CHAPTER 26

GOAL STRUCTURING NOTATION (GSN)

CONTENTS

1. INTRODUCTION

1.1   Goal Structuring Notation (GSN) is a graphical notation for presenting the structure of engineering arguments. It has in recent years been used within the risk-based Safety domain to depict Safety Case structure. The approach may be used to present any situation where one wishes to make a claim and where the support for that claim will be based upon evidence and argument. This would include situations such as R&M or legal cases.

1.2   GSN has gained some acceptance within the Functional Safety discipline as one of the primary means of depicting how particular Safety claims or Goals have been made and justified through citing or arguing the deductions from particular evidence. There are other tools and techniques, such as the Claims Argument Evidence (CAE), the ASCE (Adelard Safety Case Editor) and even mind mapping diagrams that may be used in a similar manner to GSN to present engineering arguments.

1.3   GSN provides a mechanism to address a common weakness in technical and complex arguments (such as the R&M or Safety Case), where often the dependency of a claim on specific evidence and groups of evidence lacks clarity. The use of visual aids, such as GSN, has arisen in response to poorly written Case documents. Such documents may easily become lengthy, unwieldy and obtuse through poor use of English. However, it must be recognised that graphical tools in themselves do not prevent such situations[1]; they do however allow the strengths and weaknesses of an argument to be more easily grasped.

1.4   GSN diagrams do not in themselves represent the content of the argument. The R&M Case for example, will be made by the relevant evidence, assumptions and deductions contained within reference information. Furthermore, the analysis methods employed and results derived from these analyses usually involve significant uncertainty and this is best argued and addressed within these documents.

2. PURPOSE AND BENEFITS

2.1   A GSN diagram, like any other form of diagram, merely assists with the demonstration or clarification of how the set of evidence items may be combined together and argued to demonstrate the top claim. Such visual approaches:

   a) Provide a greater chance of identifying gaps in the evidence.

   b) Provide a clear summary to all interested parties of how the case has been constructed to meet the top level Goal.

   c) Can be converted into a web-based format with the use of hyperlinks between all elements of evidence context and justification as appropriate.

2.2   The term "goal structuring" is used to describe the process of linking the elements (see Serial 0) of the GSN together in a network. The resulting structure provides a diagrammatic method that helps to clarify how the goal is broken down into Sub-Goals and then these Sub-Goals are further broken down until the point where Sub-Goals can be linked directly to supporting evidence. This method facilitates an understanding of the argument strategies

adopted, including where the argument has adopted the use of quantified and qualitative approaches.

3. THE GSN DIAGRAM

3.1   The GSN diagram helps to show how the set of evidence items may be combined together and argued to demonstrate the top claim (e.g. that the system is reliable enough to operate in a particular operating environment). In order to do this, the GSN shows how individual goals are supported by specific claims and how these claims lead to lower level goals or ultimately how the claims are supported by evidence.

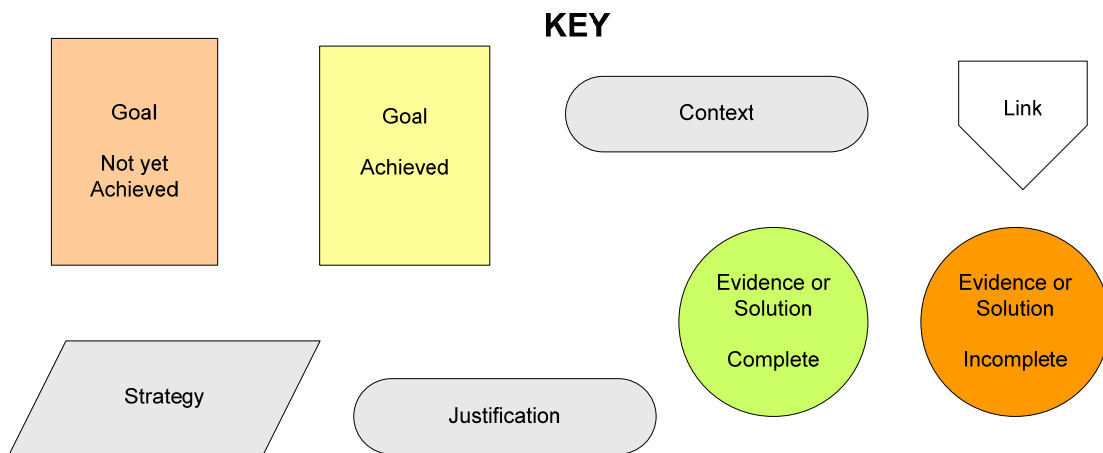**3.2**   A GSN diagram will consist of the following typical elements:

