined in sufficient detail for a precise measurement, the requirements can be measured using an approximate approach. These approaches define how requirements can be measured at higher level(s) of granularity. Scaling factors are then applied to the measurements at the higher level(s) of granularity to produce an approximate size at the level of granularity of the functional processes and their data movement sub-processes. See the 'Guideline for approximate COSMIC functional size measurement' [6].

In addition to the rules, COSMIC *recommends*<sup>8</sup> that the level of granularity at which functional processes and their data movement sub-processes are known should be the standard at which functional size measurements are required and used by providers of benchmarking services and of software tools designed to support or use functional size measurements, e.g. for estimating project effort.

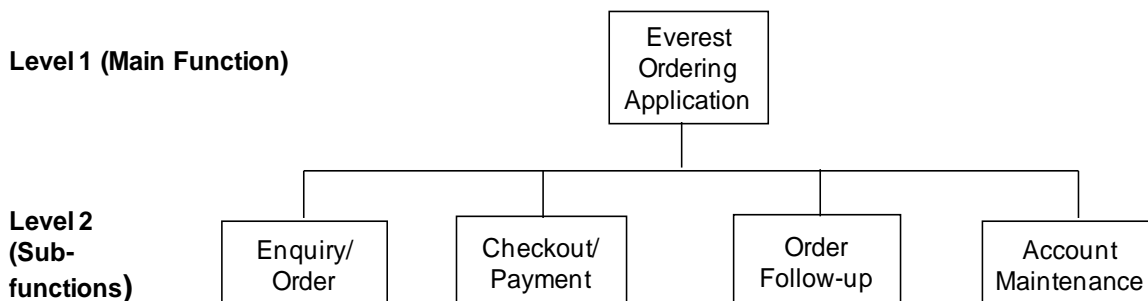
*BUSINESS EXAMPLE: The example, from the domain of business application software, is part of a well-known system for ordering goods over the Internet, which we will call the 'Everest Ordering Application'. The description below is highly-simplified for the purposes of this illustration of levels of granularity.*

*If we wished to measure this application, we might assume the purpose of the measurement is to determine the functional size of the part of the application available to the human customer users (as 'functional users'). We would then define the scope of the measurement as 'the parts of the Everest application accessible to customers for ordering goods over the Internet'. Note, however, that the purpose of this example is to illustrate different levels of granularity. We will therefore explore only some parts of the system's total functionality sufficient to understand this concept of levels of granularity.*

*At the highest 'Level 1 (Main Function)' of this part of the application a statement of the requirements of the Everest Ordering Application would be a simple summary statement such as the following.*

*'The Everest Ordering Application must enable customers to enquire upon, select, order, pay for and obtain delivery of any item of Everest's product range, including products available from third party suppliers.'*

*Zooming-in on this highest-level statement of the requirements we find that at the next lower level 2 the Everest Ordering Application consists of four sub-functions, as shown on Figure 2.8 (a).*



**Figure 2.8 (a) - Analysis of the Everest Ordering System: the first two levels of granularity**

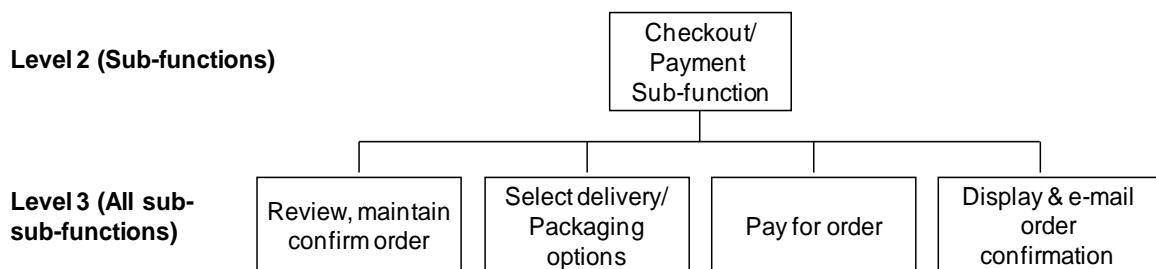
<sup>8</sup> The reason that use of the functional process level of granularity is 'recommended' rather than given as a rule is that this recommendation applies not just to individual users of the COSMIC method but to their networks of suppliers of services and tools that use the size measurements. COSMIC can only make recommendations to this wider community.

The requirements of the four sub-functions are:

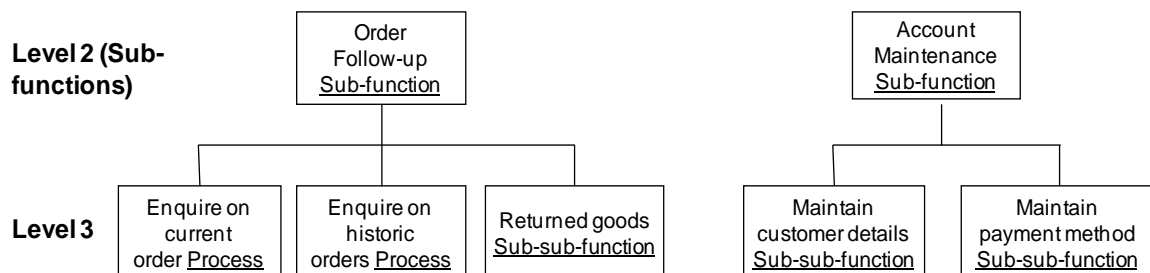
- The Enquiry/Order sub-function which enables a customer to find any product in the Everest database, as well as its price and availability and to add any selected product to a 'basket' for purchase. This sub-function also promotes sales by suggesting special offers, offering reviews of selected items and enabling general enquiries such as on delivery terms, etc. It is a very complex sub-function. We therefore do not analyze this sub-function in any further detail below level 2 for the purposes of this example.
- The Checkout/Payment sub-function which enables a customer to commit to order and pay for the goods in the basket.
- The Order Follow-up sub-function which enables a customer to enquire how far an existing order has progressed in the delivery process, to maintain their order (e.g. change delivery address) and to return unsatisfactory goods.
- The Account Maintenance sub-function which enables an existing customer to maintain various details of his/her account such as home address, means of payment, etc.

Figures 2.8 (b) and (c) show some detail that is revealed when we zoom-in on the requirements, down one further level of granularity on the Checkout/Payment sub-function, the Order Follow-up sub-function and the Account Maintenance sub-function. In this zooming-in process it is important to note that

- we have not changed the scope of the functionality to be measured, and
- all levels of the description of the Everest application show the functionality available to the customers (as functional users). A customer can 'see' the functionality of the application at all these levels of granularity.



**Figure 2.8 (b) - Decomposition of the Checkout/Payment Sub-function**



**Figure 2.8 (c) - Decomposition of the Order Follow-up and Account Maintenance Sub-function**

Figure 2.8 (c) now reveals that when we zoom-in to the lower level 3 of this particular analysis of the Order Follow-up sub-function, we find two individual functional processes<sup>9</sup> at level 3 (for two enquiries of the Order follow-up sub-function). More functional processes would be revealed if we were to continue the refinement of the Level 3 sub-sub-functions to lower levels. This example demonstrates, therefore, that when some functionality is refined in a 'top-down' approach, it cannot be assumed that the functionality shown at a particular 'level' on a diagram will always correspond to the same 'level of granularity' as this concept is defined in the COSMIC method. (This definition requires that at any one level of granularity the functionality is 'at a comparable level of detail'.)

<sup>9</sup> (Note: at this stage someone who is new to the COSMIC method may not be convinced on the basis of the definition and the rules for the 'functional process level of granularity' that the two Enquiries that have appeared at Level 3 are actually functional processes, as opposed to two sub-sub-systems that could be decomposed further. Section 3.2 on 'Identifying functional processes' will provide more evidence to support the analysis given here.)

Furthermore, other analysts might well draw the diagrams differently, showing other groupings of functionality at each level of the diagram. There is not one 'correct' way of zooming in on the functionality of such a complex system.<sup>10</sup>

Given these variations that inevitably occur in practice, a Measurer must carefully examine the various levels of an analysis diagram to find the functional processes that must be measured. Where in practice this is not possible, for example because the analysis has not yet reached the level where all functional processes have been revealed, rule (b) above must be applied. To illustrate this, let us examine the case of the 'Maintain customer details sub-sub-function' (see Figure 2.8 (c) above), in the branch of the Account Maintenance sub-function.

To an experienced Measurer, the word 'maintain' almost invariably suggests a group of events and thus a group of functional processes. We can therefore assume that this 'Maintain' sub-sub-function must comprise three functional processes, namely an 'enquire on customer details', 'update customer details' and 'delete customer details'. (The 'create customer details' process must also obviously exist, but this occurs in another branch of the system, when a customer orders goods for the first time. It is outside the scope of this simplified example.)

An experienced Measurer should be able to 'guesstimate' a size of this sub-sub-function in units of COSMIC Function Points by taking the assumed number of functional processes (three in this case) and multiplying this number by the average size of a functional process. This average size would be obtained by calibration in other parts of this system or in other comparable systems. Examples of this calibration process are given in the document 'Guideline on Approximate size measurement' [6] which also contains other examples of other approaches to approximate sizing.

Clearly, such approximation methods have their limitations. If we apply such an approach to the Level 1 statement of requirements as given above ('The Everest application must enable customers to enquire upon, select, order, pay for and obtain delivery of any item of Everest's product range ....'), we could identify a few functional processes. But more detailed analysis would reveal that the real number of functional processes in this complex application must be much greater. That is why functional sizes usually appear to increase as more details of the requirements are established, even without changes in scope. These approximation methods must therefore be used with great care at high levels of granularity, when very little detail is available.

For an example of measuring at varying levels of granularity and of decomposition, see the telecoms system example in the Guideline for approximate COSMIC functional size measurement [6].

## **2.5 Concluding remarks on the Measurement Strategy Phase**

It is essential to determine and document the parameters of the measurement strategy so as to ensure that the resulting size can be correctly understood and used in the future. The great majority of functional size measurements are carried out for a purpose that is related to development effort in some way, e.g. for project development performance measurement, or for project estimating. In many of these situations, a standard measurement pattern may be used: see the Guideline on Measurement Strategy Patterns [5].

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<sup>10</sup> Figure 2.8 may not even be an example of best practice, but it is typical of how such diagrams may be drawn.



## THE MAPPING PHASE

### 3.0 Chapter summary

This chapter discusses the second 'Mapping' phase of the measurement process by defining the key concepts of the Generic Software Model and the process to be followed in mapping the FUR of the software to the model so that the FUR can be measured. These key concepts of the Generic Software Model are: (*in italics*)

- An event causes a *functional user* to request a service from the piece of software being measured. Such an event is called a '*triggering event*' and the requested service a '*functional process*'.
- Functional processes are composed of two types of sub-processes that either move data ('*data movements*') or that manipulate data ('*data manipulation*'). Data manipulation sub-processes are not recognized separately but are considered to be accounted for by the data movements with which they are associated.
- A data movement moves a '*data group*'. A data group consists of *data attributes* that all describe one '*object of interest*', i.e. an object that is of interest in the world of the functional user concerned.
- There are four types of data movements: *Entries* and *Exits* each move one data group in and out of a functional process across a *boundary* from/to a functional user respectively. *Reads* and *Writes* each move one data group between the functional process and *persistent storage*.

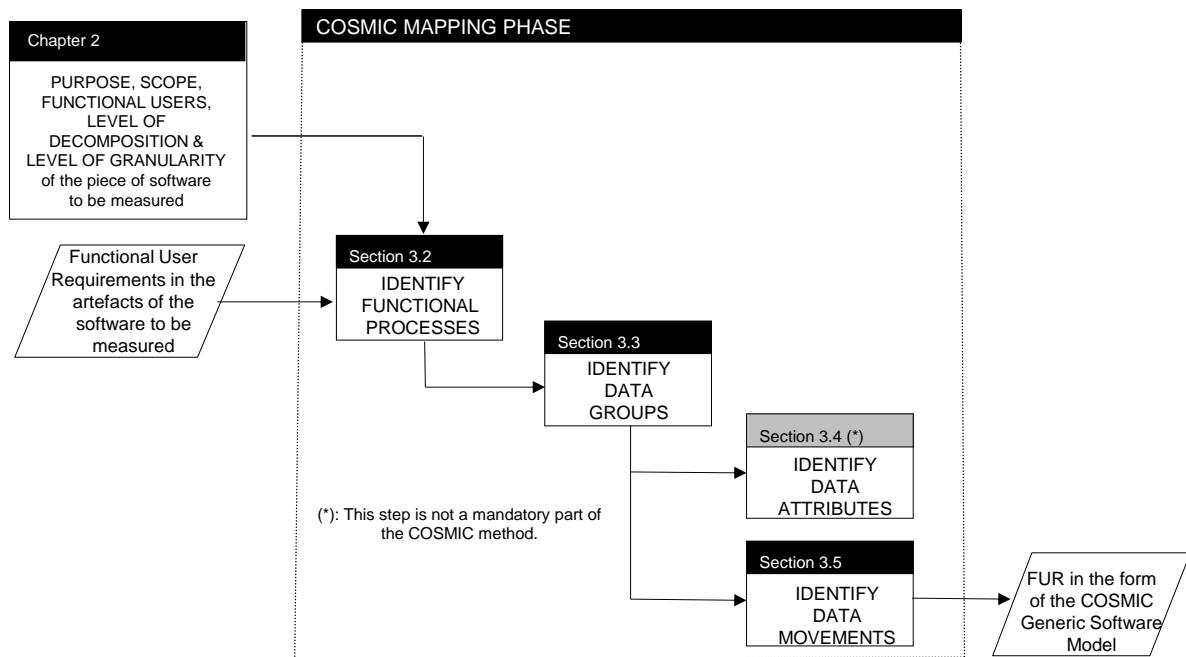
Each of these concepts is defined in this chapter which includes comprehensive principles and rules to help identify the concepts correctly, and extensive examples of the concepts for different types of software.

### 3.1 Mapping the FUR to the Generic Software Model

This chapter presents the definitions, principles, rules and the method for the mapping process. Figure 3.0 shows the steps of the process for mapping the Functional User Requirements (FUR) as in the available software artifacts to the form required by the COSMIC Generic Software Model.

Each step in this process is the subject of a specific section indicated in the step's title bar in Figure 3.0.

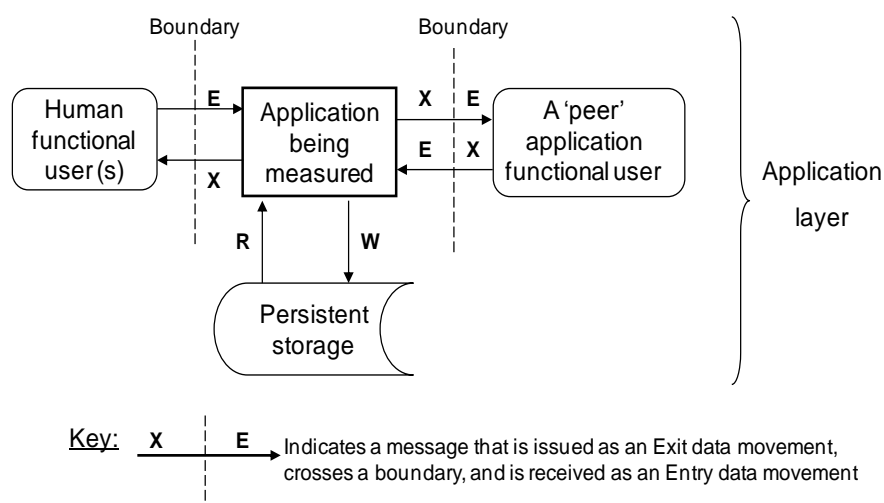
The process is designed to be applicable to a very broad range of software artifacts. We encourage Measurers to use this general process to derive more specific rules for use in their local environment to map from the software artifacts produced by their local software engineering method to the COSMIC Generic Software Model. The aim of a specific local process, illustrated with local examples, should be to reduce uncertainty in the mapping and hence to improve the accuracy and repeatability of the measurements.



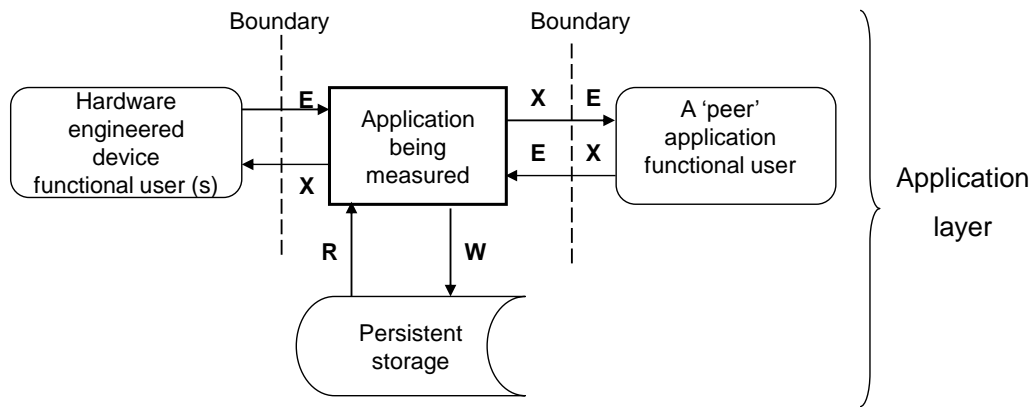
**Figure 3.0 – General method of the COSMIC mapping process**

Several guidelines are available that give guidance on the mapping from various data analysis and requirements determination methods used in different domains to the concepts of the COSMIC method. Examples are the Guideline for Sizing Business Application Software [7], the Guideline for Sizing Data Warehouse Application Software [8], the Guideline for Sizing Service-Oriented Architecture Software [9] and the Guideline for Sizing Real-time Software [4]. For the business [10] and real-time domains [11] there are also Quick Reference Guides available that give an overview of the process in a few pages.

The aim of Figures 3.1 and 3.2 is to help our transition from the Software Context Model used in the Measurement Strategy phase to the Generic Software Model. The Figures apply for a piece of business application software and for a typical piece of real-time embedded software, and correspond to Figures 2.6 and 2.7 respectively.



**Figure 3.1 - A business application with humans and another 'peer' application as its functional users**



**Figure 3.2 - A real-time embedded software application with various hardware engineered devices and peer software as its functional users**

From principle f) of the Software Context Model, we learned that the functional users of the software being measured are the 'senders and/or intended recipients of data to/from the software respectively'. Principle a) of the Generic Software Model tells us that a piece of software 'interacts with its functional users across a boundary and with persistent storage within this boundary'.

Fig. 3.1 shows the application software being measured has two functional users, human(s) and another peer application. The embedded software application of Figure 3.2 has only hardware devices as its functional users. The arrows showing the movements of data are labeled with the abbreviations showing their types (E = Entry, X = eXit, R = Read, W = Write).

Note that 'persistent storage' refers to any logical storage that the application being measured is required to access via Read or Write data movements; it does not imply any type of physical storage.

## 3.2 Identifying functional processes

This step consists in identifying the set of functional processes of the piece of software to be measured, from its Functional User Requirements.

### 3.2.1 Definitions

#### DEFINITION – Event

##### Event

Something that happens.

#### DEFINITION – Triggering event

##### Triggering event

An event, recognised in the Functional User Requirements of the software being measured, that causes one or more functional users of the software to generate one or more data groups, each of which will subsequently be moved by a triggering Entry. A triggering event cannot be sub-divided and has either happened or not happened.

NOTE: Clock and timing events can be triggering events.

#### DEFINITION – Functional process

- a) A set of data movements representing an elementary part of the Functional User Requirements for the software being measured, that is unique within that FUR and that can be defined independently of any other functional process in that FUR.
- b) A functional process may have only one triggering Entry. Each functional process starts processing on receipt of a data group moved by the triggering Entry data movement of the functional process.
- c) The set of all data movements of a functional process is the set that is needed to meet its FUR for all the possible responses to its triggering Entry.

NOTE 1: When implemented, it is an *occurrence* of a functional process that starts *executing* on receipt of an *occurrence* of a data group moved by an *occurrence* of a triggering Entry.

NOTE 2: The FUR for a functional process may require one or more other Entries in addition to the triggering Entry.

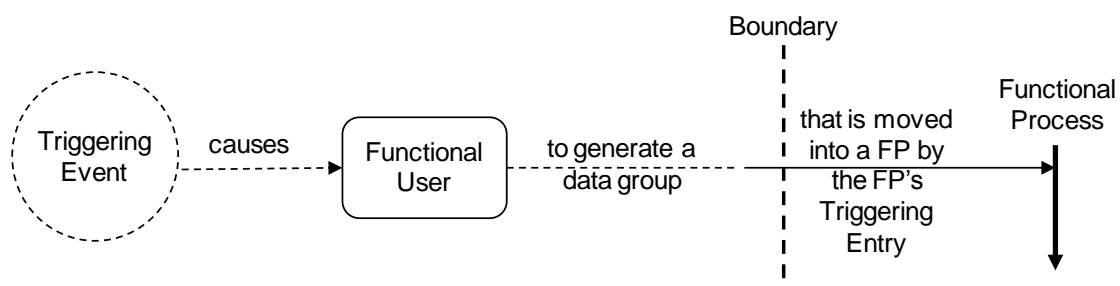
NOTE 3: If a functional user sends a data group with errors, e.g. because a sensor-user is mal-functioning or an order entered by a human has errors, it is usually the task of the functional process to determine if the event really occurred and/or if the entered data are really valid, and how to respond.

#### DEFINITION – Triggering Entry

The Entry data movement of a functional process that moves a data group generated by a functional user that the functional process needs to start processing.

The relationship between a triggering event, the functional user and the Entry data movement that triggers a functional process being measured is depicted in Figure 3.3 below. The interpretation of this diagram is: *a triggering event causes a functional user to generate a data group that is moved by the triggering Entry of a functional process to start the functional process.*

NOTE: For ease of reading, we often omit the reference to the data group and state that a functional user *initiates* a triggering Entry that starts a functional process, or even more simply that a functional user *initiates* a functional process.



**Figure 3.3 – Relationships between a triggering event, a functional user and a functional process**

All the relationships between the concepts in Figure 3.3 (the triggering event / functional user / triggering Entry / functional process) may be one-to-many, many-to one, or many-to-many, with one exception. The exception is that the data group moved by any one triggering Entry may initiate only one functional process – see rule b) for a functional process. Some examples of possible cardinalities:

- A triggering event may be sensed by many functional users, e.g. an earthquake is detected by many sensors;
- Some types of functional user can detect many types of events, e.g. human operators of a business application who initiate a triggering Entry for each event that they decide is a triggering event;

- A hardware functional user may initiate more than one triggering Entry on sensing one triggering event in certain types of safety-critical software;
- Some functional processes may be initiated by different functional users, e.g. a re-usable software component that can be called by any of its software functional users.

In practice, the cardinalities along all the chains for the software being measured (i.e. that describe the specific events that cause specific functional users to initiate specific functional processes) will be constrained by the software FUR. For a fuller discussion of the cardinalities along the chain of Figure 3.3 and for more examples, see Appendix C to this Measurement Manual.

The data group(s) that a functional user will generate as a result of a triggering event depend on the FUR of the functional process that will process the data, as illustrated by the following examples.

*BUSINESS EXAMPLE 1: A functional process of a personnel software system may be started by the triggering Entry that moves a data group describing a new employee. The data group is generated by a human functional user of the personnel software who enters the data. Normally, the event of a new employee starting work is not of interest per se. The entered data informs about the employee; it is not about the event of starting work. (However, the date of starting work will almost certainly be recorded as an attribute in the employee data group.)*

*REAL-TIME EXAMPLE 2: A functional process of a real-time software system may be started by its triggering Entry informing the functional process that a clock (functional user) has ticked. The data group moved conveys data (the tick, perhaps via a single bit) that informs only that an event has occurred.*

*REAL-TIME EXAMPLE 3: A functional process of an industrial real-time fire detection software system may be started by its triggering Entry initiated by a specific smoke detector (functional user). The data group generated by the detector conveys the information 'smoke detected' (an event has occurred) and includes the detector ID (i.e. data that can be used to determine where the event occurred).*

*REAL-TIME EXAMPLE 4: A bar code reader (a functional user) at a supermarket checkout starts a scan when a bar code appears in its window (the triggering event). The reader generates a data group, comprising an image of the bar code that is input to the checkout software. The data group image is moved by a triggering Entry into its functional process. The latter adds the product cost to the customer's bill if the code is valid, sounds a 'beep' to inform the customer that the product has been accepted, and logs the sale etc., etc.*

### **3.2.2 The approach of identifying functional processes**

The approach to identifying functional processes depends on the software artifacts that are available to the Measurer, which in turn depend on the point in the software life-cycle when the measurement is required and on the software analysis, design and development methods in use. Since the latter vary enormously, this Measurement Manual can only provide a general process for identifying functional processes.

The process of identifying functional processes, after the functional users have been identified and given the FUR for the software being measured follows the chain of Figure 3.3, i.e.

- Identify the separate events in the world of the functional users that the software being measured must respond to – the 'triggering events' (triggering events can be identified in state diagrams and in entity life-cycle diagrams, since some transitions that the software must react to correspond to triggering events);
- Identify which functional user(s) of the software may respond to each triggering event;
- Identify the triggering Entry (or Entries) that each functional user may initiate in response to the event;
- Identify the functional process started by each triggering Entry.

Use the following rules to check that candidate functional processes have been properly identified.

#### **RULES – Functional process**

- a) A functional process shall belong entirely to the measurement scope of one piece of software in one, and only one, layer.
- b) Any one triggering Entry of a piece of software being measured may initiate only one functional process in that software.
- c) A functional process shall comprise at least two data movements, an Entry plus either an Exit or a Write. There is no upper limit to the number of data movements in a functional process.
- d) An executing functional process shall be considered terminated when it has satisfied its FUR for the response to its triggering Entry. A pause during the processing for technical reasons shall not be considered as termination of the functional process.

### **3.2.3 Triggering events and functional processes in the business applications domain**

- a) Triggering events of an on-line business application usually occur in the real world of the human functional users of the application. The human user conveys the occurrence of the event to a functional process by entering data about the event.

*BUSINESS EXAMPLE 1: In a company, an order is received (triggering event), causing an employee (functional user) to enter the order data (triggering Entry conveying data about the object of interest 'order'), as the first data movement of the 'order entry' functional process.*

- b) Separate triggering event (-types) and therefore separate functional process (-types) should be distinguished in the following cases:

When a human functional user makes decisions outside the software on 'what to do next' that are independent in time and that require separate responses from the software, each separate decision is a separate triggering event for which the software must provide a separate functional process.

*BUSINESS EXAMPLE 2: A functional user enters a customer order for an item of complex industrial equipment and later confirms acceptance of the order to the customer. Between entering the order and accepting it, the user may make enquiries about whether the new order can be delivered by the requested delivery date, and about the customer's credit-worthiness, etc. Although acceptance of an order must follow entry of an order, in this case the user must make a separate decision to accept the order. This indicates separate functional processes for order entry and for order acceptance.*

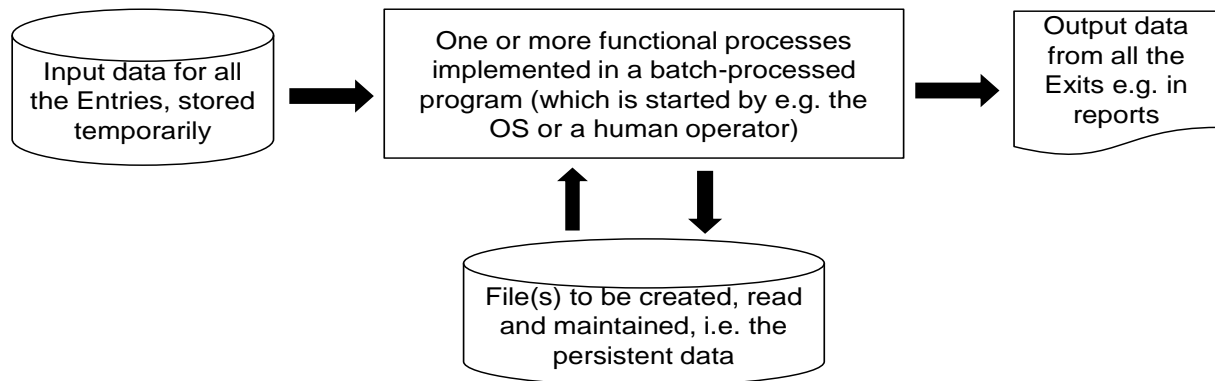
When the responsibilities for activities are separated.

*BUSINESS EXAMPLE 3: in a personnel system where the responsibility for maintaining basic personal data is separated from the responsibility for maintaining payroll data indicating separate functional users each with their own separate functional processes.*

- c) Sometimes, for an application A there may be a peer application B that needs to send data to, or obtain data from, application A. Application B triggers a functional process in application A when it needs to send data to or obtain data from application A. Application B is then a functional user of the application A.

*BUSINESS EXAMPLE 4: Suppose that on receipt of an order in Business Example 1, the order application is required to send the details of any new client to a central client-registration application, which is being measured. The order application is thus a functional user of the central application. The order application, having received data about a new client, generates the client data group which it sends to the central client-registration application which triggers a functional process to store these data.*

- d) There is no difference in principle to the analysis of a functional process whether it is required to be processed on-line or in batch mode. By definition, all data that has been entered as *input* for batch processing must be temporarily stored somewhere before the process can start. See Figure 3.4 (N.B. we distinguish input data - all the Entries - from persistent data that might also need to be read or written by the batch process.) When measuring a batch-processed application, any temporarily-stored input data should be analysed in the same way as if it were being entered directly to the application. This input data is not 'persistent data'.



**Figure 3.4 - A batch-processed 'job', implementing a collection of functional processes**

NOTE: A requirement that some input data be batch-processed is a non-functional requirement (NFR). The effect of this NFR is that the input data must be available (as a 'batch') for input to the batch processed application. How that happens in practice does not concern the analysis of the FUR of the batch processed application.

Note also that each functional process (-type) to be processed in a batch 'job' should be analyzed in its entirety, independently of any other functional processes in the same job. Each functional process in the job must have its own triggering Entry.

*BUSINESS EXAMPLE 5: Suppose the orders in the Business Example 1 above are entered by an 'off-line' process in some way, e.g. by optical scanning of paper documents and are stored temporarily for automatic batch processing. How to analyze the batch functional process? The functional user is the human who causes the order data to be entered off-line ready to be processed in batch mode; the triggering Entry of the functional process that will process the orders in batch mode is the data movement that moves the order data group from temporary storage into the process. (The off-line process, if it must be measured, involves another, separate functional process. Effectively, the functional user has initiated two triggering Entries, one starts the off-line process to load the orders to temporary storage and the other to start the batch processing of the orders.)*

*BUSINESS EXAMPLE 6: Suppose a FUR for an end-of year batch-processed application to report the outcome of business for the year, and to reset positions for the start of the next year. Physically, an end-of-year clock tick generated by the operating system causes the application to start processing. Logically, however, each functional process of the application takes its input data from the stream of data to be batch-processed. This should be analyzed in the normal way (e.g. the input data for any one functional process comprises one or more Entries, the first of which is the triggering Entry for that process).*

*However, assume there is a particular functional process of the batch-processed application that does not require any input data to produce its set of reports. Physically, the (human) functional user has delegated to the operating system the task of triggering this functional process. Since every functional process must have a triggering Entry, we may consider the end-of-year clock tick that started the batch stream as filling this role for this process. This functional process may then need several Reads and many Exits to produce its reports. Logically, the analysis of this example is no different if the human functional user initiates the production of one or more reports via a mouse click on an on-line menu item, rather than delegating the triggering of the report production in batch mode to the operating system.*

For several examples on distinguishing triggering events and functional processes in batch streams, see the 'Guideline for Sizing Business Application Software using COSMIC' [7], section 4.6.3.

### 3.2.4 Triggering events and functional processes in the real-time applications domain

- a) A triggering event is typically detected by a sensor.

*REAL-TIME EXAMPLE 1: When a sensor (functional user) detects that the temperature reaches a certain value (triggering event), the sensor sends a signal to initiate a triggering Entry data movement of a functional process to switch off a heater (another functional user).*

- b) *REAL-TIME EXAMPLE 2: A military aircraft has a sensor that detects the event 'missile approaching'. The sensor is a functional user of the software that must respond to the threat. For this software, an event occurs only when the sensor detects something, and it is the sensor (the functional user) that generates a data group to initiate a triggering Entry saying, e.g. 'sensor 2 has detected a missile', plus maybe a stream of data about how fast the missile is approaching and its co-ordinates.*

- c) Periodic signals from a clock ('clock ticks') can trigger a functional process.

*See Real-time Example 2 in section 3.2.1. There is no other data accompanying the clock-tick. The functional process obtains data from various sensors and takes whatever action is needed.*

### 3.2.5 More on separate functional processes

Software distinguishes events and provides the corresponding functional processes depending only on its FUR. When sizing software, it can sometimes be difficult to decide what the separate events are that the software is required to recognize. This is especially the case where the original requirements are no longer available and where, for example the developer may have found it economical to implement several requirements in one physical transaction. It may help with the analysis to examine the organization of data input (see below) or to examine the menus for some installed software to help distinguish the separate events that the software must respond to and the corresponding functional processes.

*BUSINESS EXAMPLE 1: Suppose there is a functional user requirement for two types of social benefits, first for an additional child and second a 'working tax credit' for those on low income. These are requirements for the software to respond to two events that are separate in the world of the human functional users. Hence there should be two functional processes, even though a single tax form may have been used to capture data for both cases.*

According to clause c) of its definition, a functional process must 'meet its FUR for all the possible responses to its triggering Entry'. This means that the same one functional process *type* must be able to deal with all possible *occurrences* of *values* of the data attributes of the data group moved by its triggering Entry, including both valid and invalid data values, and even in some cases missing data values. All these variations in values of the data moved by the triggering Entry will usually result in different processing paths being followed when the functional process executes. But in spite of all these variations, we must still identify only the one functional process type started by its one triggering Entry type. (And the Measurer only needs to identify all the data movements of this functional process; the various processing paths in which they may occur are irrelevant to the measurement.)

*BUSINESS EXAMPLE 1: A functional process that provides a general search capability against a database may be required to accept up to four search parameters (attributes of its triggering Entry). But the same functional process will function if the values of only one, two or three search parameters are entered.*

*BUSINESS EXAMPLE 2: For a functional process to register a new customer for a car rental company, it is mandatory to enter data for most data attributes, but some (e.g. some contact details) are optional and may be left blank. Regardless of whether all or a sub-set of these attributes are entered there is only one functional process for registering a new customer. Similarly, for the functional process to make a car rental reservation in the same company, there are several options which may or may not be taken up, e.g. for extra insurance, additional drivers, requests for child seats, etc. These different options lead to different processing paths within the car rental*



reservation functional process, but there is still only one functional process for reserving a car rental.

*REAL-TIME EXAMPLE: One triggering Entry (aircraft altitude information sent by the Geographical Positioning System) to a functional process of an avionics system will trigger one of two quite different processing paths within the functional process depending on the value of the Entry, i.e. whether the altitude is above or below a given height. The different paths will display different data groups on the pilot's map and, if the altitude is too low, additional warnings will be issued. There is only one functional process.*

Once identified, each functional process can be registered on an individual line, under the appropriate layer and named piece of software, in the Generic Software Model matrix (Appendix A).

### **3.2.6 Measuring the components of a distributed software system**

When the purpose of a measurement is to measure separately the size of each component of a distributed software system, a separate measurement scope must be defined for each component. In such a case the sizing of the functional processes of each component follows all the normal rules as already described.

From the process for each measurement (... define the scope, then the functional users and boundary, etc...) it follows that if a piece of software consists of two or more components, there cannot be any overlap between the measurement scope of each component. The measurement scope for each component must define a set of complete functional processes. For example, there cannot be a functional process with part in one scope and part in another. Likewise, the functional processes within the measurement scope for one component have no knowledge of the functional processes within the scope for another component, even though the two components exchange messages.

The functional user(s) of each component are determined by examining where the events occur that trigger functional processes in the component being examined. (Triggering events can only occur in the world of a functional user.)

Figure 3.6 illustrates the functional processes of the two components of a client-server distributed system and the data movements that they exchange.

### **3.2.7 Independence of functional processes sharing some common or similar functionality**

Any two or more functional processes in the same software being measured may have some functionality that is identical or very similar in each process. This phenomenon is referred to as 'functional commonality', or functional 'similarity'.

However, in the COSMIC method (as in all other FSM Methods) each functional process is defined, modelled and measured independently of, i.e. without reference to, any other functional process in the same software being measured (see clause a) of the definition of a functional process). Any required functionality that is common to or similar across any two or more functional processes in the same software being measured must be accounted for in each of these functional processes. The following are examples of functional commonality or similarity that may be found in practice.

*BUSINESS EXAMPLE: Several functional processes in the same software being measured may need the same validation functionality for e.g. 'date of order', or may need to access the same data, or may need to carry out the same interest calculation.*

*REAL-TIME EXAMPLE: Several functional processes in the same software being measured may need to obtain data from the same sensor (common movement of same data group) or may need to carry out the same scale conversion calculation, e.g. from Fahrenheit to Centigrade (common data manipulation).*

When a statement of FUR is implemented in software, any 'functional commonality' may or may not be developed as re-usable software. The extent of actual or potential software re-use arising from functional commonality or similarity may therefore need to be taken into account when using functional size measurements for performance measurement or project effort estimating purposes.

### 3.2.8 Events that trigger a software system to start executing

When measuring the size of a piece of software, identify only the events and corresponding triggering Entries that trigger the functional processes that the software must respond to as defined in its FUR. Functionality needed to start-up (or 'launch') the software itself is not part of these functional processes and should be ignored (or measured separately, if required). The following examples describe how software is started in three domains.

*BUSINESS EXAMPLE: For a business application, the functional user that starts the application may be a scheduler component of the operating system, a computer operator, or any other human user (e.g. when a PC user launches a browser or word-processing software).*

*REAL-TIME EXAMPLE: For a real-time application, the functional user that starts the application may be the operating system or network management generating a clock signal, or a human operator (e.g. to start a process control system from an operator workstation).*

*INFRASTRUCTURE EXAMPLE: For a computer operating system, the functional user that starts the operating system is a bootstrap program that is started when the computer power is switched on.*

The following are examples from two domains of the relationships that may exist, if any, between the event/process that starts the software to be measured and the events/processes that the software must execute as described in its FUR.

*BUSINESS EXAMPLE 1: An application to process the input data for a variety of functional processes in batch mode may be started by a scheduler of the operating system. If the purpose is to measure the FUR of the batch application, the 'start-the-system' functionality should be ignored. The triggering Entries for the functional processes of the batch-processed application and any other Entries that may be required will form the input data for the batch application.*

*BUSINESS EXAMPLE 2: Exceptionally, a batch-processed application to produce summary reports at the end of a time-period may be started without needing any input data provided directly from the functional user. For the analysis see Business Example 6 in section 3.2.3.*

*REAL-TIME EXAMPLE: A modern vehicle has a distributed system of Electronic Control Units (ECU's) to control many functions, e.g. engine management, brakes, air-conditioning, etc. In the AUTOSAR architecture, in a distributed system, the 'Network Management' (NM) module, which is always running, is responsible for activating the ECUs that are connected together via a network ('bus'). This module also handles the coordinated switching between the ECU operating states: Normal Operation, Low Power and Sleep. Therefore it is the NM that wakes up or puts to sleep ECU's. When measuring any ECU application software, this NM functionality should be ignored.*

## 3.3 Identifying objects of interest and data groups

### 3.3.1 Definitions and principles

This step consists in identifying the data groups referenced by the piece of software to be measured. To identify the data groups, especially in the business application software domain, it is usually helpful to identify the 'objects of interest' that they describe and perhaps also their data attributes. Data groups are moved in 'data movements' which are defined in section 3.5.

**DEFINITION – Object of interest**

Any 'thing' that is identified from the point of view of the Functional User Requirements. It may be any physical thing, as well as any conceptual object or part of a conceptual object in the world of the functional user about which the software is required to process and/or store data.

NOTE: In the COSMIC method, the term 'object of interest' is used in order to avoid terms related to specific software engineering methods. The term does not imply 'objects' in the sense used in Object Oriented methods.

**DEFINITION – Data group**

A distinct, non empty, non ordered and non redundant set of data attributes where each included data attribute describes a complementary aspect of the same object of interest.

Once identified, each candidate data group must comply with the following principles:

**PRINCIPLES – Data group**

- a) Each identified data group shall be unique and distinguishable through its unique collection of data attributes.
- b) Each data group shall be directly related to one object of interest in the software's Functional User Requirements.
- c) A data group shall be materialized within the computer system supporting the software.

Once identified, each data group can be registered in an individual column in the Generic Software Model matrix (Appendix A), under the 'Data Group Name' heading.

**3.3.2 About the materialization of a data group**

In practice, the materialization of a data group can take many forms, e.g.:

- a) As a physical record structure on a persistent storage device (file, database table, ROM memory, etc.).
- b) As a physical structure within the computer's volatile memory (data structure allocated dynamically or through a pre-allocated block of memory space).
- c) As the clustered presentation of functionally-related data attributes on an input/output device (display screen, printed report, control panel display, etc.).
- d) As a message in transmission between a device and a computer, or over a network, etc

**3.3.3 About the identification of objects of interest and data groups**

The definition and principles of objects of interest and of data groups are intentionally broad in order to be applicable to the widest possible range of software. This quality sometimes results in it being difficult to apply the definition and principles when measuring a specific piece of software. Therefore, the following examples are designed to assist in the application of the principles to specific cases.

When faced with a need to analyze a group of data attributes that is moved in or out of a functional process or is moved by a functional process to or from persistent storage, *it is critically important* to decide if the attributes all convey data about a single 'object of interest', since it is the latter that determine the number of separate 'data groups' as defined by the COSMIC method that will be moved by data movements. For instance, if the data attributes to be input to a functional process are attributes of three separate objects of interest, then we need to identify three separate 'Entry' data movements.