KEY

Goal

Not yet
Achieved

Goal

Achieved

Context

Link

Evidence or
Solution

Complete

Evidence or
Solution

Incomplete

Strategy

Justification

Figure 1 – Typical Goal Structuring Notation Elements

3.3   The structured argument is built top down, decomposing the top level Goal into lower level, more detailed goals. Good practice is to use a simple dome shaped diagram to provide an overview of the overall argument and required evidence. The diagram is dome shaped as it builds out from the top level goal and broadens as each successive layer is developed. The nodes can be colour coded to show the status of the evidence and ownership of the evidence defined within the evidence or solution element or at a higher level, e.g. Sub-Goals. The particular notation adopted and supporting evidence available will depend on the specific project or programme.

3.4   In the example discussed below, a colour coding has been used in order to facilitate understanding of the function of the diagram and has been split into three key areas:

a) Goals and Sub-Goals are shaded yellow. Goals and Sub-Goals are propositions that we wish to be true. They may be quantified or qualitative and they may be provable (e.g. quick release fasteners are used on the access cover). However when goals are applied in the R&M domain it is quite likely they will not be provable but will instead include an element of uncertainty (e.g. The analysis has shown that the item has a predicted reliability of 95%).

b) Intermediate explanatory steps are shaded grey. Intermediate explanatory steps between goals and the evidence include statements, references, justifications and assumptions.

c) The evidence or solutions are shaded green. The evidence or solutions form the foundation of the argument and will typically include the deliverables or documents in an engineering programme. These will be specific analysis or test results reports that provide evidence of an attribute of the system.

3.5 It should be noted that the use of certain elements for each of the key aspects of the GSN diagram is not universally adopted and different diagrams use different notation depending upon the author and the tool used. An attempt to standardise the approach and the notation is currently underway[2].

4. STRUCTURED ARGUMENT USING GSN

4.1 This Section presents a simplified example of on how to generate a GSN diagram. The example provides limited instances of the use of each element type in order to simplify the resulting diagrams and allow the purpose of these elements to be understood.

4.2 The first step when creating a GSN is to define the overall objective of the argument, termed the Goal. The example presented here describes the application of GSN to present the key evidence and arguments to support the top level **Goal**; "The System meets its R&M Requirements".

Goal: The goals within a GSN present statements which we wish to be true. Each goal comprises a single unambiguous statement consisting of:

a) A noun phase (subject) e.g. The System... This is then followed by

b) A verb phase (a statement which is either true of false) e.g. … meets its Reliability Requirements.

4.3 Figure 1 identifies an example of a potential top level goal which is then broken down into 2 Sub-Goals. Each goal is satisfied by the development of solutions or **Strategies** later supported by evidence further down the diagram.

Strategy: The strategy provides an intermediate explanatory step, which describes the relationship between a goal and a set of sub-goals or between a goal and the solution(s) or evidence. This will be used where the step between the goal and evidence is too great and therefore requires further definition.