## Objects of interest and data groups in the business applications domain

*BUSINESS EXAMPLE 1: In the domain of business application software, an object of interest could be 'employee' (physical) or 'order' (conceptual), assuming the software is required to store data about employees or orders. In the case of 'order', it commonly follows from the FUR of multi-line orders that two objects of interest are identified: 'order' and 'order-line'. The corresponding data groups could be named 'order data', and 'order-line data'.*

Data groups are formed whenever there is an ad hoc enquiry which asks for data about some 'thing', i.e. an 'object of interest', about which data is not held on persistent storage, but which can be derived from data held on persistent storage. The Entry data movement in an ad hoc enquiry (the selection parameters to derive the required data) and the Exit data movement (containing the desired attributes) both move data groups about such a 'thing'. These are transient data groups that do not survive the execution of the functional process. They are valid data groups because they cross the boundary between the software and its functional user(s).

*BUSINESS EXAMPLE 2: Assume an ad hoc enquiry against a personnel database to extract a list of names of all employees aged over 35. The Entry moves a data group containing the selection parameters. The Exit moves a data group containing the single attribute 'name'. The object of interest (or 'thing') of the data groups moved by both the Entry and the Exit is 'all employees aged over 35'. It is important to clearly name a transient data group in relation to its object of interest. Do not relate the transient data group's name to the object(s) of interest from which the transient data group is derived.*

For a detailed discussion on methods of analyzing data to determine objects of interest and separate data groups, the reader is referred to the 'Guideline for Sizing Business Application Software using COSMIC' [7].

## Objects of interest and data groups in the real-time software domain

*REAL-TIME EXAMPLE 1: Data movements which are Entries from physical devices typically contain data about the state of a single object of interest, such as whether a valve is open or closed, or indicate a time at which data in short-term, volatile storage is valid or invalid, or contain data that indicates a critical event has occurred and which causes an interrupt. Similarly an Exit command to switch a warning lamp on or off conveys data about a single object of interest.*

*REAL-TIME EXAMPLE 2: A message-switch software system may receive a message data group as an Entry and route it forward unchanged as an Exit, as per the FUR of the particular piece of software. The attributes of the message data group could be, for example, 'message ID, sender ID, recipient ID, route\_code and message\_content'; the object of interest of the message is 'message'.*

*REAL-TIME EXAMPLE 3: A common data structure, representing objects of interest that are mentioned in the FUR, which can be maintained by functional processes, and which is accessible to most of the functional processes found in the measured software.*

*REAL-TIME EXAMPLE 4: A reference data structure, representing graphs or tables of values found in the FUR, which are held in permanent memory (ROM memory, for instance) and accessible to most of the functional processes found in the measured software.*

*REAL-TIME EXAMPLE 5: Files, commonly designated as 'flat files', representing objects of interest mentioned in the FUR, which are held on a persistent storage device.*

### 3.3.4 Data or groups of data that are not candidates for data movements

Any data appearing on input or output screens or reports that are not related to an object of interest to a functional user should not be identified as indicating a data movement, so should not be measured.

*BUSINESS EXAMPLE 1: Application-general data such as headers and footers (company name, application name, system date, etc) appearing on all screens.*

*BUSINESS EXAMPLE 2: 'Control commands' (a concept defined only in the business application domain) that enables a functional user to control their use of the software, rather than to move data, e.g. page up/down commands, clicking 'OK' to acknowledge an error message, etc. - see further section 3.5.10.*

The COSMIC Generic Software Model assumes that all manipulation of data within a functional process is associated with one of the four data movement types, see section 3.5.6. Hence no movements or manipulation of data groups within a functional process may be identified as candidates for a data movement in addition to the Entries, Exits, Reads and Writes. (For examples of manipulation and movements of data that might be mis-interpreted as data movements, see section 3.5.4, principle c) for a Read, and section 3.5.5 principle d) for a Write).

### **3.3.5 The functional user as object of interest**

In many real-time software systems, such as described in Real-time Example 1 in section 3.3.3 above, the Strategy phase may show that a physical device such as a sensor could be a functional user and later in the Mapping phase that it is also an object of interest. This is simply because the physical device 'interacts with the software' and at the same time the physical device is a 'thing...about which the software is required to process and/or store data'. In effect the physical device interacts with the software across the boundary to provide information about itself in the form of a data group describing some aspect of itself.

*REAL-TIME EXAMPLE: Suppose a temperature sensor 'A' sends a measure of the current temperature of a material for processing by a functional process. In one view the sensor can be regarded as providing information about its own state. The sensor therefore meets the criteria for identification as an object of interest and may be mapped from the FUR as such. However, the physical sensor is in the world of the users and '...interacts with the software...across the boundary', it therefore also meets the criteria for identification as a functional user and again may be mapped as such. So the temperature sensor could be added to the Software Context Model, and the object of interest 'temperature sensor' could be added to the Generic Software Model.*

## **3.4 Identifying data attributes (optional)**

This section discusses the identification of data attributes referenced by the piece of software to be measured. In this version of the measurement method, it is not mandatory to identify the data attributes. However, understanding the concept of a 'data attribute' is necessary in order to understand the section on 'measuring changes...' where a FUR to change a data attribute can result in the data movement being measured. Also, it may be helpful to analyze and identify data attributes in the process of distinguishing data groups and objects of interest, and data attributes might also be identified if a sub-unit of the size measure is required, as presented in section 4.5 'Extending the COSMIC measurement method'.

### **3.4.1 Definition**

<b>DEFINITION – Data attribute</b>
The smallest parcel of information, within an identified data group, carrying a meaning from the perspective of the software's Functional User Requirements.

*BUSINESS EXAMPLE: Data attributes in the context of the business applications domain are for example data elements registered in the data dictionary and data attributes appearing in a logical data model.*

*REAL-TIME EXAMPLE: Data attributes in the context of real-time application software are for example 'signal', representing a signal received from a sensor and 'From (address)', 'To (address)', 'Contents', representing parts of a message in transmission.*

### 3.4.2 About the association of data attributes and data groups

In theory, a data group might contain only one data attribute if this is all that is required, from the perspective of the Functional User Requirements, to describe the object of interest. In practice, such cases occur commonly in real-time application software (e.g. the Entry conveying the tick of a real-time clock); they are less common in business application software.

## 3.5 Identifying the data movements

This step consists in identifying the data movements (Entry, Exit, Read and Write) of each functional process.

### 3.5.1 Definition of the data movement types

#### DEFINITION – Data movement

A base functional component which moves a single data group type.

NOTE 1: There are four types of data movement: Entry, Exit, Read and Write (-types).

NOTE 2: For measurement purposes, each data movement type is considered to include certain associated data manipulations – see section 3.5.6 for details.

NOTE 3: More precisely, it is an *occurrence* of a data movement, not a data movement type that actually moves the data group *occurrences* (not types). This comment also applies to the definitions of Entry, Exit, Read and Write.

#### DEFINITION – Entry (E)

A data movement that moves a data group from a functional user across the boundary into the functional process where it is required.

NOTE: An Entry is considered to include certain associated data manipulations (see section 3.5.6).

#### DEFINITION – Exit (X)

A data movement that moves a data group from a functional process across the boundary to the functional user that requires it.

NOTE: An Exit is considered to include certain associated data manipulations (see section 3.5.6).

#### DEFINITION – Read (R)

A data movement that moves a data group from persistent storage into the functional process which requires it.

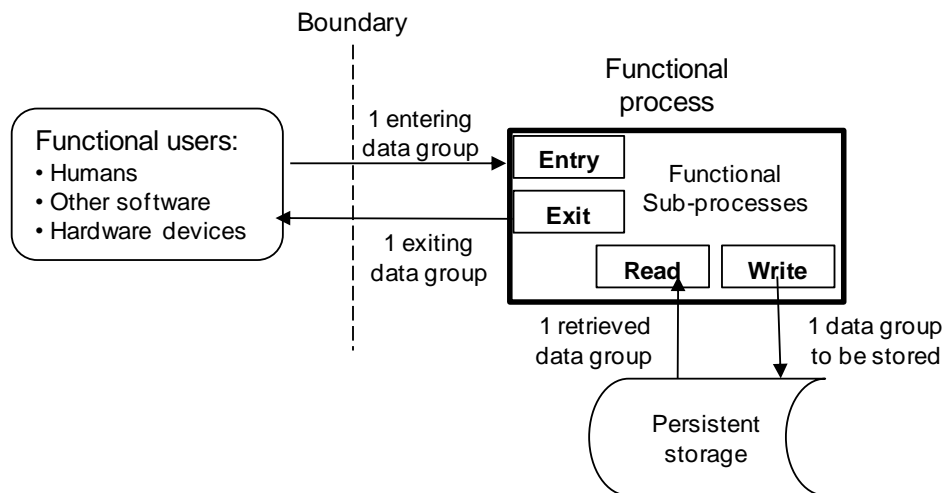
NOTE: A Read is considered to include certain associated data manipulation (see section 3.5.6).

#### DEFINITION – Write (W)

A data movement that moves a data group lying inside a functional process to persistent storage.

NOTE A Write is considered to include certain associated data manipulation (see section 3.5.6).

Figure 3.5, below, illustrates the overall relationship between the four types of data movement, the functional process to which they belong and the boundary of the measured software.



**Figure 3.5 - The four types of data movement, each moving one data group, and their relationship with a functional process. (A functional process can, of course have many E, X, R and W data movements.)**

### 3.5.2 Identifying Entries (E)

A candidate Entry data movement must comply with the following principles:

PRINCIPLES – Entry (E)	
a)	An Entry shall move a single data group describing a single object of interest from a functional user across the boundary and into the functional process of which the Entry forms part. If the input to a functional process comprises more than one data group, each describing a different object of interest, identify one Entry for each unique data group in the input. (See also section 3.5.7 on 'Data movement uniqueness'.)
b)	An Entry shall not exit data across the boundary, or read or write data from/to persistent storage.

The following rules help to confirm the status of a candidate Entry data movement:

RULES – Entry (E)	
a)	The data group of a triggering Entry may consist of only one data attribute which simply informs the software that 'an event Y has occurred'. Very often, especially in business application software, the data group of the triggering Entry has several data attributes which inform the software that 'an event Y has occurred and here is the data about that particular event'.
b)	Clock-ticks that are triggering events shall always be external to the software being measured. Therefore, for example, a clock-tick event occurring every 3 seconds shall be associated with an Entry moving a data group of one data attribute. Note that it makes no difference whether the triggering event is generated periodically by hardware or by another piece of software outside of the boundary of the software being measured.

- c) Unless a specific functional process is necessary, obtaining the time from the system's clock shall not be considered to cause an Entry.
- d) If an occurrence of a specific event triggers the Entry of a data group comprising up to 'n' data attributes of a particular object of interest and the FUR allows that other occurrences of the same event can trigger an Entry of a data group which has values for attributes of only a sub-set of the 'n' attributes of the object of interest, then one Entry shall be identified, comprising all 'n' data attributes.

When identifying Entries in a screen that enables human functional users to input data into functional processes, e.g. as in an on-line business application, analyze only screens that are filled with data. Ignore i) any screen that is formatted but otherwise 'blank' except for possible default values, and ii) ignore all field and other headings that enable human users to understand the input data required.

NOTE. It may be necessary to consider field and other headings when measuring FUR for changes to Entries – see section 4.4.1.

*BUSINESS EXAMPLE illustrating rule c): When a functional process adds a time stamp to a record to be made persistent or to be output, no Entry is identified for obtaining the system's clock value.*

Once identified, each Entry data movement can be registered by marking the corresponding cell of the Generic Software Model matrix (Appendix A) with an 'E'.

### 3.5.3 Identifying Exits (X)

A candidate Exit data movement must comply with the following principles:

#### PRINCIPLES – Exit (X)

- a) An Exit shall move a single data group describing a single object of interest from the functional process of which the Exit forms part across the boundary to a functional user. If the output of a functional process comprises more than one data group, identify one Exit for each unique data group in the output. (See also section 3.5.7 on 'Data movement uniqueness'.)
- b) An Exit shall not enter data across the boundary, or read or write data from/to persistent storage.

The following rules might be useful to confirm the status of a candidate Exit data movement:

#### RULES – Exit (X)

- a) An enquiry which outputs fixed text, (where 'fixed' means the message contains no variable data values, e.g. the result of pressing a button for 'Terms & Conditions' on a shopping web-site), shall be modeled as having one Exit for the fixed text output.  
NOTE: For the output from 'Help' functionality, see the 'Guideline for sizing Business Application Software'. For the output of messages concerned with error conditions or confirming success, see section 3.5.11 of this Measurement Manual.
- b) If an Exit of a functional process moves a data group comprising up to 'n' data attributes of a particular object of interest and the FUR allows that the functional process may have an occurrence of an Exit that moves a data group which has values for attributes of only a sub-set of the 'n' attributes of the object of interest, then one Exit shall be identified, comprising all 'n' data attributes.
- c) When identifying Exits, ignore all field and other headings that enable human users to understand the output data.  
NOTE: It may be necessary to consider field and other headings when measuring FUR for changes to Exits – see section 4.4.1



Once identified, each Exit data movement can be registered by marking the corresponding cell of the Generic Software Model matrix (Appendix A) with an 'X'.

See also section 3.5.11 for how to identify Exit data movements for error messages.

### 3.5.4 Identifying Reads (R)

A candidate Read data movement must comply with the following principles:

PRINCIPLES – Read (R)
<ul style="list-style-type: none"> <li>a) A Read shall move a single data group describing a single object of interest from persistent storage to a functional process of which the Read forms part. If the functional process must retrieve more than one data group from persistent storage, identify one Read for each unique data group that is retrieved. (See also section 3.5.7 on 'Data movement uniqueness'.)</li> <li>b) A Read shall not receive or exit data across the boundary or write data to persistent storage.</li> <li>c) During a functional process, movement or manipulation of constants or variables which are internal to the functional process and that can be changed only by a programmer, or computation of intermediate results in a calculation, or of data stored by a functional process resulting only from the implementation, rather than from the FUR, shall not be considered as Read data movements.</li> <li>d) A Read data movement always includes any 'request to Read' functionality (so a separate data movement shall never be counted for any 'request to Read' functionality). See also section 3.5.9.</li> </ul>

The following rules might be useful to confirm the status of a candidate Read data movement:

RULES – Read (R)
<ul style="list-style-type: none"> <li>a) Identify a Read when, according to the FUR, the software being measured must retrieve a data group from persistent storage.</li> <li>b) Do not identify a Read when the FUR of the software being measured specify any software or hardware functional user as the source of, or as the means of retrieving, the data group. (For this case see the principles and rules for Entries and Exits.)</li> </ul>

Once identified, each Read data movement can be registered by marking the corresponding cell of the Generic Software Model matrix (Appendix A) with an 'R'.

### 3.5.5 Identifying Writes (W)

Once identified, the candidate Write data movement must comply with the following principles:

PRINCIPLES – Write (W)
<ul style="list-style-type: none"> <li>a) A Write shall move a single data group describing a single object of interest from the functional process of which the Write forms part to persistent storage. If the functional process must move more than one data group to persistent storage, identify one Write for each unique data group that is moved to persistent storage. (See also section 3.5.7 on 'Data movement uniqueness'.)</li> <li>b) A Write shall not receive or exit data across the boundary, or read data from persistent storage.</li> </ul>

- c) A requirement to delete a data group from persistent storage shall be measured as a single Write data movement.
- d) The following shall not be considered as Write data movements:
  - The movement or manipulation of any data that did not exist at the start of a functional process and that has not been made persistent when the functional process is complete;
  - Creation or update of variables or intermediate results that are internal to the functional process;
  - Storage of data by a functional process resulting only from the implementation, rather than from the FUR. (An example would be the storage of data temporarily during a large sort process in a batch-processed job.)

The following rules might be useful to confirm the status of a candidate Write data movement:

<b>RULES – Write (W)</b>
a) Identify a Write when, according to the FUR, the software being measured must move a data group to persistent storage. b) Do not identify a Write when the FUR of the software being measured specify any software or hardware functional user as the destination of, or as the means of moving, the data group. (For this case see the principles and rules for Entries and Exits.)

Once identified, each Write data movement can be registered by marking the corresponding cell of the Generic Software Model matrix (Appendix A) with a 'W'.

### 3.5.6 On the data manipulations associated with data movements

Sub-processes are, as defined in principle (d) of the Generic Software Model (see section 1.3), either data movements, or data manipulations. However, by a COSMIC convention (see principle (j) of the Generic Software Model), the separate existence of data manipulation sub-processes is not recognized.

<b>DEFINITION – Data manipulation</b>
Anything that happens to data other than movement of the data into or out of a functional process, or between a functional process and persistent storage.

The following principle and rules determine how the COSMIC method deals with data manipulation.

<b>PRINCIPLE – Data manipulation associated with data movements</b>
All data manipulation in a functional process shall be associated with the four types of data movement (E, X, R, and W). By convention, the data movements of a functional process are assumed also to represent the data manipulation of the functional process.
<b>RULES – Data manipulation associated with data movements</b>
a) An Entry data movement includes all data manipulation to enable a data group to be entered by a functional user (e.g. formatting and presentation manipulations) and to be validated,

- b) An Exit data movement includes all data manipulation to create the data attributes of a data group to be output and/or to enable the data group to be output (e.g. formatting and presentation manipulations) and to be routed to the intended functional user,
- c) A Read data movement includes all computation and/or logical processing needed in order to retrieve a data group from persistent storage.
- d) A Write data movement includes all computation and/or logical processing to create or to update a data group to be written, or to delete a data group.
- e) The data manipulation associated with any of these data movements does not include any data manipulation that is needed after the data movement has been successfully completed, nor does it include any data manipulation associated with any other data movement.

*BUSINESS EXAMPLE 1: An Entry includes all manipulation needed to format a screen to enable a human user to enter data and to validate the entered data EXCEPT any Read(s) that might be required to validate some entered data or codes, or to obtain some associated code descriptions.*

*BUSINESS EXAMPLE 2: An Exit includes all manipulation to format output and prepare some data attributes for printing (or output on a screen), including the human-readable field headings<sup>11</sup> EXCEPT any Read(s) or Entries that might be required to supply the values or descriptions of some of the printed data attributes.*

The need to define which kinds of data manipulation are associated with which types of data movement arises only when measuring *changes* to software (see section 4.4). A typical required change affects both the attributes moved and the manipulation associated with a particular data movement, but it *may* affect only the manipulation of the data, not the movement of the data. Such a change still needs to be identified and measured. So when there is any requirement to change some data manipulation in a functional process, the Measurer needs to identify which the data movement is associated with which the change to the data manipulation is associated.

### **3.5.7 Data movement uniqueness and possible exceptions<sup>12</sup>**

The Generic Software Model assumes that *normally* in any one functional process *all* data describing any one object of interest that is required by that functional process is input in one Entry data movement type and/or read in one Read data movement type and/or written in one Write data movement type and/or output in one Exit data movement type. The model further assumes that all data manipulation resulting from all possible values of the data attributes of a data group that is moved is associated with the one data movement.

*EXAMPLE illustrating this latter assumption: Consider two occurrences of a given functional process (-type). Suppose that in the first occurrence the values of some attributes to be moved lead to a data manipulation sub-process (-type) 'A' and that in another occurrence of the same functional process the attribute values lead to a different data manipulation sub-process (-type) 'B'. In such circumstances, both data manipulation sub-processes 'A' and 'B' should be associated with the same one data movement and hence only the one data movement should normally be identified and counted in that functional process.*

There can, however, be *exceptional* circumstances in which *different* data group types describing a given object of interest may be required (in the FUR) to be moved in a data movement of the same type (E, R, W, X) in the same functional process. Alternatively, and again exceptionally, the same data group may be required to be moved in the same data movement type (E, R, W or X) in the same functional process, but with different associated data manipulation.

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<sup>12</sup> This section was entitled 'De-duplication of data movements' in version 2.2 of the Measurement Manual. The term 'de-duplication' was felt to be unhelpful, so the terminology has been changed.

The following rules cover the normal situation (rule a)), possible valid exceptions (rules b) and c)) and cases that might appear valid, but which are not valid (rules d) and e)).

RULES – Data movement uniqueness and possible exceptions
<p>a) Unless the Functional User Requirements specify otherwise, all data groups describing any one object of interest that are required to be entered into one functional process, and all associated data manipulation shall be identified and counted as one Entry (type).</p> <p>(NOTE: A functional process may, of course, be required to handle multiple Entry types, each moving a data group describing a different object of interest (type).)</p> <p>The same equivalent rule applies to any Read, Write or Exit data movement in any given functional process.</p> <p>b) More than one Entry data movement (type), each moving a data group describing the same object of interest (type) in a given functional process (type) may be identified and counted if there is a Functional User Requirement for these multiple Entries and <i>at least one</i> of the following applies:</p> <ul style="list-style-type: none"> <li>• the Entries differ by moving their data group from a different functional user</li> <li>• the Entries move different data groups,</li> <li>• the Entries have different associated data manipulation.</li> </ul> <p>The same equivalent rule applies for Exits in any given functional process.</p> <p>NOTE: Any one functional process may have only one triggering Entry.</p> <p>c) More than one Read data movement (type), each moving a data group describing the same object of interest (type) in a given functional process (type) may be identified and counted if there is a Functional User Requirement for these multiple Reads and <i>at least one</i> of the following applies</p> <ul style="list-style-type: none"> <li>• the Reads move different data groups,</li> <li>• the Reads have different associated data manipulation.</li> </ul> <p>The same equivalent rule applies for Writes in any given functional process.</p> <p>d) Repeated <i>occurrences</i> of a data movement type (i.e. each occurrence moving the same data group type with the same data manipulation type) shall not be identified and counted more than once in any one functional process.</p> <p>e) If the multiple <i>occurrences</i> of a data movement type in a given functional process differ in their associated data manipulation because different <i>values</i> of the data attributes of the data group moved result in different processing paths being followed, the data movement type shall not be identified and counted more than once in that process.</p>

The following examples illustrate the above rules.