4.4 In the example, the strategy to achieve Goal G01 is to address two aspects of the System Reliability separately. Sub-Goals have been developed from Goal G01 based upon the context provided by the System Requirements and the risk management process. Two Sub-Goals are shown in the diagram; G02 and G03.
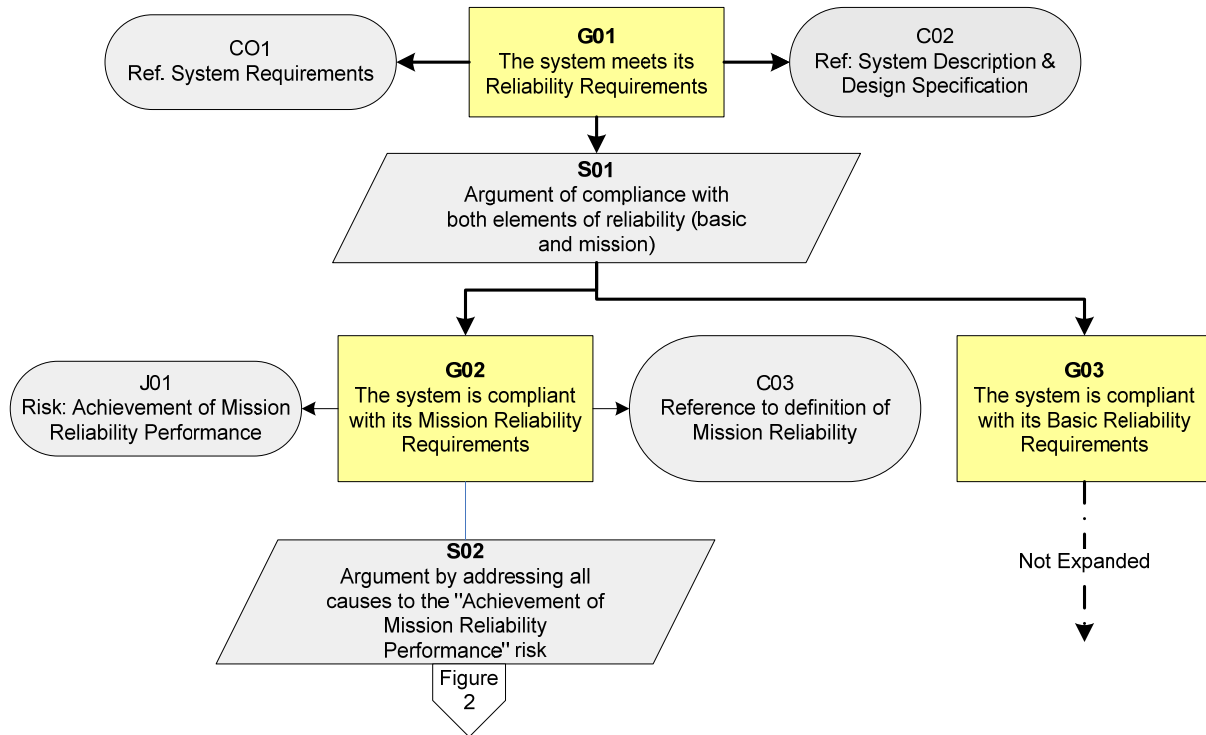
Figure 2 - Example of R&M Case High Level Goal Expanded

4.5 Clearly much expansion would be required here in order to fully understand the context of the Goals. Typical questions raised by the very limited Goals in Figure 2 include; what are the boundaries of the system, where and what are the requirements, etc. These details can be summarised or referenced using the **Context** Element.

Context: The context elements are used to provide statements or references which clarify contextual information in the claim/goal.

4.6 In the example, context is provided by reference to the System Requirements (C01), the System Description (C02) and the Definition of Mission Reliability (C03).

4.7 Alternatively, the brevity of the typical statement of the Goal within a GSN diagram may require further support or **Justification**.

Justification: The justification states why the strategy/goal is a solution. The wording will be limited to single unambiguous statements consisting of a noun phase (subject) followed by a verb phase (a statement which is either true of false).

4.8 In the example, Goal G02 is justified by reference to the risk that the system will not achieve the Mission Reliability Requirements. This risk may have been identified through the project risk management process and may be used to support the need for Goal G02.

4.9 Goal G02 is further developed by argument in Figure 3 which provides the justification for that goal. A **link** element is therefore used to identify this subsequent diagram. Links are used where required to split diagrams into sections that the suit the purpose of the author. For example, it may be required to fit GSN onto a certain number or size of pages and/or represent specific sections of a report.

4.10 Finally in Figure 2, Goal G03 is not developed further in this example and has therefore been identified as "Not Expanded". Goals have not been expanded in this simplified example to aid clarity and would be expanded in a working GSN.

4.11 In Figure 3, Strategy S02 is developed to address the causes of the risk discussed above that have been identified to date. For the purposes of the example, these causes have been considered to comprise potential shortcomings in:

a) The tender assessment process.