*BUSINESS EXAMPLE 1 for rule a): In any one functional process, any Read of data describing a particular object of interest is considered logically to return all the required attributes describing that object of interest (i.e. the whole of the required 'state vector' of that object of interest). Hence normally only one Read of any data about any one object of interest is functionally needed and should be identified in any one functional process.*

*BUSINESS EXAMPLE 2 for rules a) and c): Following on from Example 1, since any data that is read must have been made persistent by a Write statement, the normal case (rule a) is that one Write would be identified that moves a data group containing all the data attributes of an object of interest required to be made persistent in a given functional process. Exceptionally, however suppose FUR for a single functional process to write two different data groups describing the same object of interest, e.g. for later use by two different functional users in other functional processes. An example where rule c) applies would be where a single functional process A is required to store two data groups from a bank's current account files for later use by separate programs. The first*

data group is 'overdrawn account' details' (which includes the negative balance attribute). The second data group is 'high value account' details' (which only has the account holder's name and address, intended for a marketing mail-shot). Functional process A will have two Writes, one for each data group.

*REAL-TIME EXAMPLE 3 for rule b): A functional process is required to accept two Entries from different sensors (functional users) each describing different data about the same object of interest (the event), e.g. a test explosion. Identify two Entries.*

*BUSINESS EXAMPLE 4 for rule b): Suppose FUR exist for a single functional process to produce two or more Exits moving different data groups describing the same object of interest, intended for different functional users. For example when a new employee joins a company a report is produced for the employee to sign off his personal data as valid and a message is sent to Security to authorize the employee to enter the building. Identify two Exits.*

*BUSINESS EXAMPLE 5 for rule d): Suppose the FUR to print a club's membership records which have some complete and some incomplete data for the different members. Identify one Exit.*

*BUSINESS EXAMPLE 6 for rule d): Suppose a Read is required in the FUR that in practice requires many retrieval occurrences, as in a search through a file. For sizing purposes, identify only one Read.*

*REAL-TIME EXAMPLE 7 for rule c): Suppose in a real-time functional process, the FUR requires that data must be entered from a given functional user, e.g. a hardware device, twice at a fixed time interval in order to measure a rate of change during the process. Data from the first Entry must be stored temporarily (it does not need to be made persistent as it will not survive the functional process). Data from the second Entry must be compared against the first data entered to calculate the rate of change. There is no data manipulation associated with the two Entries. (The calculation of the rate of change must be associated with the Exit that reports the rate.) Hence the two Entries are identical. They are therefore multiple occurrences of the same Entry. Only one Entry may be identified for this data for this functional process. (Refer to section 3.5.6 for the types of data manipulation that are considered to be associated with an Entry.)*

*BUSINESS EXAMPLE 8 for rule d): See section 3.5.2, rule d) for Entries, and section 3.5.3, rule b) for Exits.*

*BUSINESS EXAMPLE 9 for rule e): Suppose a functional process is required which provides various data manipulation options depending on the values of the data attributes of an Entry. Identify only one Entry.*

*BUSINESS EXAMPLE 10 for rule e): Suppose the FUR for a general enquiry functional process allows the user to enter up 1, 2 or 3 selection criteria for the enquiry. identify one Entry.*

*BUSINESS EXAMPLE 11 for rule e): Suppose a Read of a data group is required in the FUR, but the developer decides to implement it by two commands to retrieve different sub-sets of data attributes of the same object of interest from persistent storage at different points in the functional process. Identify only one Read.*

### **3.5.8 When a functional process is required to move data to or from persistent storage**

This section describes the data movements involved when a functional process of a piece of software is required to obtain some data from persistent storage, via four examples:

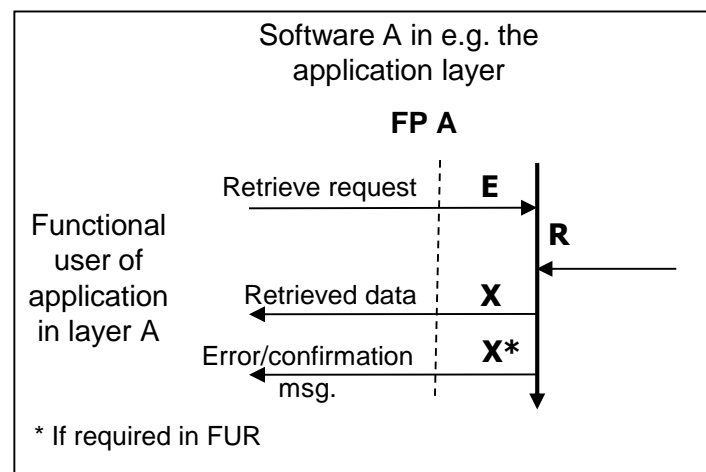
- Example 1 is typical of application software but could apply to software in any layer, except for the layer where software interacts directly with a physical hardware store. The functional process is required to retrieve data from persistent storage but the FUR do not require involvement of any other software;
- Example 2 for software with a 'client-server' architecture where a functional process of a client must request the server for some persistent data;
- Example 3 where different pieces of software have different access rights to persistent data;
- Example 4 where the data must be obtained directly from a physical hardware store perhaps by device driver software.

The examples are illustrated using the conventions of Message Sequence Diagrams. The notation of these diagrams is as follows:

- A bold vertical arrow pointing downwards represents a functional process.
- Horizontal arrows represent data movements, labeled E, X, R or W for Entry, Exit, Read and Write, respectively. Entries and Reads are shown as arrows incoming to the functional process and Exits and Writes as outgoing arrows; they appear in the sequence required, from top to bottom, of the functional process.
- A vertical dotted line represents a boundary.

**EXAMPLE 1:** When a functional process is required to move a data group to or from persistent storage. This example concerns a piece of software A that is required to retrieve a stored data group where the FUR of software 'A' are not concerned with how those data accesses are handled by any other software in the same or different layers.

The functional users of the software A could be, for example, human users if the software A is in the application layer making an enquiry on a stored data group. Figure 3.6 shows the COSMIC model of this enquiry. The enquiry is triggered by an Entry, followed by a Read of the data group from persistent storage and then an Exit with the enquiry result. FP A is not concerned with where the data is retrieved from, only that it is persistent data.



**Figure 3.6 - Solution for a Read issued by software 'A' in the application layer**

An exactly analogous model would apply if the functional process FP A were required to make a data group persistent via a Write data movement. By convention, the Read and the Write data movements are considered to account for any return code or reporting of an error condition.

Figure 3.6 shows a possible application-specific error message which could be issued by FP A if, for example, the requested record is not found. However, an error condition not specific to the application, e.g. 'disk failure' would not be counted as an Exit for FP A. See also section 3.5.11 on error/confirmation messages.

**EXAMPLE 2:** When a functional process is required to obtain some data from another piece of software.

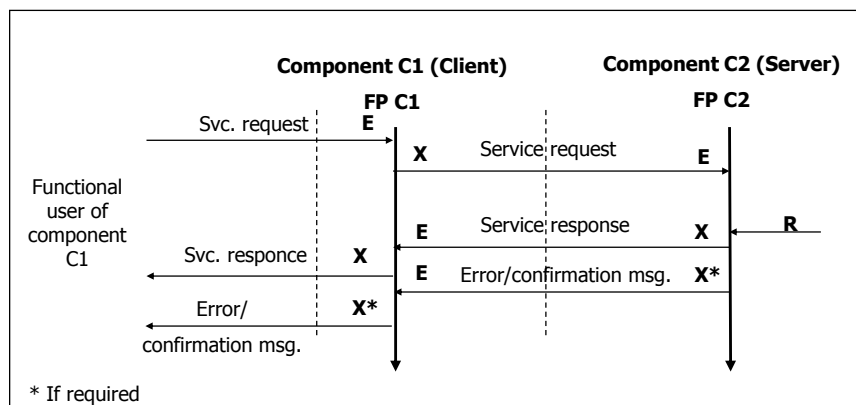
In this example, the pieces of software to be measured are assumed to have a 'client/server' relationship, i.e. where one piece, the client, obtains services and/or data from the other piece, the 'server', in the same or a different layer. Figure 3.7 shows an example of such a relationship, in which the two pieces are major components of the same application. In any such client/server relationship, the FUR of the client component C1 would identify the server component C2 as one of its functional users, and vice versa. The same relationship would exist and the same diagram would apply if the two pieces were separate applications, or if one of the pieces were a component of a separate application.

Physically, the two components could execute on separate processors; in such a case they would exchange data via the respective operating systems and any other intermediate layers of their processors in a software architecture such as shown in Figure 2.2. But logically, applying the COSMIC models, the two components exchange data via an Exit followed by an Entry data movement. All intervening software and hardware is ignored in this model. (See also the right-hand side of Figure 3.1 for a similar example.).

Figure 3.7 shows that a functional process FP C1 of the client component C1 is triggered by an Entry from a functional user (such as a human) which consists, for example, of the parameters of the enquiry. The FUR of component C1 will recognize that this component must ask the server component C2 for the required data, and must tell it what data group is required.

To obtain the required data group, FP C1 issues an Exit to component C2 containing the enquiry request parameters. This Exit data movement crosses the boundary between C1 and C2 and so becomes the triggering Entry of a functional process FP C2 in the component C2. The functional process FP C2 of component C2 is assumed to obtain the required data group via a Read from its own persistent storage, and sends the data back to C1 via an Exit. Functional process FP C1 of component C1 receives this data as an Entry. FP C1 then passes the data group on as an Exit to satisfy the enquiry of its functional user.

Taking into account the possible error/confirmation message issued by the client, this Example 2 enquiry therefore requires 5 data movements (i.e. 5 CFP) to satisfy the enquiry request for component C1 and 3 CFP for component C2. This compares with the 4 CFP (1 x E, 1 x R and 2 x X) that would have been required for component C1 if it had been able to retrieve the data group from persistent storage within its own boundary via a Read as shown in Figure 3.6.



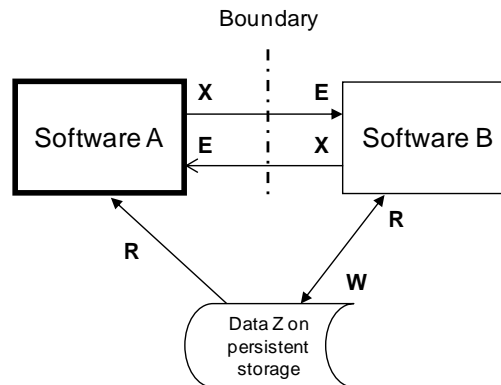
**Figure 3.7 - Data exchanges between client and server components**

Component C2 will probably, of course, use the services of some storage device driver software in another layer of the software architecture to retrieve the data from the hardware, as in Example 4, Figure 3.9 (b).

Examples 1 and 2 illustrate the data movements when it is clear from the FUR that the software being measured must access the persistent storage within its own boundary, or must pass the access request to another piece of software outside its boundary, respectively. Sometimes, however, the piece of software being measured may have to use different 'routes' to access the persistent data depending on the specific data attributes to be accessed and/or the type of access (storage or retrieval). This can arise when access to data by the software being measured is subject to varying rules or 'rights' due to issues of e.g. security or privacy, or the need to ensure data integrity by restricting access for all create, update and delete processes. Where the FUR of the software being measured are unclear on this point, the Measurer must take care to determine the actual rights of access. (Do NOT confuse 'right of access' to data with data 'ownership'; the latter is irrelevant to the COSMIC model. Persistent storage is an abstract concept: it is not 'owned' by any piece of software.)

**EXAMPLE 3:** The software has different rights of access to stored data for different purposes.

See Figure 3.8. A piece of software A to be measured is allowed to retrieve certain stored data Z (as in Example 1, Figure 3.6), but it is not allowed to maintain (i.e. create, update or delete) this same data Z directly. When the software A is required to maintain the data Z, software A must pass its request to another piece of software B via an Exit followed by an Entry (analogous to Example 2, Figure 3.7 of component C1 passing its request to component C2). The piece of software B is required to ensure the integrity of the data Z by ensuring consistent validation, so it processes all data maintenance requests for the data Z.



**Figure 3.8 - Persistent data Z within the boundary of both software A and B for a Read**

In this Example 3, COSMIC models would show that the data Z is held on persistent storage within the boundary of the piece of software A but only for retrieval purposes where it can be accessed by Read data movements. For software B, this same data Z is held on persistent storage within its boundary and software B can both Read and Write this data Z. For error handling in this Example, see Examples 1 and 2 above

**INFRASTRUCTURE EXAMPLE 4:** How persistent data is obtained by the device driver software that interacts with the physical storage device.

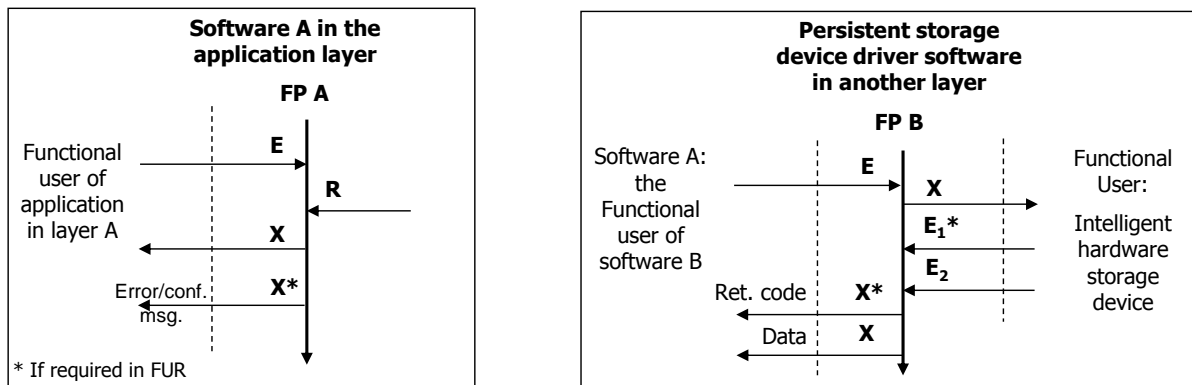
This example concerns the piece of software A of Example 1 that is required to retrieve a stored data group. We also consider a separate piece of software 'B' that is the device driver for the intelligent hardware storage which holds the data group that the piece of software A is required to access. (We ignore the probable presence of an operating system for simplicity; the operating system effectively transmits application requests to the device driver software and returns the results of requests.)

The two pieces of software are in different layers in an architecture such as shown in Figure 2.2. Software A is in e.g. the application layer, and software B is in a device driver layer. Physically, there is probably a hierarchical relationship between the two pieces and (ignoring the operating system) a physical interface between software in the two layers, as shown for example in Figure 2.2. However, the models of the functional processes of software A and B are independent of the nature of the relationship between the layers, which may be hierarchical or bi-directional.

The functional users of the software B in the driver layer are the piece of software A (ignoring the operating system) and the intelligent hardware storage device which holds the required data. ('Intelligent' means that the device must be told what data is needed.)

Suppose that an enquiry functional process FP A of the software A needs to retrieve a stored data group. Figure 3.9 (a) shows the COSMIC model of this enquiry. Figure 3.9 (b) shows the functional process FP B of the software B in the device driver layer that handles the physical retrieval of the required data from a hardware storage device (such as a disk or USB memory stick).





**Figures 3.9 (a) and (b) - Solution for a Read issued by software A in the application layer to software B in the device driver layer**

Figure 3.9 (b) shows that the Read request of the software A is received as a triggering Entry to the functional process FP B, which passes on the request as an Exit to the hardware device. The response of the latter depends on the particular hardware device. The device may just return the requested data, shown as Entry  $E_2$  in Figure 3.9 b). The device may also issue a separate error message describing the success or the reason for the failure of the request, e.g. 'data not found', or disk error', shown as Entry  $E_1^*$  in Figure 3.9 b). FP B returns the data to the software A as an Exit. FP B also normally issues a 'return code' describing the success or reason for the failure of the request. (Although the return code may be physically attached to the returned data, it is logically a different data group to that of the returned data - it is data about the outcome of the request process). For FP A no Entry for these messages is identified, as the Read data movement accounts for the returned data and error messages, according to rule d) for an Entry). For FP A, an Exit is identified for an error/confirmation message, if required.

Note: in practice, there may be more data movements between the device driver software and the intelligent hardware device than are shown in Fig 3.8 b). For example, this Figure does not show the effect of the device driver measuring a timeout for non-response from the hardware.

Comparing Examples 2 and 4, we see that in Example 4 the models of the piece of software A and the device driver B of Example 4 cannot be combined as they are in Example 2. This is because A and B are in different layers and a Read does not cross a boundary. Figure 3.9 (b) shows that the software A is a functional user of the device driver software B. But the reverse is not true, because a Read does not cross a boundary. In contrast, Figure 3.7 can show the two components in one model because Component C1 is a functional user of component C2, and vice versa, and they share a common boundary.

### 3.5.9 When a functional process requires data from a functional user

If a functional process must obtain data from a functional user there are two cases. If the functional process does not need to tell the functional user what data to send, a single Entry is sufficient (per object of interest). If the functional process needs to tell the functional user what data to send, an Exit followed by an Entry are necessary. The following rules apply:

#### **RULES – A functional process requiring data from a functional user**

- A functional process shall obtain a data group via an Entry data movement from a functional user, *when the functional process does not need to tell the functional user what data to send*, as in any of the following four cases:
  - when a functional user sends a triggering Entry which initiates the functional process;
  - when a functional process, having received a triggering Entry, waits, expecting the arrival of a further Entry from the functional user (can occur when a human functional user enters data to business application software);

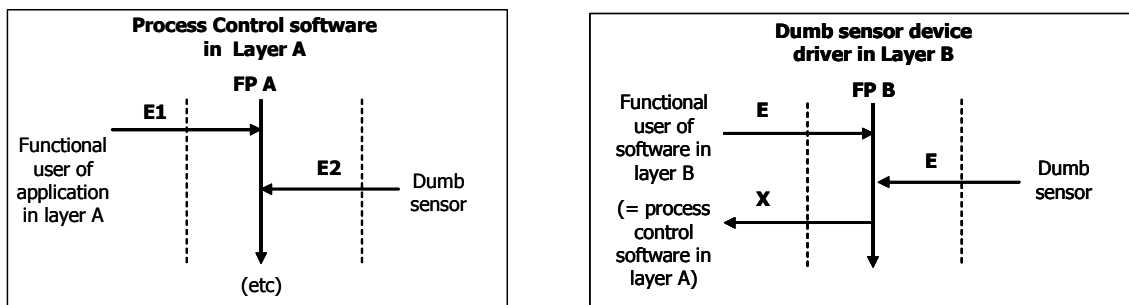
- when a functional process, having started, requests the functional user, 'send me your data now, if you have any' and the functional user sends its data;
- when a functional process, having started, inspects the state of a functional user and retrieves the data it requires.

In the latter two cases (typically occurring in real-time 'polling' software), by convention no Exit from the functional process shall be identified to obtain the required data. The functional process merely needs to send a prompt message to a functional user and the functionality of that prompt message is considered to be part of the Entry. The functional process knows what data to expect. Only one Entry shall be identified for this case.

- b) Where a functional process needs to obtain the services of a functional user (for instance to obtain data) and *the functional user needs to be told what to send* (typically where the functional user is another piece of software outside the scope of the software being measured), an Exit followed by Entry data movement shall be identified. The Exit contains the request for the specific data; the Entry contains the returned data.

*REAL-TIME EXAMPLE 1 of rule a), third or fourth bullet: Suppose a functional process of a real-time process control application software system is required to poll an array of identical dumb sensors. At the application level, the request for the data by the functional process and the receipt of the data is accounted for by one Entry (type). (Since the sensors are identical only one Entry (type) is identified and counted although there are multiple occurrences.)*

*Suppose further that the request for the data must in practice be passed to a piece of device driver software in a lower layer of the software architecture, which physically obtains the required data from the sensor array as illustrated in the layered architecture of Figure 2.3. The functional processes of the process control application software and of the device driver software for the dumb sensors would be as shown in Figures 3.10 (a) and (b) below.*



**Figure 3.10 (a) and (b) - Solution for a poll of dumb sensors issued by software A in the process control application layer handled by software B in the dumb sensor device driver layer**

*Figure 3.10 (a) shows that the application software functional process FP A is triggered by an Entry E1 e.g. from a clock tick. This functional process then obtains data via Entry E2 from the dumb sensor array to receive the multiple occurrences of the sensor readings. The dumb sensors are also functional users of the process control software in this application level model. (The presence of the device driver software is unknown at this level.)*

*Figure 3.10 (b) shows the model for the software that drives the dumb sensor devices. It receives data via an Entry from the application (probably in practice via an operating system) as the trigger of a functional process FP B. This functional process obtains the required data via an Entry E from its functional user, the dumb sensor array.*

*The data group is passed back to the process control software via an Exit. This Exit is received as the Entry E2 by the application functional process FP A. FP A then continues with its processing of the sensor data. Again, the fact that there are multiple occurrences of this cycle of gathering data from each of the identical sensors is irrelevant to the model.*

*The apparent mis-match between the one Entry E2 from a dumb sensor to the process control application software and the Entry followed by an Exit data movement of the device driver software is due to the convention that an Entry from a dumb sensor is considered to include any 'request to enter' functionality since the dumb functional user has no capability of dealing with any message from a functional process.*

*REAL-TIME EXAMPLE 2 of rule b): Suppose a functional process sends to one of its functional users such as an 'intelligent' hardware device or another peer piece of software some parameters for an enquiry or the parameters for a calculation, or some data to be compressed. The response from the functional user is obtained via an Exit followed by an Entry data movement, as described in section 3.5.8, Example 2.*

### 3.5.10 Navigation and display control commands for human users ('control commands')

A 'control command' is a command that is recognized in any application which may be used by human functional users and which must be ignored when measuring a functional size. The definition is:

#### **DEFINITION – Control command**

A command that enables human functional users to control their use of the software but which does not involve any movement of data about an object of interest of the FUR of the software being measured.

NOTE: A control command is not a data movement because the command does not move data about an object of interest. Examples are 'page up/down' commands; hitting a Tab or Enter key, clicking on the 'OK' to confirm a previous action, pressing a button to continue, etc.

#### **RULE – Control commands in applications with a human interface**

In an application with a human interface 'control commands' shall be ignored as they do not involve any movement of data about an object of interest.

*EXAMPLES: Control commands are the functions that enable a human functional user to control the display (or not) of a header or of sub-totals that have been calculated, navigate up and down and between physical screens, click 'OK' to acknowledge an error message or to confirm some entered data, etc. Control commands therefore also include menu commands that enable the functional user to navigate to one or more specific functional processes but which do not themselves initiate any one functional process, and commands to display a blank screen for data entry.*

N.B. Outside the domain of applications with a human user interface, the concept of a 'control command' has no special meaning and any signal or movement of data about an object of interest coming from a functional user must be accounted for, i.e. must be measured.

### 3.5.11 Error/Confirmation Messages

#### **DEFINITION – Error/confirmation message**

An Exit issued by a functional process for the attention of a human user that either confirms only that entered data has been accepted, or only that there is an error in the entered data.

NOTE: If a message to a human user provides other data than just confirming that entered data has been accepted, or that entered data is in error, then this other data should be identified as a data group moved by an Exit and not as an error/confirmation message.

## **RULES – Error/Confirmation messages and other indication of error conditions**

- a) One Exit shall be identified to account for all types of error/confirmation messages issued by a functional process of the software being measured from all possible causes according to its FUR, e.g. successes or failures of: validation of entered data or for a call to retrieve data or to make data persistent, or for the response from a service requested of another piece of software.

NOTE: If the FUR of the functional process do not require any type of error/confirmation message to be issued, do not identify any corresponding Exit.

- b) All other data, issued or received by the software being measured, to/from its hardware or software functional users should be analyzed according to the FUR as Exits or Entries respectively, according to the normal COSMIC rules, regardless of whether or not the data values indicate an error condition.
- c) Reads and Writes are considered to account for any associated reporting of error conditions. Therefore no Entry to the functional process being measured shall be identified for any error indication received as a result of a Read or Write of persistent data.
- d) No Entry or Exit shall be identified for any message indicating an error condition that might be issued whilst using the software being measured but which is not required to be processed in any way by the FUR of that software, e.g. an error message issued by the operating system.

*BUSINESS EXAMPLE 1 illustrating rule a): In a human-computer dialogue, examples of error messages occurring during validation of data being entered could be 'format error', 'customer not found', 'error: please tick check box indicating you have read our terms and conditions', 'credit limit exceeded', etc. All such error messages should be considered as occurrences of one Exit in each functional process where such messages occur (which could be named 'error messages').*

*BUSINESS EXAMPLE 2 illustrating rule a): functional process 'A' can potentially issue 2 distinct confirmation messages and 5 error messages to its functional users. Identify one Exit to account for all these  $5 + 2 = 7$  error/confirmation messages. Functional process 'B' can potentially issue 8 error messages to its functional users. Identify one Exit to account for these 8 error messages.*

*BUSINESS EXAMPLE 3 illustrating rule b): In a human-computer dialogue, if a message is output in error situations but it contains functional user data, then it should be counted as an Exit in the functional process where it occurs. An example of such a message could be 'Warning: the amount you wish to withdraw exceeds your overdraft limit by \$100' (where the \$100 is a calculated variable). In this example, the Exit contains a data group about the customer's bank account.*

*BUSINESS EXAMPLE 4 illustrating rule d): Error messages output to the human users but not generated or processed by the application software being measured should be completely ignored in the measurement of the application. An example of such a message passed on from the operating system could be 'printer X is not responding'.*

*REAL-TIME EXAMPLE 1 illustrating rule b): In a real-time system, a functional process that periodically checks the correct functioning of all hardware devices might issue a message that reports 'Sensor X has failed', where 'X' is a variable. This message should be identified as one Exit in that functional process.*

*REAL-TIME EXAMPLE 2 illustrating rule b). The FUR of REAL-TIME EXAMPLE 1 in section 3.5.9 may also state that the FP's A and B must handle an error condition when the device driver software fails to obtain the data from one or more of the array of dumb sensors. A dumb sensor cannot, by definition, issue an error message. The device driver FP B will, most likely, obtain a string of values from the array of dumb sensors, e.g. state 1, state 2, state 3, no response, state 5, no response, state 7, etc. and will pass this string back to the FP A of the application. No separate error message should be identified as an Exit from FP B of the device driver software, nor as an Entry to FP A of the process control application.*

## THE MEASUREMENT PHASE

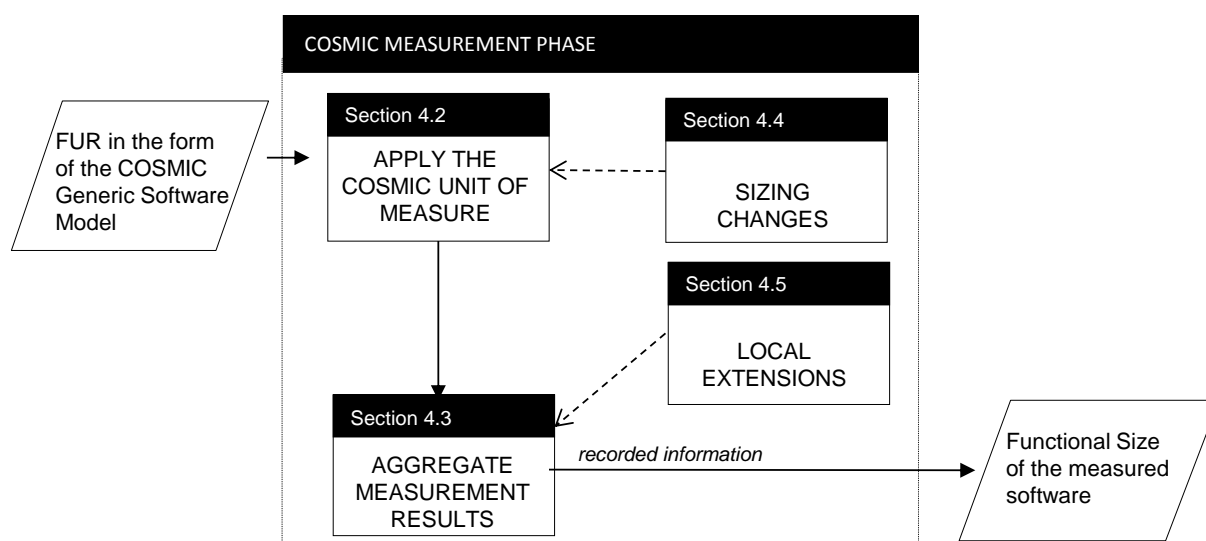
### 4.0 Chapter summary

This chapter discusses the final step of the measurement process. First, the COSMIC unit of measure is defined (namely one data movement is measured as one COSMIC Function Point, or 'CFP'). Then the rules are given for assigning a size to the FUR of the software being measured. Rules are defined for how to aggregate sizes of different pieces of software.

Also, rules are defined for how to size required changes to software (as dealt with in 'enhancement' projects). Finally, the chapter discusses the possibility of 'local extensions' to the standard COSMIC method which may be used, for example, in the local environment of an organization that desires to account for some aspect of functionality in a way which is meaningful as a local standard.

### 4.1 The measurement phase process

The general method for measuring a piece of software when its Functional User Requirements have been expressed in terms of the COSMIC Generic Software Model is summarized in Figure 4.0 below.



**Figure 4.0 – General process for the COSMIC Measurement Phase**

Each step in this method is the subject of a specific section of this chapter where the definitions and principles to apply are presented, along with some rules and examples.

## 4.2 Applying the measurement function

### DEFINITION – COSMIC unit of measurement

1 CFP (Cosmic Function Point) which is defined as the size of one data movement.

NOTE: The unit of measurement was previously known as a 'Cfsu' (COSMIC functional size unit.)

Arising from this definition, each data movement (Entry, Exit, Read or Write) that is required to be added, changed or deleted for the software being measured is also measured as 1 CFP.

## 4.3 Aggregating measurement results

This step consists in aggregating the sizes of all identified data movements, into a single functional size value. This step is accomplished according to the following rules.

### 4.3.1 General rules of aggregation

#### RULES – Aggregating measurement results

- a) For any functional process, the functional sizes of individual data movements shall be aggregated into a single functional size value in units of CFP by adding them together.

$$\text{Size (functional process}_i\text{)} = \sum \text{size(Entries}_i\text{)} + \sum \text{size(Exits}_i\text{)} + \sum \text{size(Reads}_i\text{)} + \sum \text{size(Writes}_i\text{)}$$

- b) For any functional process, the functional size of changes to its Functional User Requirements shall be aggregated from the sizes of the data movements that have been added, modified or deleted in the functional process to give a size of the change in units of CFP, according to the following formula.

$$\text{Size (Change(functional process}_i\text{))} = \sum \text{size (added data movements}_i\text{)} + \sum \text{size (modified data movements}_i\text{)} + \sum \text{size (deleted data movements}_i\text{)}$$

For more on aggregating functional size, see section 4.3.2. For measuring the size of the changed software, see section 4.4.2.

- c) The size of a piece of software within a defined scope shall be obtained by aggregating the sizes of the functional processes for the piece, subject to rules e) and f) below.
- d) The size of any change to a piece of software within a defined scope shall be obtained by aggregating the sizes of all changes to all functional processes for the piece, subject to rules e) and f) below
- e) Sizes of pieces of software or of changes to pieces of software may be added together only if measured at the same functional process level of granularity of their FUR.
- f) Sizes of pieces of software and/or changes in the sizes of pieces of software within any one layer or from different layers shall be added together only if it makes sense to do so, for the purpose of the measurement.
- g) The size of a piece of software cannot be obtained by adding up the sizes of its components (regardless of how the piece is decomposed) *unless* the size contributions of inter-component data movements are eliminated.
- h) If the COSMIC method is extended locally (for example to measure some aspect of size not covered by the standard method), then the size measured via the local extension shall be reported separately as described in section 5.1 and may NOT be added to the size obtained by the standard method, measured in CFP (see further in section 4.5).

*EXAMPLE 1 for rules b) and c): A requested change to a piece of software might be: 'add one new functional process of size 6 CFP, and in another functional process add one data movement, make modifications to three other data movements and delete two data movements.' The total size of the requested change is  $6 + 1 + 3 + 2 = 12$  CFP.*

*EXAMPLE 2 for rule f): If various major parts of a piece of software are developed using different technologies, by different project sub-teams, there may be no practical value in adding their sizes together.*

*EXAMPLE 3 for rule g): If a piece of software is*

- first measured 'as a whole', i.e. all within one scope*
- then secondly the size of each of its components is measured separately, i.e. each with its own scope,*

*then the total size from adding up the size of all the separate components (in the second case) will exceed the size when measured 'as a whole' (in the first case) due to the contribution to size of all the inter-component data movements. These inter-component data movements are not visible when the piece is measured 'as a whole' . See also the example in the section on measuring at varying levels of granularity in pure software architectures in the 'Advanced and Related Topics' [12] document.*

It is to be noted that, *within* each identified layer, the aggregation function is fully scalable. Therefore a sub-total can be generated for individual functional processes or for all the software within a layer, depending on the purpose and scope of each measurement exercise and subject to rules d), e) and f) above.

#### **4.3.2 More about functional size aggregation**

In a context where functional size is to be used as a variable in a model, to estimate effort for instance, and the software to be measured extends over more than one layer, aggregation will typically be performed per layer since software in different layers is often not implemented with the same technology.

*EXAMPLE 1: Consider software where the application layer is to be implemented using a third generation language and a set of existing libraries, while a driver layer might be implemented using assembly language. The effort-per-unit-size associated with the construction of the software in each layer will, most probably, be different, and, consequently, an effort estimate will be prepared separately for the software in each layer. It is unlikely there will be any value in adding the sizes of the software in the two layers*

*EXAMPLE 2: If a project team has to develop a number of major pieces of software and is interested in its overall productivity, it can add together the work-hours needed to develop each piece. Similarly, it can add together the sizes of the major pieces it has developed if (but only if) those sizes satisfy the rules given above.*

The reason that sizes of pieces of software from different layers of a standard layered architecture, measured at the same functional process level of granularity, may be added together is that such an architecture has a coherently defined set of functional users. Software in each layer is a functional user of software in the other layers that it uses and any piece of software in a layer may be a functional user of any of its peer pieces of software. The requirements of such an architecture impose that the FUR of the various pieces must exchange messages. It is therefore only logical and reasonable that the sizes of the various pieces may be added together, always subject to rules d), e) and f) above. However, in contrast, the size of any piece of software may *not* be obtained by adding up the sizes of its component re-usable objects unless the inter-object data movements are eliminated, as per rule g) above.

Aggregating the measurement results by type of data movement might be useful for analyzing the contribution of each type to the total size of the software in a given a layer and might thus help characterize the functional nature of the measured software in the given layer.

#### 4.4 More on measurement of the size of changes to software

A 'functional change' to existing software is interpreted in the COSMIC method as 'any combination of additions of new data movements or of modifications or deletions of existing data movements'. The terms 'enhancement' and 'maintenance'<sup>13</sup> are often used for what we here call a 'functional change'.

The need for a change to software may arise from either

- a new FUR (i.e. only additions to the existing functionality), or
- from a change to the FUR (perhaps involving additions, modifications and deletions) or
- from a 'maintenance' need to correct a defect

The rules for sizing any of these changes are the same but the Measurer is alerted to distinguish the various circumstances when making performance measurements and estimates.

When a piece of software is completely replaced, for instance by re-writing it, with or without extending and/or omitting functionality, the functional size of this change is the size of the replacement software, measured according to the normal rules for sizing new software. This case will not be considered further in this section. The Measurer should be aware, however, of the need when making performance measurements or estimates to distinguish between projects to develop entirely new software and projects to 're-develop' or 'replace' existing software.

Often, an obsolete part of an application is deleted ('disconnected' would be a better description) by leaving the program code in place and by just removing the link to the obsolete functionality. When the functionality of the obsolete part amounts to 100 CFP but the part can be disconnected by changing, say, 2 data movements, 100 and not 2 data movements shall be identified as the size of the functional change. We measure the size of the requirement, not the size that was implemented.

Note that for estimation purposes it may be advisable to use a different productivity for this part of the functional change, since disconnecting is quite different from 'real' deletes. Alternatively, for estimating purposes it may be preferable to measure the size that will be implemented (2 CFP in the example) rather than the size of the requirement (100 CFP in the example). If the 'project size' of 2 CFP is measured, this should be clearly documented and distinguished from a measurement of the FUR which require that the application should be reduced in size by 100 CFP.

Note the difference between the size of the functional change (discussed here) and the change in the functional size of the software. Usually, they are different. In section 4.4.2 the size of the latter is addressed.

##### 4.4.1 Modifying functionality

Any data movement of a given type (E, X, R and W) involves two types of functionality: it moves a single data group and it has some associated data manipulation (for the latter, see section 3.5.6). Hence for measurement purposes a data movement is considered to be functionally modified as follows.

<b>DEFINITION – Modification (of the functionality of a data movement)</b>
a) A data movement is considered to be functionally modified if at least one of the following applies: <ul style="list-style-type: none"><li>• the data group moved is modified,</li><li>• the associated data manipulation is modified.</li></ul>
b) A data group is modified if at least one of the following applies: <ul style="list-style-type: none"><li>• one of more new attributes are added to the data group,</li><li>• one or more existing attributes are removed from the data group,</li><li>• one or more existing attributes are modified, e.g. in meaning or format (but not in their values)</li></ul>



<sup>13</sup> A normal measurement convention is that the functional size of a piece of software does not change if the software must be changed to correct a defect so as to bring the software in line with its FUR. The functional size of the software does change if the change is to correct a defect in the FUR.



- c) A data manipulation is modified if it is functionally changed in any way.

*EXAMPLE: A data manipulation is modified for instance by changing the calculation, the specific formatting, presentation, and/or validation of the data. 'Presentation' can mean, for example the font, background colour, field length, field heading, number of decimal places, etc.*

Control commands and application-general data of business applications do not involve data movements, as no data about objects of interest is moved. Therefore, changes to control commands and application-general data should not be measured. As an example, when the screen colour for all screens is changed, this change should not be measured. (See section 3.5.10 for an explanation of control commands and application-general data.)

#### **RULES – Modifying a data movement**

- a) If a data movement must be modified due to a change of the data manipulation associated with the data movement and/or due to a change in the number or type of the attributes in the data group moved, one changed CFP shall be measured, regardless of the actual number of modifications in the one data movement.
- b) If a data group must be modified, data movements moving the modified data group whose functionality is not affected by the modification to the data group shall not be identified as changed data movements.

**NOTE:** A modification to any data appearing on input or output screens that are not related to an object of interest to a functional user shall not be identified as a changed CFP. (See section 3.3.4 for examples of such data.)

*EXAMPLE for rules a) and b): Suppose a requirement to add or to modify the data attributes of a data group  $D_1$ , such that after modification it becomes  $D_2$ . In the functional process A where this modification is required, all data movements affected by the modification should be identified and counted as modified. So, as per rule a), if the changed data group  $D_2$  is made persistent and/or is output in functional process A, identify one Write and/or one Exit data movement respectively as modified. However, it is possible that other functional processes Read or Enter this same data group  $D_2$ , but their functionality is unaffected by the modification because they do not process the changed or added data attributes. These functional processes continue to process the data group moved as if it were still  $D_1$ . So, as per rule (b), these data movements in the other functional processes that are not affected by the modification to the data movement(s) of functional process A must NOT be identified and counted as modified.*

*BUSINESS EXAMPLE: If an error/confirmation message is required to be changed (i.e. texts added, modified or deleted) it should be identified for measurement, regardless of whether or not the changed text is a consequence of a requirement to change another data movement.*

#### **4.4.2 Size of the functionally changed software**

After functionally changing a piece of software, its new total size equals:

- the original size,
- plus the functional size of all the added data movements,
- minus the functional size of all the removed data movements.

Modified data movements have no influence on the size of the piece of software as they exist both before and after the modifications have been made.

## **4.5 Extending the COSMIC measurement method**

### **4.5.1 Introduction**

The COSMIC method of measuring a functional size does not presume to measure all possible aspects of software 'size'. Thus the method is currently not designed to measure separately and explicitly the size of the FUR of data manipulation sub-processes. The influence on size of data manipulation sub-processes is taken into account via a simplifying assumption that is valid for a wide range of software domains, as defined in section 1.1 on the applicability of the method. Also, the influence of the number of data attributes per data movement on software size is not captured.

Other parameters such as 'complexity' (however defined) might be considered to contribute to functional size. A constructive debate on this matter would first require commonly-agreed definitions of the other elements within the ill-defined notion of 'size' as it applies to software. Such definitions are still, at this point, the subject of further research and of much debate.

Nevertheless, the COSMIC size measure is considered to be a good approximation for the method's stated purpose and domain of applicability. Yet, it may be that within the local environment of an organization using the COSMIC measurement method, it is desired to account for such functionality in a way which is meaningful as a local standard. For this reason, the COSMIC measurement method has provision for local extensions. When such local extensions are used, the measurement results must be reported according to the special convention presented in section 5.1. The following sections show how to extend the method with a local standard.

### **4.5.2 Data manipulation-rich software**

The COSMIC method was designed to measure 'data movement-rich' software. Like all other true Functional Size Measurement (FSM) methods, it was not designed to measure explicitly the functionality of data manipulation. Instead, the method assumes that the amount of data manipulation functionality is accounted for by the number of data movement types (see further below). This assumption has proven to be reasonable for all the practical purposes such as project performance measurement and estimating for which the method was designed and for the domains in which it is commonly used.

Experience has shown however that the method can also often be successfully applied to size 'data manipulation-rich' software, e.g. some scientific/engineering software. This is true, for example, where the software must handle high volumes of data, leading to very large numbers of data movement types. The latter may effectively account for any mathematically-complex data manipulation that may also be present. By 'successfully applied', we mean that the method has produced meaningful and useful sizes in relation to the purpose of the measurement. Examples include the sizing of expert systems, software to digitally process continuous variables, software that collects and analyzes data from scientific experiments or from engineering measurements, etc.