b) The influence of the R&M manager, and

c) The coherence of the Reliability programme with the programme as it addresses other Defence Lines of Development (DLoDs).
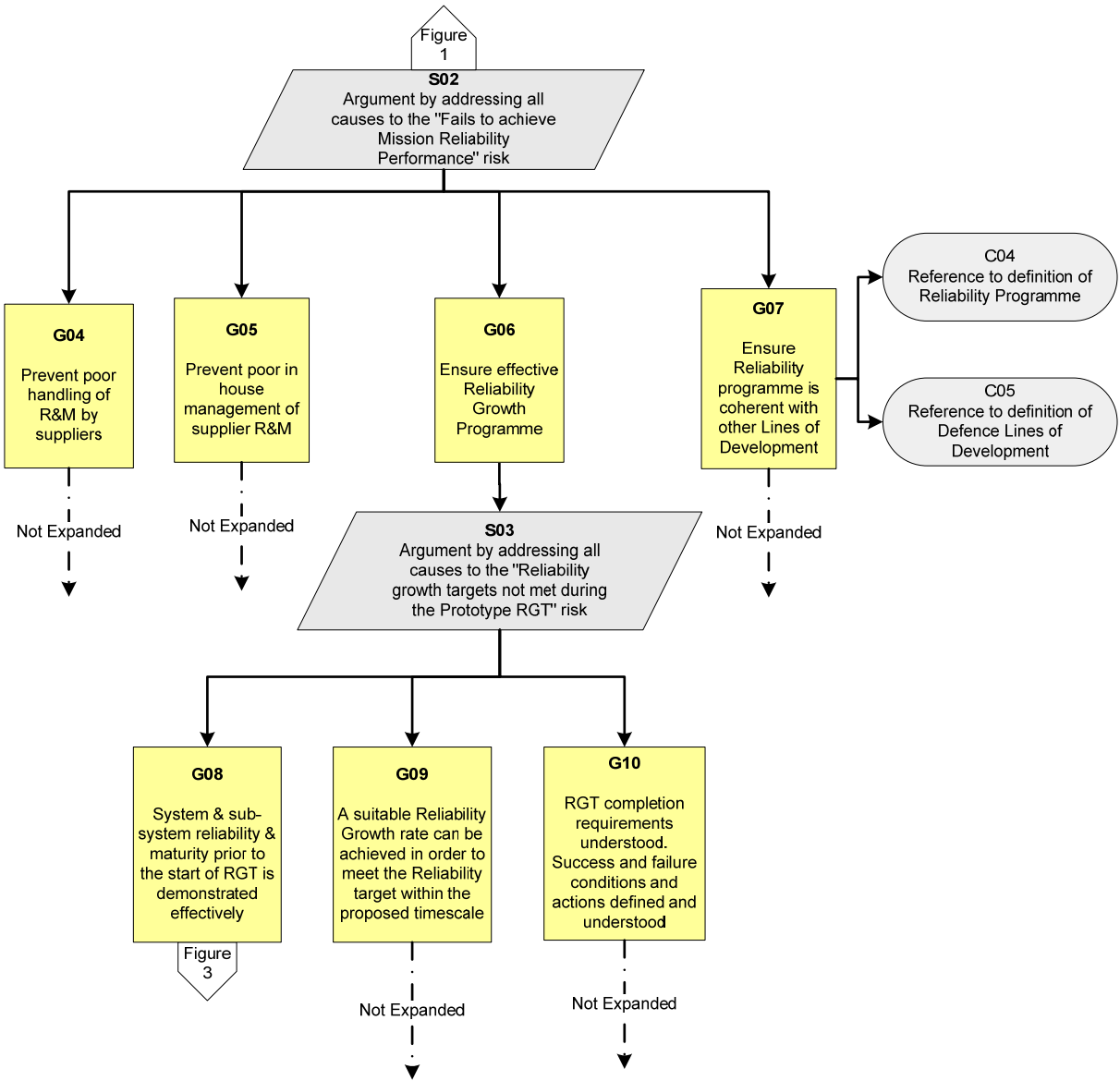
Figure 3 - Expansion of S02 Mission Reliability Achievement

4.12 It can be seen from Figure 3 that this GSN structure can be used to reflect and depict the structure of the risk process, breaking risks into causes and subsequently into controls and finally to base events which described the outcome of the mitigation activities (supporting evidence). It will also address programme activities to verify compliance with requirements.