However, given the fundamental design of the COSMIC method, users of the method, when faced with measuring a functional size of software that is rich in data manipulation, should decide for themselves whether the method really produces functional sizes that are meaningful and useful in relation to the purpose of the measurement. Where the method cannot account adequately for data manipulation, it may be possible to develop a local extension to the method to overcome the limitation – see section 4.5.

### **4.5.3 Limitations on the factors contributing to functional size**

Within its domains of applicability, the COSMIC method does not attempt to measure all possible aspects of functionality that might be considered to contribute to software 'size'. For example, the measurement method does not explicitly capture the influence of software 'complexity'. But there are many types of complexity e.g. architectural, semantic, timing, process, data, etc., and in measuring functional size, the method actually accounts in a simple way for the contribution to size of process complexity (and thus indirectly of data complexity).

The method also does not consider the influence of the number of data attributes per data movement on software functional size. As described in section 4.5.6, if desired, such aspects of functional size may be supported by a local extension to the COSMIC measurement method.

#### **4.5.4 Limitations on measuring very small pieces of software**

All functional size measurement methods are based on the assumptions of a simplified model of software functionality that is intended to be reasonable 'on average' for its intended domain of applicability. Caution is therefore needed when measuring, comparing or using sizes of very small pieces of software, and especially of very small changes to a piece of software, where the 'average' assumption may break down. In the case of the COSMIC method, 'very small' means 'a few data movements'.

#### **4.5.5 Local extension with complex algorithms**

If it is judged necessary to account for complex algorithms, a local standard may be arranged for this exceptional functionality. In any functional process where there is an abnormally complex data manipulation functional sub-process, the Measurer is free to assign his or her own locally-determined Function Points.

*EXAMPLE: A local extension standard could be: 'In our organization, one Local FP is assigned for mathematical algorithms such as (list of locally meaningful and well-understood examples). Two Local FP's are assigned for (another list of examples), etc.'*

#### **4.5.6 Local extension with sub-units of measurement**

When more precision is required in the measurement of data movements, then a sub-unit of the measure can be defined. For example, a meter can be sub-divided into 100 centimeters or 1000 millimeters. By analogy, the movement of a single data attribute could be used as a sub-unit of measurement. Measurements on a small sample of software in the field trials of COSMIC indicated that on the software measured, the average number of data attributes per data movement did not vary much across the four types of data movement. For this reason and for ease of measurement reasons the COSMIC unit of measurement, 1 CFP, has been fixed at the level of one data movement. However, caution is clearly needed when comparing the sizes measured in CFP of two different pieces of software where the average number of data attributes per data movement differs sharply across the two pieces of software.

Anyone wishing to refine the COSMIC method by introducing a sub-unit of measurement is free to do so but must make it clear that the resulting size measures are not expressed in standard COSMIC Function Points.

## MEASUREMENT REPORTING

### 5.0 Chapter summary

When a measurement is finished and accepted, the result must be reported and data about the measurement archived so as to ensure that the result is always unambiguously interpretable. The chapter lists the parameters that should be considered for recording.

### 5.1 Labeling

The Generic Software Model can be depicted in matrix form where rows represent functional processes (which might be grouped by layers), columns represent data groups and cells hold the identified sub-processes (Entry, Exit, Read and Write). This representation of the Generic Software Model is presented in Appendix A.

COSMIC measurement results are to be reported and archived according to the following conventions. When reporting a COSMIC functional size it should be labeled according to the following convention, in accordance with the ISO/IEC 14143-1:2007 standard.

#### RULE – COSMIC measurement labeling

A COSMIC measurement result shall be noted as '**x** CFP (v.y)', where:

- '**x**' represents the numerical value of the functional size,
- '**v.y**' represents the identification of the standard version of the COSMIC method used to obtain the numerical functional size value '**x**'.

NOTE: If a local approximation method was used to obtain the measurement, but otherwise the measurement was made using the conventions of a standard COSMIC version, the above labeling convention shall be used, but use of the approximation method should be noted elsewhere – see section 5.2.

*EXAMPLE: A result obtained using the rules of this Measurement Manual is noted as '**x** CFP (v4.0)'*

When local extensions are used, as defined in section 4.5 above, the measurement result must be reported as defined below.

#### RULE – COSMIC local extensions labeling

A COSMIC measurement result using local extensions shall be noted as:

'**x** CFP (v. y) + z Local FP', where:

- '**x**' represents the numerical value obtained by aggregating all individual measurement results according to the standard COSMIC method, version v.y,
- '**v.y**' represents the identification of the standard version of the COSMIC method used to obtain the numerical functional size value '**x**'.
- '**z**' represents the numerical value obtained by aggregating all individual measurement results obtained from local extensions to the COSMIC method.

## 5.2 Archiving COSMIC measurement results

When archiving COSMIC measurement results, the following information should be kept so as to ensure that the result is always interpretable.

### **RULE – COSMIC measurement reporting**

In addition to the actual measurements, recorded as in 5.1, some or all of the following attributes of each measurement should be recorded, depending on the measurement purpose and the desired level of comparability to other measurements, e.g. for benchmarking purposes.

- a) Identification of the measured software component (name, version ID or configuration ID).
- b) The sources of information used to identify the FUR used for the measurement
- c) The domain of the software.
- d) A description of the architecture of layers in which the measurement is made, if applicable.
- e) A statement of the purpose of the measurement.
- f) A description of the scope of the measurement, and its relation to the overall scope of a related set of measurements, if any. (Use the generic scope categories in section 2.2).
- g) The measurement pattern used (COSMIC or local), with the processing mode (on-line or batch).
- h) The functional users of the software.
- i) The level of granularity of the available software artefacts and the level of decomposition of the software.
- j) The point in the project life-cycle when the measurement was made (especially whether the measurement is an estimate based on incomplete requirements, or was made on the basis of actually delivered functionality).
- k) The target or believed error margin of the measurement.
- l) Indications whether the standard COSMIC measurement method was used, and/or a local approximation to the standard method, and/or whether local extensions were used (see section 4.5). Use the labeling conventions of sections 5.1 or 5.2.
- m) An indication whether the measurement is of developed or delivered functionality ('developed' functionality is obtained by creating new software; 'delivered' functionality includes 'developed' functionality and also includes functionality obtained by other means than creating new software, i.e. including all forms of re-use of existing software, implementation of packages, use of existing parameters to add or change functionality, etc).
- n) An indication of whether the measurement is of newly provided functionality or is the result of an 'enhancement' activity (i.e. the sum is of added, changed and deleted functionality – see 4.4).
- o) The number of major components, if applicable, whose sizes have been added together for the total size recorded.
- p) The percentage of functionality implemented by re-used software.
- q) For each scope within the overall measurement scope, one measurement matrix, as specified in Appendix A.
- r) The Measurer's name and any COSMIC certification qualifications; the date of the measurement.

## REFERENCES

All the COSMIC documents listed below, including translations into other languages, can be found on the Web at [www.cosmicon.com](http://www.cosmicon.com).

The COSMIC document titles do not give the method version number to which they relate. All documents are being updated to bring them in line with version 4.0 of the method.

- [1] ISO/IEC 14143/1:2011 Software Engineering – COSMIC: a functional size measurement method, [www.iso.org](http://www.iso.org)
- [2] Introduction to the COSMIC Method of measuring software
- [3] (Example of several papers by the same authors) Al-Sarayreh, K.T. and A. Abran, Specification and Measurement of System Configuration Non Functional Requirements, 20th International Workshop on Software Measurement (IWSM 2010), Stuttgart, Germany, 2010
- [4] Guideline for Sizing Real-time Software
- [5] Guideline for 'Measurement Strategy Patterns'
- [6] Guideline for approximate COSMIC functional size measurement (under construction)
- [7] Guideline for Sizing Business Application Software
- [8] Guideline for sizing Data Warehouse Application Software
- [9] Guideline for Sizing Service-Oriented Architecture Software
- [10] Quick Reference Guide to the COSMIC method for sizing Business Application Software
- [11] Quick Reference Guide to the COSMIC method for sizing Real-Time Application Software
- [12] Advanced and Related Topics
- [13] Guideline for Convertibility (under construction)
- [14] International Vocabulary of Basic and General Terms in Metrology, International Organization for Standardization, Switzerland, 2<sup>nd</sup> edition, 1993, ISBN 92-67-01075-1
- [15] ISO/IEC 15939:2002, Systems and Software Engineering – Measurement Process, definition 3.24
- [16] Adapted from Merriam Webster's Collegiate Dictionary, 10<sup>th</sup> Edition
- [17] Adapted from Merriam Webster's Collegiate Dictionary, 10<sup>th</sup> Edition, and La Petit Larousse Illustré, 1996 Edition



## Appendix B

### APPENDIX B – EVOLUTION OF NON-FUNCTIONAL REQUIREMENTS – EXAMPLES

The following table lists a few examples of requirements statements that may appear initially at the system level (even before requirements have been allocated to software or hardware) or at the software level as non-functional but that evolve, wholly or partly as a project progresses, into a mixture of FUR for software and statements of requirements that are truly 'non-functional'.

- Column 1: examples of statements of system or software NFR
- Column 2: examples of software FUR that might result, as a project progresses, from the NFR in column 1. The FUR may be for software to be developed or to be acquired e.g. 'COTS' (Commercial Off-the-Shelf) software.
- Column 3: examples of the requirements and constraints on the system or project that might remain after separating out the software FUR in column 2. These are therefore true 'non-functional' requirements.

System or software requirements that may initially appear as Non-Functional	Examples of FUR for software, to be developed or acquired, that may evolve from the initial system NFR	Examples of true NFR that may remain after some initial system requirements have evolved into software FUR
The system response time during peak-hour shall not exceed an average of X seconds.	Software to: <ul style="list-style-type: none"> <li>• Feed external data needed by the system in real-time</li> <li>• Monitor and report on the average response time</li> </ul>	<ul style="list-style-type: none"> <li>• Specific (fast) hardware</li> <li>• Some software to be written in a low-level language</li> <li>• The specific response time target statement</li> </ul>
The system availability shall exceed Y% averaged over each calendar year	Software to enable fast switching of processing to a back-up processor without interruption to service	<ul style="list-style-type: none"> <li>• Back-up hardware processor operating in 'hot standby' mode</li> <li>• The specific availability target statement</li> </ul>
Application parameters shall be easily maintainable by user staff	Software to enable users to maintain parameter tables	(None)
The system shall be usable by members of the general public with no training and a Z% successful completion rate	Software to: <ul style="list-style-type: none"> <li>• provide comprehensive Help facilities</li> <li>• provide well-structured menus for ease of use</li> <li>• support partially-sighted users</li> </ul>	<ul style="list-style-type: none"> <li>• Requirements for Braille keyboards</li> <li>• Extensive testing by members of the general public</li> <li>• The specific Z% target completion rate statement</li> </ul>
The user shall have the option to secure files by encryption	Software to encrypt and decrypt files on demand of the user	Use of a hardware 'dongle' or encryption key device
The system shall be portable across X, Y and Z hardware/software environments	A layer of software to isolate the main functionality from the specific interface requirements of the X, Y and Z environments	Use of a highly portable language such as Java



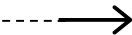



## Appendix C

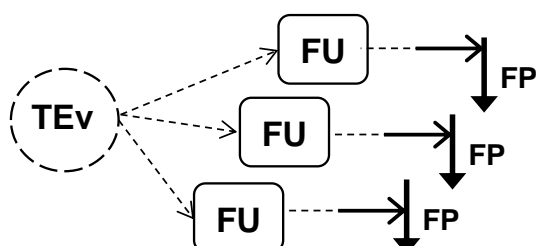
### APPENDIX C – CARDINALITY OF TRIGGERING EVENTS, FUNCTIONAL USERS AND FUNCTIONAL PROCESSES

All the relationships along the triggering event / functional user / triggering Entry / functional process chain (as shown in Figure 3.3) may be many-to-many in principle, with one exception. (The exception is that any one triggering Entry may initiate only one functional process – see rule b) for a functional process in section 3.2.2.).

The table below shows examples of possible relationships. Note that the cases may not be exhaustive. The table uses the following abbreviations and symbols.

	Triggering event		Functional User
	Data group (dotted part) moved by a triggering Entry (solid arrow)		Functional Process

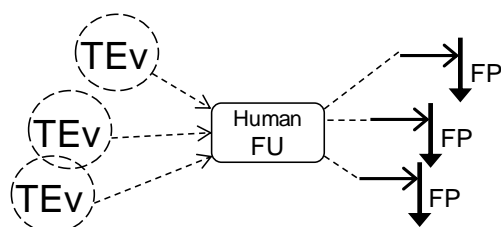
#### 1. A single triggering event may cause multiple FU's to each initiate a triggering Entry in the same or in different software systems. Each triggering Entry starts its own FP



*REAL TIME EXAMPLE:* The triggering event of an earthquake may be detected by multiple independent FU sensors. Each FU initiates a triggering Entry that starts its FP in the same or in different systems.

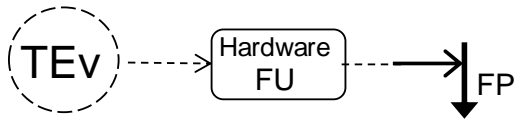
*BUSINESS EXAMPLE:* The triggering event of a new employee starting work causes one human FU to enter basic employee data to a Personnel system and another human FU to enter salary data to a Payroll system.

#### 2. Each triggering event causes a human FU to initiate a different triggering Entry. Each triggering Entry starts its FP in the same or in different software systems

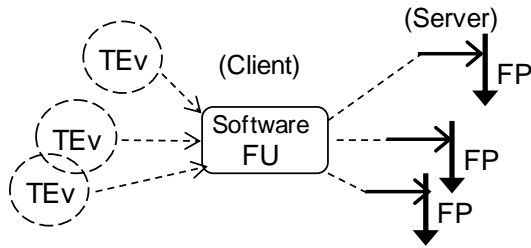


*BUSINESS EXAMPLE:* In a police emergency telephone call-handling system, many types of triggering events may be reported causing a human FU to decide to initiate different triggering Entries. Each of these starts its FP to record the event. Additionally, the human user may initiate different enquiry triggering Entries. Each of these starts its FP in the same call-handling system or in other systems.

**3. A hardware or software FU may be designed to sense (or ‘generate’) one or more specific type(s) of events. Each of these causes the FU to initiate a triggering Entry. Each of these starts its FP in the same software system.**

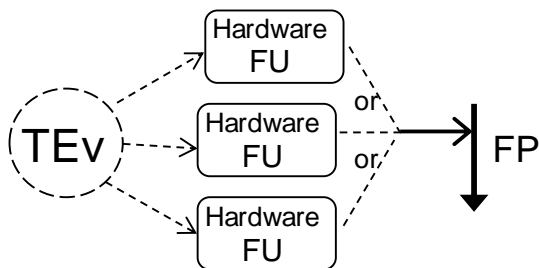


*REAL-TIME EXAMPLE:* When the temperature of a liquid reaches a pre-set level (the triggering event), a thermocouple FU initiates a triggering Entry to start its FP in one specific software system.



*BUSINESS EXAMPLE:* In a distributed software application, the client component is a FU of the server component. Different needs for information (the triggering events) of the client component cause it to initiate different triggering Entries, each to start its FP of the server component, for each different type of service it needs.

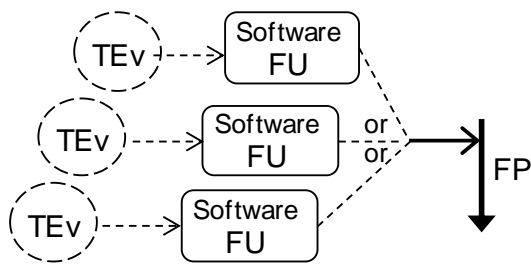
**4. Two or more hardware FU's of the same software may sense the same triggering event. Each FU may initiate the triggering Entry that starts the same one FP.**



*REAL-TIME EXAMPLE:* The triggering event of an abnormal situation in a real-time process control system, may be sensed by one or more hardware FU's. Each FU may initiate the one emergency shut-down FP.

(NOTE: Any one occurrence of this FP will be initiated by the first FU to sense the triggering event.)

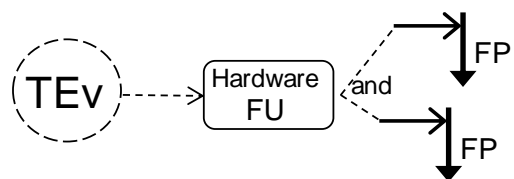
**5. Two or more software FU's may each initiate a triggering Entry that starts the same one FP.**



*INFRASTRUCTURE EXAMPLE:* Several software FU's may each 'call', i.e. initiate, the same FP in the same re-usable software component. (In this case the software FU 'generates' the event when it calls the component.)

(NOTE: Any one occurrence of this FP can be initiated by only one of its possible software FU's at any one time.)

**6. On sensing one triggering event, a FU may initiate two or more triggering Entries. Each triggering Entry starts its FP in the same software.**



*REAL-TIME EXAMPLE:* In a duplex safety-critical control system, one triggering event may cause a FU (usually hardware) to initiate two triggering Entries, each starting its FP. The two FP's could, for example, have the same FUR but be developed by separate groups as a result of a diversity strategy.

## APPENDIX D – SUMMARY OF COSMIC METHOD PRINCIPLES AND RULES

The table below identifies each principle and rule found in the COSMIC Measurement Method for the purpose of precise referencing, with the section number in the left column.

Sec.	PRINCIPLES AND RULES DESCRIPTION
1.3.1	<p><b>The COSMIC Software Context Model</b></p> <p><b>Principles</b></p> <ul style="list-style-type: none"> <li>a) Software is bounded by hardware.</li> <li>b) Software is typically structured into <b>layers</b>.</li> <li>c) A layer may contain one or more separate '<b>peer</b>' pieces of software.</li> <li>d) Any piece of software to be measured, shall be defined by its measurement <b>scope</b>, which shall be confined wholly within a single layer.</li> <li>e) The scope of a piece of software to be measured shall depend on the <b>purpose</b> of the measurement.</li> <li>f) The <b>functional users</b> of a piece of software to be measured shall be identified from its Functional User Requirements (FUR) as the senders and/or intended recipients of data to/from the software respectively.</li> <li>g) The FUR of software may be expressed at different <b>levels of granularity</b>.</li> <li>h) A precise COSMIC size measurement of a piece of software requires that its FUR are known at a level of granularity at which its <b>functional processes</b> and sub-processes may be identified.</li> <li>i) An approximate COSMIC size measurement of a piece of software is possible if its FUR are measured at a high level of granularity by an approximation approach and scaled to the level of granularity of the functional processes and sub-processes.</li> </ul>
1.3.2	<p><b>The Generic Software Model</b></p> <p><b>Principles</b></p> <ul style="list-style-type: none"> <li>a) A piece of software interacts with its functional users across a <b>boundary</b>, and with <b>persistent storage</b> within this boundary.</li> <li>b) Functional user requirements of a piece of software to be measured can be mapped into unique functional processes.</li> <li>c) Each functional process consists of sub-processes.</li> <li>d) A sub-process may be either a <b>data movement</b> or a <b>data manipulation</b>.</li> <li>e) A data movement moves a single <b>data group</b>.</li> <li>f) There are four data movement types, <b>Entry</b>, <b>Exit</b>, <b>Write</b> and <b>Read</b>. An Entry moves a data group into a functional process from a functional user. An Exit moves a data group out of a functional process to a functional user. A Write moves a data group from a functional process to persistent storage. A Read moves a data group from persistent storage to a functional process.</li> <li>g) A data group consists of a unique set of <b>data attributes</b> that describe a single <b>object of interest</b>.</li> <li>h) Each functional process is started by its <b>triggering Entry</b> data movement. The data group moved by the triggering Entry is generated by a functional user in response to a <b>triggering event</b>.</li> <li>i) A functional process shall include at least one Entry data movement and either a Write or an Exit data movement, i.e. it shall include a minimum of two data movements. There is no upper limit to the number of data movements in a functional process</li> </ul>

Sec.	PRINCIPLES AND RULES DESCRIPTION
	j) As an approximation for measurement purposes, data manipulation sub-processes are not separately measured; the functionality of any data manipulation is assumed to be accounted for by the data movement with which it is associated
1.4	<b>The COSMIC measurement principle</b> <b>Principles</b> a) The size of a functional process is equal to the number of its data movements b) The functional size of a piece of software of defined scope is equal to the sum of the sizes of its functional processes
2.2	<b>Measurement scope</b> <b>Rules</b> a) The scope of a Functional Size Measurement shall be derived from the purpose of the measurement. b) The scope of any one measurement shall not extend over more than one layer of the software to be measured
2.2.2	<b>Layer</b> <b>Principles</b> a) Software in one layer provides a set of services that is cohesive according to some defined criterion, and that software in other layers can utilize without knowing how those services are implemented. b) The relationship between software in any two layers is defined by a 'correspondence rule' which may be either <ul style="list-style-type: none"> <li>• 'hierarchical', i.e. software in layer A is allowed to use the services provided by software in layer B but not vice versa (where the hierarchical relationship may be up, down or sideways), or</li> <li>• 'bi-directional', i.e. software in layer A is allowed to use software in layer B, and vice versa.</li> </ul> c) Software in one layer exchanges data groups with software in another layer via their respective functional processes. d) Software in one layer does not necessarily use all the functional services supplied by software in another layer. e) Software in one layer of a defined software architecture may be partitioned into other layers according to a different defined software architecture.
2.3.1	<b>Functional users</b> <b>Rules</b> a) The functional users of a piece of software to be measured shall be derived from the purpose of the measurement. b) When the purpose of a measurement of a piece of software is related to the effort to develop or modify the piece of software, then the functional users should be all the senders and/or intended recipients of data to/from the new or modified functionality, as required by its FUR.
2.4.3	<b>Functional process level of granularity</b> <b>Rules</b> a) Precise functional size measurement of a piece of software requires that its FUR are known at a level of granularity at which its functional processes and data movement sub-processes may be identified. b) If some requirements must be measured before they have been defined in sufficient detail for a precise measurement, the requirements can be measured using an approximate approach. These approaches define how requirements can be measured at higher level(s) of granularity. Scaling factors are then applied to the measurements at the higher level(s) of granularity to produce an approximate size

Sec.	PRINCIPLES AND RULES DESCRIPTION
	<p>at the level of granularity of the functional processes and their data movement sub processes. See the 'Guideline for approximate COSMIC functional size measurement' [6].</p>
3.2.2	<p><b>Functional process</b></p> <p><b>Rules</b></p> <ul style="list-style-type: none"> <li>a) A functional process shall belong entirely to the measurement scope of one piece of software in one, and only one, layer.</li> <li>b) Any one triggering Entry of a piece of software being measured may initiate only one functional process in that software.</li> <li>c) A functional process shall comprise at least two data movements, an Entry plus either an Exit or a Write. There is no upper limit to the number of data movements in a functional process.</li> <li>d) An executing functional process shall be considered terminated when it has satisfied its FUR for the response to its triggering Entry. A pause during the processing for technical reasons shall not be considered as termination of the functional process.</li> </ul>
3.3.1	<p><b>Data group</b></p> <p><b>Principles</b></p> <ul style="list-style-type: none"> <li>a) Each identified data group shall be unique and distinguishable through its unique collection of data attributes.</li> <li>b) Each data group shall be directly related to one object of interest in the software's Functional User Requirements.</li> <li>c) A data group shall be materialized within the computer system supporting the software.</li> </ul>
3.5.2	<p><b>Entry (E)</b></p> <p><b>Principles</b></p> <ul style="list-style-type: none"> <li>a) An Entry shall move a single data group describing a single object of interest from a functional user across the boundary and into the functional process of which the Entry forms part. If the input to a functional process comprises more than one data group, each describing a different object of interest, identify one Entry for each unique data group in the input. (See also section 3.5.7 on 'Data movement uniqueness'.)</li> <li>b) An Entry shall not exit data across the boundary, or read or write data from/to persistent storage.</li> </ul> <p><b>Rules</b></p> <ul style="list-style-type: none"> <li>a) The data group of a triggering Entry may consist of only one data attribute which simply informs the software that 'an event Y has occurred'. Very often, especially in business application software, the data group of the triggering Entry has several data attributes which inform the software that 'an event Y has occurred and here is the data about that particular event'.</li> <li>b) Clock-ticks that are triggering events shall always be external to the software being measured. Therefore, for example, a clock-tick event occurring every 3 seconds shall be associated with an Entry moving a data group of one data attribute. Note that it makes no difference whether the triggering event is generated periodically by hardware or by another piece of software outside of the boundary of the software being measured.</li> <li>c) Unless a specific functional process is necessary, obtaining the time from the system's clock shall not be considered to cause an Entry.</li> <li>d) If an occurrence of a specific event triggers the Entry of a data group comprising up to 'n' data attributes of a particular object of interest and the FUR allows that other occurrences of the same event can trigger an Entry of a data group which has</li> </ul>

Sec.	PRINCIPLES AND RULES DESCRIPTION
	<p>values for attributes of only a sub-set of the 'n' attributes of the object of interest, then one Entry shall be identified, comprising all 'n' data attributes.</p> <p>e) When identifying Entries in a screen that enables human functional users to input data into functional processes, e.g. as in an on-line business application, analyze only screens that are filled with data. Ignore i) any screen that is formatted but otherwise 'blank' except for possible default values, and ii) ignore all field and other headings that enable human users to understand the input data required.</p> <p>NOTE. It may be necessary to consider field and other headings when measuring FUR for changes to Entries – see section 4.4.1.</p>
3.5.3	<p><b>Exit (X)</b></p> <p><b>Principles</b></p> <p>a) An Exit shall move a single data group describing a single object of interest from the functional process of which the Exit forms part across the boundary to a functional user. If the output of a functional process comprises more than one data group, identify one Exit for each unique data group in the output. (See also section 3.5.7 on 'Data movement uniqueness'.)</p> <p>b) An Exit shall not enter data across the boundary, or read or write data from/to persistent storage.</p> <p><b>Rules</b></p> <p>a) An enquiry which outputs fixed text, (where 'fixed' means the message contains no variable data values), e.g. the result of pressing a button for 'Terms &amp; Conditions' on a shopping web-site, shall be modeled as having one Exit for the fixed text output.</p> <p>NOTE: For the output from 'Help' functionality, see the 'Guideline for sizing Business Application Software'. For the output of messages concerned with error conditions or confirming success, see section 3.5.11 of this Measurement Manual.</p> <p>b) If an Exit of a functional process moves a data group comprising up to 'n' data attributes of a particular object of interest and the FUR allows that the functional process may have an occurrence of an Exit that moves a data group which has values for attributes of only a sub-set of the 'n' attributes of the object of interest, then one Exit shall be identified, comprising all 'n' data attributes.</p> <p>c) When identifying Exits, ignore all field and other headings that enable human users to understand the output data.</p> <p>NOTE: It may be necessary to consider field and other headings when measuring FUR for changes to Exits – see section 4.4.1</p>
3.5.4	<p><b>Read (R)</b></p> <p><b>Principles</b></p> <p>a) A Read shall move a single data group describing a single object of interest from persistent storage to a functional process of which the Read forms part. If the functional process must retrieve more than one data group from persistent storage, identify one Read for each unique data group that is retrieved. (See also section 3.5.7 on 'Data movement uniqueness'.)</p> <p>b) A Read shall not receive or exit data across the boundary or write data to persistent storage.</p> <p>c) During a functional process, movement or manipulation of constants or variables which are internal to the functional process and that can be changed only by a programmer, or computation of intermediate results in a calculation, or of data stored by a functional process resulting only from the implementation, rather than from the FUR, shall not be considered as Read data movements.</p> <p>d) A Read data movement always includes any 'request to Read' functionality (so a separate data movement shall never be counted for any 'request to Read' functionality). See also section 3.5.9.</p>

Sec.	PRINCIPLES AND RULES DESCRIPTION
	<p><b>Read (R) continued</b></p> <p><b>Rules</b></p> <ul style="list-style-type: none"> <li>a) Identify a Read when, according to the FUR, the software being measured must retrieve a data group from persistent storage.</li> <li>b) Do not identify a Read when the FUR of the software being measured specify any software or hardware functional user as the source of, or as the means of retrieving, the data group. (For this case see the principles and rules for Entries and Exits.)</li> </ul>
3.5.5	<p><b>Write (W)</b></p> <p><b>Principles</b></p> <ul style="list-style-type: none"> <li>a) A Write shall move a single data group describing a single object of interest from the functional process of which the Write forms part to persistent storage. If the functional process must move more than one data group to persistent storage, identify one Write for each unique data group that is moved to persistent storage. (See also section 3.5.7 on 'Data movement uniqueness'.)</li> <li>b) A Write shall not receive or exit data across the boundary, or read data from persistent storage.</li> <li>c) A requirement to delete a data group from persistent storage shall be measured as a single Write data movement.</li> <li>d) The following shall not be considered as Write data movements: <ul style="list-style-type: none"> <li>• The movement or manipulation of any data that did not exist at the start of a functional process and that has not been made persistent when the functional process is complete;</li> <li>• Creation or update of variables or intermediate results that are internal to the functional process;</li> <li>• Storage of data by a functional process resulting only from the implementation, rather than from the FUR. (An example would be the use of storage to store data temporarily during a large sort process in a batch-processed job.)</li> </ul> </li> </ul> <p><b>Rules</b></p> <ul style="list-style-type: none"> <li>a) Identify a Write when, according to the FUR, the software being measured must move a data group to persistent storage.</li> <li>b) Do not identify a Write when the FUR of the software being measured specify any software or hardware functional user as the destination of, or as the means of moving, the data group. (For this case see the principles and rules for Entries and Exits.)</li> </ul>

3.5.6	<p><b>Data manipulation associated with data movements</b></p> <p><b>Principle</b></p> <p>All data manipulation in a functional process shall be associated with the four types of data movement (E, X, R, and W). By convention, the data movements of a functional process are assumed also to represent the data manipulation of the functional process.</p> <p><b>Rules</b></p> <ol style="list-style-type: none"> <li>An Entry data movement includes all data manipulation to enable a data group to be entered by a functional user (e.g. formatting and presentation manipulations) and to be validated,</li> <li>An Exit data movement includes all data manipulation to create the data attributes of a data group to be output and/or to enable the data group to be output (e.g. formatting and presentation manipulations) and to be routed to the intended functional user,</li> <li>A Read data movement includes all computation and/or logical processing needed in order to retrieve a data group from persistent storage.</li> <li>A Write data movement includes all computation and/or logical processing to create or to update a data group to be written, or to delete a data group.</li> <li>The data manipulation associated with any of these data movements does not include any data manipulation that is needed after the data movement has been successfully completed, nor does it include any data manipulation associated with any other data movement.</li> </ol>
3.5.7	<p><b>Data movement uniqueness and possible exceptions</b></p> <p><b>Rules</b></p> <ol style="list-style-type: none"> <li>Unless the Functional User Requirements specify otherwise, all data groups describing any one object of interest that are required to be entered into one functional process, and all associated data manipulation shall be identified and counted as one Entry (type).  (NOTE: A functional process may, of course, be required to handle multiple Entry types, each moving a data group describing a different object of interest (type).)  The same equivalent rule applies to any Read, Write or Exit data movement in any given functional process.</li> <li>More than one Entry data movement (type), each moving a data group describing the same object of interest (type) in a given functional process (type) may be identified and counted if there is a Functional User Requirement for these multiple Entries and <i>at least one</i> of the following applies: <ul style="list-style-type: none"> <li>the Entries differ by moving their data group from a different functional user,</li> <li>the Entries move different data groups,</li> <li>the Entries have significantly different associated data manipulation.</li> </ul> The same equivalent rule applies for Exits in any given functional process. NOTE: Any one functional process may have only one triggering Entry.</li> <li>More than one Read data movement (type), each moving a data group describing the same object of interest (type) in a given functional process (type) may be identified and counted if there is a Functional User Requirement for these multiple Reads and <i>at least one</i> of the following applies <ul style="list-style-type: none"> <li>the Reads move different data groups,</li> <li>the Reads have significantly different associated data manipulation.</li> </ul> The same equivalent rule applies for Writes in any given functional process.</li> </ol>



	<p>d) Repeated <i>occurrences</i> of a data movement type (i.e. each occurrence moving the same data group type with the same data manipulation type) shall not be identified and counted more than once in any one functional process.</p> <p>e) If the multiple <i>occurrences</i> of a data movement type in a given functional process differ in their associated data manipulation because different <i>values</i> of the data attributes of the data group moved result in different processing paths being followed, the data movement type shall not be identified and counted more than once in that process.</p>
<b>3.5.9</b>	<p><b>A functional process requiring data from a functional user</b></p> <p><b>Rules</b></p> <p>a) A functional process shall obtain a data group via an Entry data movement from a functional user, <i>when the functional process does not need to tell the functional user what data to send</i>, as in any of the following four cases:</p> <ul style="list-style-type: none"> <li>• when a functional user sends a triggering Entry which initiates the functional process;</li> <li>• when a functional process, having received a triggering Entry, waits, expecting the arrival of a further Entry from the functional user (can occur when a human functional user enters data to business application software);</li> <li>• when a functional process, having started, requests the functional user, 'send me your data now, if you have any' and the functional user sends its data;</li> <li>• when a functional process, having started, inspects the state of a functional user and retrieves the data it requires.</li> </ul> <p>In the latter two cases (typically occurring in real-time 'polling' software), by convention no Exit from the functional process shall be identified to obtain the required data. The functional process merely needs to send a prompt message to a functional user and the functionality of that prompt message is considered to be part of the Entry. The functional process knows what data to expect. Only one Entry shall be identified for this case.</p> <p>b) Where a functional process needs to obtain the services of a functional user (for instance to obtain data) and <i>the functional user needs to be told what to send</i> (typically where the functional user is another piece of software outside the scope of the software being measured), an Exit followed by Entry data movement shall be identified. The Exit contains the request for the specific data; the Entry contains the returned data.</p>
<b>3.5.10</b>	<p><b>Control commands in applications with a human interface</b></p> <p><b>Rule</b></p> <p>In an application with a human interface 'control commands' shall be ignored as they do not involve any movement of data about an object of interest.</p>
<b>3.5.11</b>	<p><b>Error/Confirmation messages</b></p> <p><b>Rules</b></p> <p>a) One Exit shall be identified to account for all types of error/confirmation messages issued by a functional process of the software being measured from all possible causes according to its FUR, e.g. successes or failures of: validation of entered data or for a call to retrieve data or to make data persistent, or for the response from a service requested of another piece of software.</p> <p>NOTE: If the FUR of the functional process do not require any type of error/confirmation message to be issued, do not identify any corresponding Exit.</p> <p>b) All other data, issued or received by the software being measured, to/from its hardware or software functional users should be analyzed according to the FUR as Exits or Entries respectively, according to the normal COSMIC rules, regardless of whether or not the data values indicate an error condition.</p>

	<p>c) Reads and Writes are considered to account for any associated reporting of error conditions. Therefore no Entry to the functional process being measured shall be identified for any error indication received as a result of a Read or Write of persistent data.</p> <p>d) No Entry or Exit shall be identified for any message indicating an error condition that might be issued whilst using the software being measured but which is not required to be processed in any way by the FUR of that software, e.g. an error message issued by the operating system.</p>
<b>4.3.1</b>	<p><b>Aggregating measurement results</b></p> <p><b>Rules</b></p> <p>a) For any functional process, the functional sizes of individual data movements shall be aggregated into a single functional size value in units of CFP by adding them together.</p> $\text{Size (functional process}_i\text{)} = \sum \text{size(Entries}_i\text{)} + \sum \text{size(Exits}_i\text{)} + \sum \text{size(Reads}_i\text{)} + \sum \text{size(Writes}_i\text{)}$ <p>b) For any functional process, the functional size of changes to its Functional User Requirements shall be aggregated from the sizes of the data movements that have been added, modified or deleted in the functional process to give a size of the change in units of CFP, according to the following formula.</p> $\text{Size (Change(functional process}_i\text{))} = \sum \text{size (added data movements}_i\text{)} + \sum \text{size (modified data movements}_i\text{)} + \sum \text{size (deleted data movements}_i\text{)}$ <p>For more on aggregating functional size, see section 4.3.2. For measuring the size of the changed software, see section 4.4.</p> <p>c) The size of a piece of software within a defined scope shall be obtained by aggregating the sizes of the functional processes for the piece, subject to rules e) and f) below</p> <p>d) The size of any change to a piece of software within a defined scope shall be obtained by aggregating the sizes of all changes to all functional processes for the piece, subject to rules e) and f) below.</p> <p>e) Sizes of pieces of software or of changes to pieces of software may be added together only if measured at the same functional process level of granularity of their FUR.</p> <p>f) Sizes of pieces of software and/or changes in the sizes of pieces of software within any one layer or from different layers shall be added together only if it makes sense to do so, for the purpose of the measurement.</p> <p>g) The size of a piece of software cannot be obtained by adding up the sizes of its components (regardless of how the piece is decomposed) <i>unless</i> the size contributions of inter-component data movements are eliminated.</p> <p>h) If the COSMIC method is extended locally (for example to measure some aspect of size not covered by the standard method), then the size measured via the local extension must be reported separately as described in section 5.1 and may NOT be added to the size obtained by the standard method, measured in CFP (see further in section 4.5).</p>
<b>4.4.1</b>	<p><b>Modifying a data movement</b></p> <p><b>Rules</b></p> <p>a) If a data movement must be modified due to a change of the data manipulation associated with the data movement and/or due to a change in the number or type of the attributes in the data group moved, one changed CFP shall be measured, regardless of the actual number of modifications in the one data movement.</p>

	<p>b) If a data group must be modified, data movements moving the modified data group whose functionality is not affected by the modification to the data group shall not be identified as changed data movements.</p> <p>NOTE: A modification to any data appearing on input or output screens that are not related to an object of interest to a functional user shall not be identified as a changed CFP. (See section 3.3.4 for examples of such data.)</p>
<b>5.1</b>	<p><b>COSMIC measurement labeling</b></p> <p><b>Rules</b></p> <p>A COSMIC measurement result shall be noted as '<b>x</b> CFP (v.y)', where:</p> <ul style="list-style-type: none"> <li>'x' represents the numerical value of the functional size,</li> <li>'v.y' represents the identification of the standard version of the COSMIC method used to obtain the numerical functional size value 'x'.</li> </ul> <p>NOTE: If a local approximation method was used to obtain the measurement, but otherwise the measurement was made using the conventions of a standard COSMIC version, the above labeling convention shall be used, but use of the approximation method should be noted elsewhere – see section 5.2.</p>
<b>5.1</b>	<p><b>COSMIC local extensions labeling</b></p> <p><b>Rule</b></p> <p>A COSMIC measurement result using local extensions shall be noted as:</p> <p style="text-align: center;">'<b>x</b> CFP (v.y) + z Local FP', where:</p> <ul style="list-style-type: none"> <li>'x' represents the numerical value obtained by aggregating all individual measurement results according to the standard COSMIC method, version v.y,</li> <li>'v.y' represents the identification of the standard version of the COSMIC method used to obtain the numerical functional size value 'x'.</li> <li>'z' represents the numerical value obtained by aggregating all individual measurement results obtained from local extensions to the COSMIC method.</li> </ul>
<b>5.2</b>	<p><b>COSMIC measurement reporting</b></p> <p><b>Rule</b></p> <p>In addition to the actual measurements, recorded as in 5.1, some or all of the following attributes of each measurement should be recorded, depending on the measurement purpose and the desired level of comparability to other measurements, e.g. for benchmarking purposes.</p> <ol style="list-style-type: none"> <li>Identification of the measured software component (name, version ID or configuration ID).</li> <li>The sources of information used to identify the FUR used for the measurement</li> <li>The domain of the software</li> <li>A description of the architecture of layers in which the measurement is made, if applicable.</li> <li>A statement of the purpose of the measurement.</li> <li>A description of the scope of the measurement, and its relation to the overall scope of a related set of measurements, if any. (Use the generic scope categories in section 2.2)</li> <li>The measurement pattern used (COSMIC or local), with the processing mode (on-line or batch)</li> <li>The functional users of the software</li> <li>The level of granularity of the available software artefacts and the level of decomposition of the software.</li> </ol>

	<ul style="list-style-type: none"> <li>j) The point in the project life-cycle when the measurement was made (especially whether the measurement is an estimate based on incomplete requirements, or was made on the basis of actually delivered functionality).</li> <li>k) The target or believed error margin of the measurement.</li> <li>l) Indications whether the standard COSMIC measurement method was used, and/or a local approximation to the standard method, and/or whether local extensions were used (see section 4.5). Use the labeling conventions of sections 5.1 or 5.2.</li> <li>m) An indication whether the measurement is of developed or delivered functionality ('developed' functionality is obtained by creating new software; 'delivered' functionality includes 'developed' functionality and also includes functionality obtained by other means than creating new software, i.e. including all forms of re-use of existing software, implementation of packages, use of existing parameters to add or change functionality, etc).</li> <li>n) An indication of whether the measurement is of newly provided functionality or is the result of an 'enhancement' activity (i.e. the sum is of added, changed and deleted functionality – see 4.4).</li> <li>o) The number of major components, if applicable, whose sizes have been added together for the total size recorded.</li> <li>p) The percentage of functionality implemented by re-used software</li> <li>q) For each scope within the overall measurement scope, one measurement matrix, as specified in Appendix A.</li> <li>r) The Measurer's name and any COSMIC certification qualifications; the date of the measurement</li> </ul>
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# Appendix E

## APPENDIX E – THE MAIN CHANGES FROM VERSION 3.0.1 TO VERSION 4.0

This Appendix contains a summary of the principal changes made in the evolution of the COSMIC functional size measurement method from version 3.0.1 to the present version 4.0.

To trace the earlier evolution of the method, please refer to the Measurement Manual for each earlier version of the method (2.2, 3.0 and 3.0.1).

A 'MUB' is a Method Update Bulletin, published between major releases of the Measurement Manual to announce and explain proposed changes.