4.13 In the final figure, Figure 4, the notation is further developed to address the Goal G08, one Sub-Goal and the evidence required.
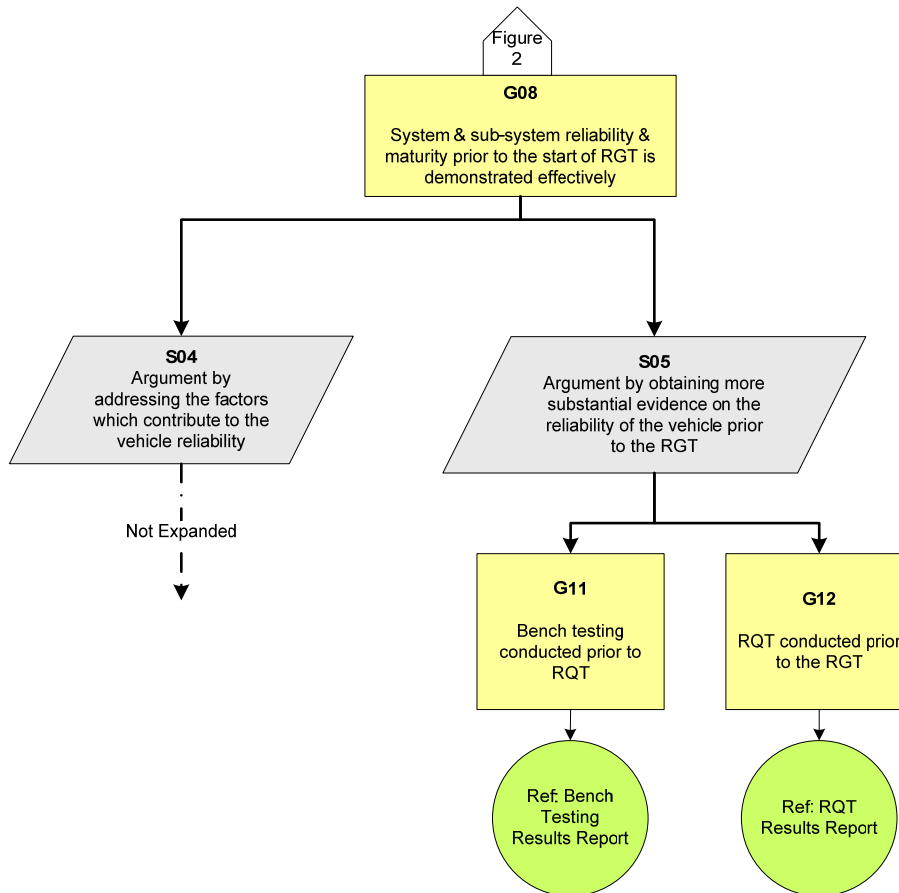

Figure 4 - Expansion of Goal G08 - Reliability Growth Programme is Effective

4.14 The downward development of the GSN concludes when all the lowest level of Sub-Goals can be clearly supported by reference items of evidence. Figure 4 demonstrates the conclusion of the GSN at its lowest level for Goals G11 and G12. These goals are met in each case by an item of founding evidence, or a **Solution**.

<u>**Solution:**</u> The Solution identifies information or evidence which supports the goal. The evidence can include (but is not limited to) process information, product information, qualitative data, quantitative data, subjective information, service history, analysis or test results.

4.15 It would be quite possible to develop the GSN further as the items of evidence cited in the example (e.g. the Bench Testing Results Report) could be supported by their own GSN. However, over complication of GSN should be avoided. Diagrams can become unwieldy, in many instances a case (be it Safety or R&M) will be complex as it relies upon a significant

volume of supporting evidence, much of which exists at the project level. Therefore it is recommended that GSN diagrams are used to plan and support the outline of the case only, accepting that much of the rigour of the argument will be embedded in detail documents, such as analysis or test reports.

LEAFLET C26/0

REFERENCES

1   HC1025. An independent Review into the Broader Issues Surrounding the Loss of the RAF Nimrod MR2 Aircraft XV230 in Afghanistan in 2006. Charles Haddon- Cave QC. 28 October 2009.

2   Draft GSN Standard, Version 1.0, Draft for comment, 2010, latest Version can be found at http://www.goalstructuringnotation.info/, Department of Computer Science, University of York.

3   The Goal Structuring Notation – A Safety Argument Notation. Tim Kelly and Rob Weaver. University of York. 2004.

4   Safety Handbook Initial Release. A guide to good safety management practice. Issue: 1.0, April 2010. Ministry of Defence.

5   A Systematic Approach to Safety Case Maintenance, undated, Tim Kelly, John McDermid, Department of Computer Science, University of York.

6   DEF STAN 00-42 Part 3 Issue 3, Reliability and Maintainability (R&M) Assurance Guide Part 3 R&M Case, Date 14 March 2008.