V4.0 Ref	Change
-	Simplified figure numbering applied, sequenced per chapter rather than per (sub-) section (e.g. 'Figure 3.5.8.3' is now 'Figure 3.8').
Chs.1 to 5	A summary has been added for each of the Chapters 1 – 5.
1.1	Sections 1.1.2, 1.1.3 and 1.1.4 on 'limitations of the method' have been moved to section 4.5. The title of 1.1.1 has been removed as its text is now the whole of 1.1.
1.2	The definition of 'Functional User Requirements' has been moved from section 2.2 and is further qualified when used in the COSMIC method (MUB 11).
1.2.3	A new section 1.2.3 on 'Non-Functional Requirements' has been added (MUB 10).
1.3.1	Principle g) of the COSMIC Software Context Model (SCM) was simplified (MUB 7) and subsequently has been removed to be merged with principle a) of the Generic Software Model (GSM) where it more logically belongs.
1.5	This new section refers to 4.5, which now contains the three 'limitations' previously discussed in sections 1.1.2, 1.1.3 and 1.1.4
2.2	The rules for the 'Scope' are now the Rules for a 'Measurement Scope'.
2.2.2	The definition of 'layer' has been revised to make it consistent with SEI concepts (MUB 9). Figure 2.4 has been added to show how Layers depend on the architectural 'view' of the software.
2.2.2	The definition and principles for 'peer component' have been removed as they are no longer necessary in the COSMIC method (MUB 9)
2.3.2	Note 1 to the definition of persistent storage has been re-phrased for clarity (MUB 7) (This definition was in section 3.3.1 in the MM v3.0.1.
2.3.3	A section on 'Context Diagrams' has been added.
2.4.3	The large example of the levels of granularity of the 'Everest' system has been re-written for greater clarity.
3.1	The principle 'Applying the Generic Software Model' has been removed as it is already stated in the description of the SCM and the GSM, and in the description of the Measurement Process.
3.2	The definitions of the concepts of triggering event, functional user, triggering Entry and functional processes have been improved (MUB 11).
3.2	The possible degrees of the relationships (i.e. 'cardinalities') between events, functional users, triggering Entries and functional processes are specified much more completely, illustrated in Fig. 3.3, and many examples are given in Appendix C (MUB 11).
3.2.2	The process for identifying functional processes is now described more clearly.

3.2.2	Rules for a functional process have been updated and simplified (MUB 11).
3.2.3 b)	The discussion of how to analyze and measure batch-processed business applications has been expanded and made much clearer, with the addition of a new Fig. 3.4 (MUB 11)
3.2.7	A new section has been added explaining how to measure functional processes that share some functionality in common or that are very similar (MUB 11)
3.2.8	A new section has been added explaining the need to distinguish between the triggering event that starts a software system, and the triggering event that starts a functional process (MUB 11).
3.5	The former section 4.1 'Identifying the data movements' has been moved to Chapter 3, section 3.5.
3.5.1	Figure 3.5 (formerly Fig. 4.1.1) shows more clearly the relationships between a functional process and the four types of data movements (E, X, R and W).
3.5.5	Principle d) for a Write has been modified to prevent contradiction with principle c) (MUB 7).
3.5.6	The statements on the data manipulation associated with data movements are in fact rules and have therefore been provided with a rules box. At the same time, the wording is simplified.
3.5.7	Rule b) which concerns when two or more data movements of the same type moving data about the same object of interest may be identified in the same functional process has been expanded into two rules b) and c), and made much clearer. Several examples have been added in this section.
3.5.8	Several changes have been made in this section. Example 1 has been split into two Examples (1 and 4). Example 3 has been added which illustrates the case when the software being measured is allowed (or not) to access the required data on persistent storage (MUB 7 v2). The analysis of error messages is now discussed for each these examples, referring to the new section 3.5.11 for rules on error/confirmation messages.
3.5.10	The concept of 'control command' has been generalized to any application with a human interface.
3.5.11	A new section has been added with a definition and precise rules for measuring error/confirmation messages and other error conditions.
4.4.1	Note 1 to the Rules of Modifying a data movement has been removed as it is inconsistent: a change of a code value is not a change of an attribute type (i.e. it should not be counted). But a required change to a format or format heading is also not necessarily a change of an attribute type, yet it should be counted.
4.4.1	The definition of changes of a data movement, and hence to data group or to the associated data manipulation has been converted into a definition for 'Modification (of the functionality of a data movement)'.
4.5	Sections 1.1.2, 1.1.3 and 1.1.4 on limitations of the COSMIC method have been moved to become 4.5.2, 4.5.3 and 4.5.4 respectively. The previous section 1.1.2 (now 4.5.2) 'Non-applicable domain' has been re-titled as 'Data manipulation-rich software' and the first paragraph of this section has been replaced, as practice has shown that the COSMC method <i>can</i> be used to measure size for several types of software listed in this 'limitations' statement (MUB 8).
References	All references are now in this section.
Appendix A	The diagram has been updated to show totals.
Appendix B	Appendix has been added with examples of Non-functional Requirements that evolve partly or wholly into Functional User Requirements (MUB 10)
Appendix C	Appendix has been added with examples and diagrams of the cardinality of relationships between triggering events, functional users, triggering Entries and

	functional processes.
Appendix D	Summary of Principles and Rules has been updated.
Appendix F	The Glossary of Terms has been moved from the 'Documentation Overview and Glossary of Terms' document (V3.0) to this Appendix F of the MM v4.0, and has been updated.

## APPENDIX F - GLOSSARY OF TERMS

The following terms are used throughout the COSMIC functional size measurement method (the 'COSMIC method'), according to the definitions found in this section. Terms already defined by ISO, such as 'Functional Size Measurement' or 'unit of measurement', together with their ISO definition have also been adopted for the COSMIC method.

For many of the terms listed in the glossary, when appropriate, the suffix 'type' is shown. Since any functional size measurement method aims to identify 'types' and not 'occurrences' of data or functions, almost invariably throughout the COSMIC method we will be concerned with 'types' and not 'occurrences'. Consequently, in the texts we will drop the suffix 'type' from these terms for the sake of readability, except when we specifically need to distinguish type and occurrence. This is also the convention adopted in the International Standard (ISO/IEC 19761:2003) definition of the COSMIC method. Occasionally this convention leads to difficulties when drafting these definitions – see for example Note 3 of the definition of 'data movement type' below, which does not appear in the International Standard.

NOTE: Terms that are used only in the domain-specific COSMIC 'guidelines' are defined in those guidelines; they are not shown below.

In the definitions given below:

- terms that are defined elsewhere in this glossary are under-lined, for ease of cross-reference.
- terms that originate in the ISO Standard for the COSMIC method (ISO/IEC 19761) or that are otherwise specific to the COSMIC method are shown in **bold italics**.
- other terms that have been adopted from ISO but that are not specific to the COSMIC method are shown in **bold**.

**Application.** A software system for collecting, saving, processing, and presenting data by means of a computer.

NOTE: This is an adaptation of the definition given in ISO/IEC 24570:2005 Software engineering -- NESMA functional size measurement method version 2.1.

(Alternative definition for 'application software'). Software designed to help users perform particular tasks or to handle particular types of problems, as distinct from software that controls the computer itself.

NOTE: This is a slight adaptation of the definition given in ISO/IEC 24765:2010 Systems and software engineering-vocabulary, 4.5).

**Application-general data.** Any data related to the application in general and not related to an object of interest of a specific functional process.

**Base functional component (BFC).** An elementary unit of the Functional User Requirements defined by an FSM method for measurement purposes [1].

NOTE: The COSMIC method defines a data movement type as a BFC.

**Base functional component type (BFC type).** A defined category of BFC's [1]. The COSMIC method has four BFC types, the Entry, Exit, Read and Write (-types).

**Boundary.** A conceptual interface between the software being measured and its functional users.

NOTE: It follows from the definition that there is a boundary between any two pieces of software in the same or different layers that exchange data where one piece of software is a functional user of the other, and/or vice versa.



**Component.** Any part of a software system that is separate for reasons of the software architecture, and/or that it was specified, designed or developed separately.

**Control command.** A command that enables human functional users to control their use of the software but which does not involve any movement of data about an object of interest of the FUR of the software being measured.

NOTE: A control command is not a data movement because the command does not move data about an object of interest. Examples are 'page up/down' commands; hitting a Tab or Enter key, clicking on the 'OK' to confirm a previous action, pressing a button to continue, etc.

**COSMIC unit of measurement.** 1 CFP (Cosmic Function Point), which is defined as the size of one data movement

NOTE: The unit of measurement was previously known as a 'Cfsu' (COSMIC functional size unit)

**Data attribute type (synonym 'data element type').** The smallest parcel of information, within an identified data group type, carrying a meaning from the perspective of the software's Functional User Requirements.

**Data group type.** Any distinct, non empty, non ordered and non redundant set of data attribute types where each included data attribute type describes a complementary aspect of the same object of interest.

**Data manipulation.** Anything that happens to data other than a movement of the data into or out of a functional process, or between a functional process and persistent storage.

**Data movement type.** A base functional component which moves a single data group type.

NOTE 1: There are four sub-types of data movement types: Entry, Exit, Read and Write (-types).

NOTE 2: For measurement purposes, each data movement sub-type is considered to include certain associated data manipulation – see the Measurement Manual for details.

NOTE 3: More precisely, it is an *occurrence* of a data movement, not a data movement *type*, that actually *moves* the data group *occurrences* (not *types*). This comment also applies to the definitions of Entry, Exit, Read and Write.

**E.** Abbreviation for 'Entry type'.

**Entry type.** A data movement that moves a data group from a functional user across the boundary into the functional process where it is required.

NOTE: An Entry type is considered to include certain associated data manipulation – see the Measurement Manual for details.

**Error/confirmation message.** An Exit issued by a functional process for the attention of a human user that either confirms only that entered data has been accepted, or only that there is an error in the entered data.

NOTE: If a message to a human user provides other data than just confirming that entered data has been accepted, or that entered data is in error, then this other data should be identified as a data group moved by an Exit and not as an error/confirmation message.

**Event type.** Something that happens.

**Exit type.** A data movement that moves a data group from a functional process across the boundary to the functional user that requires it.

NOTE: An Exit type is considered to include certain associated data manipulation – see the Measurement Manual for details.

**Functional process type**

- a) A set of data movements representing an elementary part of the Functional User Requirements for the software being measured, that is unique within that FUR and that can be defined independently of any other functional process in that FUR
- b) A functional process may have only one triggering Entry. Each functional process starts processing on receipt of a data group moved by the triggering Entry data movement of the functional process.
- c) The set of all data movements of a functional process is the set that is needed to meet its FUR for all the possible responses to its triggering Entry.

NOTE 1: When implemented, it is an *occurrence* of a functional process that starts *executing* on receipt of an *occurrence* of a data group moved by an *occurrence* of a triggering Entry.

NOTE 2: The FUR for a functional process may require one or more other Entries in addition to the triggering Entry.

NOTE 3: If a functional user sends a data group with errors, e.g. because a sensor-user is malfunctioning or an order entered by a human has errors, it is usually the task of the functional process to determine if the event really occurred and/or if the entered data are really valid, and how to respond.

**Functional process level of granularity.** A level of granularity of the description of a piece of software at which

- the functional users are individual humans or engineered devices or pieces of software (and not any groups of these) AND
- single events occur that the piece of software must respond to (and not any level at which groups of events are defined).

NOTE 1: In practice, software documentation and hence functional user requirements often describe functionality at varying levels of granularity, especially when the documentation is still evolving.

NOTE 2: 'Groups of these' (functional users) might, for example, be a 'department' whose members handle many types of functional processes, or a 'control panel' that has many types of instruments, or 'central systems'.

NOTE 3: 'Groups of events' might, for example, be indicated in a statement of FUR at a high level of granularity by an input stream to an accounting software system labelled 'sales transactions' or by an input stream to an avionics software system labelled 'pilot commands'.

**Functional Size.** A size of the software derived by quantifying the Functional User Requirements.<sup>[1]</sup>

**Functional Size Measurement (FSM).** The process of measuring functional size. <sup>[1]</sup>

**Functional Size Measurement Method.** A specific implementation of FSM defined by a set of rules, which conforms to the mandatory features of ISO/IEC 14143-1:1998. <sup>[1]</sup>

**Functional User.** A (type of) user that is a sender and/or an intended recipient of data in the Functional User Requirements of a piece of software.

**Functional User Requirements (FUR).** A sub-set of the user requirements. Requirements that describe what the software shall do, in terms of tasks and services.

NOTE 1: Functional User Requirements relate to but are not limited to:

- data transfer (for example Input customer data, Send control signal);
- data transformation (for example Calculate bank interest, Derive average temperature);
- data storage (for example Store customer order, Record ambient temperature over time);
- data retrieval (for example List current employees, Retrieve aircraft position).

Examples of user requirements that are not Functional User Requirements include but are not limited to:

- quality constraints (for example usability, reliability, efficiency and portability);
- organizational constraints (for example locations for operation, target hardware and compliance to standards);
- environmental constraints (for example interoperability, security, privacy and safety);
- implementation constraints (for example development language, delivery schedule).

**Input.** Data for which the values are independent of the software, which is entered from a user and which are used by the software at some point during its operation. The generic definition of input used in this manual is notably different from the specific definition used by the International Function Point Users Group (IFPUG). In COSMIC, input consists of all the Entries involved in a particular functional process type.

**Layer.** A functional partition of a software system architecture

**Level of decomposition.** Any level resulting from dividing a piece of software into components (named 'Level 1', for example), then from dividing components into sub-components ('Level 2'), then from dividing sub-components into sub-sub components (Level 3'), etc.

NOTE 1: Not to be confused with 'level of granularity'.

NOTE 2: Size measurements of the components of a piece of software may only be directly comparable for components at the same level of decomposition.

**Level of granularity.** Any level of expansion of the description of a single piece of software (e.g. a statement of its requirements, or a description of the structure of the piece of software) such that at each increased level of expansion, the description of the functionality of the piece of software is at an increased and uniform level of detail.

NOTE: Measurers should be aware that when requirements are evolving early in the life of a software project, at any moment different parts of the required software functionality will typically have been documented at different levels of granularity.

**Measurement method** [14]. A logical sequence of operations, described generically, used in the performance of measurements.

**Measurement (Strategy) Pattern.** A standard template that may be applied when measuring a piece of software from a given software functional domain, that defines the types of functional user that may interact with the software, the level of decomposition of the software and the types of data movements that the software may handle.

**Model** [16]. A description or analogy used to help visualize a concept that cannot be directly observed.

**Modification (of the functionality of a data movement)**

- a) A data movement is considered to be functionally modified if at least one of the following applies:
  - the data group moved is modified
- the associated data manipulation is modified
- b) A data group is modified if at least one of the following applies:
  - one or more new attributes are added to the data group
  - one or more existing attributes are removed from the data group
  - one or more existing attributes are modified, e.g. in meaning or format (but not in their values)
- c) A data manipulation is modified if it is functionally changed in any way.

**Non-Functional Requirement.** Any requirement for or constraint on a hardware/software system or software product, or on a project to develop or maintain such a system or product, except a functional user requirement for software.

NOTE: System or software requirements that are initially expressed as non-functional often evolve as a project progresses wholly or partly into FUR for software.

**Object of interest type.** Any 'thing' that is identified from the point of view of the Functional User Requirements. It may be any physical thing, as well as any conceptual object or part of a conceptual object in the world of the functional user about which the software is required to process and/or store data.

NOTE: In the COSMIC method, the term 'object of interest' is used in order to avoid terms related to specific software engineering methods. The term does not imply 'objects' in the sense used in Object Oriented methods.

**Operating environment (software).** The set of software operating concurrently on a specified computer system.

**Output.** Data for which the value depends on the operation of the software and which is therefore created or otherwise modified by the software during its operation before being sent to a user. The generic definition of output used in this manual is notably different from the specific definition used by the International Function Point Users Group (IFPUG). In COSMIC, output consists of all the Exits involved in a particular functional process type.

**Peer pieces of software.** Two pieces of software are peers of each other if they reside in the same layer.

**Persistent storage.** Storage which enables a functional process to store data beyond the life of the functional process and/or which enables a functional process to retrieve data stored by another functional process, or stored by an earlier occurrence of the same functional process or stored by some other process.

NOTE 1: In the COSMIC model, persistent storage is a concept that exists only within the boundary of the software being measured, it cannot therefore be considered as a functional user of the software being measured.

NOTE 2: An example of 'some other process' would be in the manufacture of read-only memory.

**Piece of software.** Any discrete item of software at any level of decomposition from the level of a whole software system down to and including the level of the smallest component of a software system.

**Purpose of a measurement.** A statement that defines why a measurement is being made, and what the result will be used for.

**R.** Abbreviation for 'Read type'.

**Read type.** A data movement that moves a data group from persistent storage into the functional process which requires it.

NOTE: A Read type is considered to include certain associated data manipulation – see the Measurement Manual for details.

**Scaling (of a measurement).** The process of converting a size measurement at one unit of measurement to a measurement at another unit of measurement.

**Scope (of a measurement).** The set of Functional User Requirements to be included in a specific functional size measurement instance. [1]

NOTE: (Specific to the COSMIC method.) A distinction should be made between the 'overall scope', i.e. all the software that should be measured according to the purpose, and the 'scope' of any individual piece of software within the overall scope, whose size should be measured separately. In the Measurement Manual, the term 'scope' (or the expression 'measurement scope') will relate to an individual piece of software whose size must be measured separately.

**Software** [17]. A set of computer instructions, data, procedures and maybe documentation operating as a whole, to fulfill a specific set of purposes, all of which can be described from a functional perspective through a finite set of Functional User Requirements, technical and quality requirements.

**Software System.** A system that consists only of software.

**Sub-process type.** A part of a functional process that either moves data (into the software from a functional user or out of the software to a functional user, or to or from persistent storage) or that manipulates data.

**System.** A combination of hardware, software and manual procedures organized to achieve stated purposes.

NOTE: The above definition is an adaptation of the ISO/IEC 15288:2008 definition. In the COSMIC definition, 'hardware, software and manual procedures' replaces 'interacting elements' in the ISO/IEC definition.

**Triggering Entry type.** The Entry data movement of a functional process that moves a data group, generated by a functional user, that the functional process needs to start processing.

NOTE The FUR for a functional process may require one or more other Entries in addition to the triggering Entry.

**Triggering event type.** An event, recognized in the Functional User Requirements of the software being measured, that causes one or more functional users of the software to generate one or more data groups, each of which will subsequently be moved by a triggering Entry. A triggering event cannot be sub-divided and has either happened or not happened.

NOTE: Clock and timing events can be triggering events.

**Unit of measurement [14].** A particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitudes relative to that quantity. It is to be noted that units of measurement have conventionally assigned names and symbols.

See also 'COSMIC unit of measurement'

**User [1].** Any person or thing that communicates or interacts with the software at any time.

NOTE: Examples of 'thing' include, but are not limited to, software applications, animals, sensors, or other hardware.

**Value (of a quantity) [14].** The magnitude of a particular quantity, generally expressed as a unit of measurement multiplied by a number.

**W.** Abbreviation for 'Write type'.

**Write type.** A data movement that moves a data group lying inside a functional process to persistent storage.

Note: a Write is considered to include certain associated data manipulation – see the Measurement Manual for details.

**X.** Abbreviation for 'Exit type'.

## APPENDIX G - CHANGE REQUEST AND COMMENT PROCEDURE

The COSMIC Measurement Practices Committee (MPC) is very eager to receive feedback, comments and, if needed, Change Requests for this guideline. This appendix sets out how to communicate with the COSMIC MPC. All communications to the COSMIC MPC should be sent by e-mail to the following address:

[mpc-chair@cosmicon.com](mailto:mpc-chair@cosmicon.com)

### Informal general feedback and comments

Informal comments and/or feedback concerning the guideline, such as any difficulties of understanding or applying the COSMIC method, suggestions for general improvement, etc should be sent by e-mail to the above address. Messages will be logged and will generally be acknowledged within two weeks of receipt. The MPC cannot guarantee to action such general comments.

### Formal change requests

Where the reader of the guideline believes there is a defect in the text, a need for clarification, or that some text needs enhancing, a formal Change Request ('CR') may be submitted. Formal CR's will be logged and acknowledged within two weeks of receipt. Each CR will then be allocated a serial number and it will be circulated to members of the COSMIC MPC, a world wide group of experts in the COSMIC method. Their normal review cycle takes a minimum of one month and may take longer if the CR proves difficult to resolve. The outcome of the review may be that the CR will be accepted, or rejected, or 'held pending further discussion' (in the latter case, for example if there is a dependency on another CR), and the outcome will be communicated back to the Submitter as soon as practicable.

A formal CR will be accepted only if it is documented with all the following information.

- Name, position and organization of the person submitting the CR.
- Contact details for the person submitting the CR.
- Date of submission.
- General statement of the purpose of the CR (e.g. 'need to improve text...').
- Actual text that needs changing, replacing or deleting (or clear reference thereto).
- Proposed additional or replacement text.
- Full explanation of why the change is necessary.

A form for submitting a CR is available from the [www.cosmicon.com](http://www.cosmicon.com) site. The decision of the COSMIC MPC on the outcome of a CR review and, if accepted, on which version the CR will be applied to, is final.

### Questions on the application of the COSMIC method

The COSMIC MPC regrets that it is unable to answer questions related to the use or application of the COSMIC method. Commercial organizations exist that can provide training and consultancy or tool support for the method. Please consult the [www.cosmicon.com](http://www.cosmicon.com) web-site for further detail.