

# Applying Goal Based Requirements Engineering to a large COTS Procurement Programme

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**Abstract:** This paper describes an applied research activity addressing improvements to the approach to Requirements Engineering in NATS. It outlines the key features of the approach; describes the most important results of a Case Study evaluation relating to the implementation of the approach, and goes on to highlight some early experiences from the early stages of implementation.

## 1. Introduction.

Investigations into Requirements Engineering (RE) practices in National Air Traffic Services Ltd (NATS) [1] established that there were a number of weaknesses perceived in the discipline by practitioners. This recognition resulted in the establishment of a research and evaluation project to identify and evaluate an alternative approach, usable by practitioners in NATS, and matched to NATS particular business needs.

Following the definition of an improved approach by NATS and UCL, the project conducted a Case Study, where the approach was exercised, evaluated and improved. The resulting approach is now being implemented in one of NATS' largest COTS based procurement projects.

The aim of this paper is to describe some of the results of this project as they relate to the implementation of RE process research in an industrial setting. To do this the paper is structured as follows: Section 2 outlines the Goal Based approach being used in NATS, and describes the most important results of the Case Study as they relate to practical implementation. Section 3 provides the context for the actual industrial application by describing the particular features of the Future Centres procurement project in which the approach is now being used. Section 4 reports some of the key experiences to date involved in bringing this particular piece of applied research into the practice community. Finally, Section 5 outlines the future of the research project.

## 2. Goal Based RE Research in NATS

The highlights of the NATS/UCL approach have been presented previously [2]. The main features can be summarised as including:

- Pre-Requirements Specification Traceability.[3] Particularly tracing to information sources, stakeholders, and the values they place on particular Goals.
- Explicit Recording of Assumptions: Implementing an explicit distinction between the 'World' and the 'Machine'.[4]
- Measurable Acceptance Criteria. Including explicit statements of how stakeholders will be satisfied that their Goals are met (or are likely to be met).
- Implementation in commercially available tools. The information model, process and evolution are implemented in commercially available tools.
- Service-Centred. Requirements are traceable to the components, or potential components, that will implement them through the concept of provided and required services [5].

Initial research activities centred on the evaluation of the initial information model and process. This was carried out on a case study system in NATS - a stand-alone Minimum Safe Altitude Warning (MSAW) System. This led to a number of developments of the model, and added significantly to experience in tool use and possible processes. Findings in this case study related both to the utility of the NATS/UCL as a RE approach, and to the issues surrounding the practical implementation of such an approaching NATS.

The focus of this report is the implementation activities, rather than evaluating the benefits of the approach itself, and below we highlight the key results of the Case Study in this light.

Understanding and Concepts. Although the Case Study was conducted by experienced analysts, considerable discussion and re-work was required as a common understanding of the best way to represent and refine Goals emerged. While this eventually settled down in the Case Study, it would present a significant problem in fielding the approach in a project with less experienced and potentially sceptical practitioners. We concluded that a gradual introduction, with a commensurate building up of experience in NATS would be important. Nonetheless, the importance of guidelines and constraints to reduce variability and misunderstanding should not be underestimated and should be available for any implementation on a live project.

Tool Issues. No requirements management tool we found could handle the fairly complex relationships embodied in the information model. This required the construction of a 'practical' derivation of the model to implement the concepts embodied in the conceptual model. Unfortunately, this tended to make the information model more confusing to those unfamiliar with its rationale. Furthermore, data entry became a complex task requiring the creation of multiple entries and the creation of a complex set of links, in the correct order, and as an atomic set. While this was workable in the Case Study context with only one, relatively experienced, analyst entering the data, it would present problems in a larger project setting, and tool customising would be needed to hide the underlying complexity.

Requirements Management (RM) Tools & Graphical Interfaces. A further issue with currently available tools was that there was little support for data entry, modification and presentation in a graphical form. As one of the significant benefits of a Goal directed approach is in presenting the results this way, this was a severe weakness. In the case study this was addressed by using a separate graphics application and maintaining manual the correspondence between the two. Again, a much better approach would be needed in any large-scale application.

The Role of 'Assumptions'. While the recording of information relating to Assumptions was followed, detailed examination of their relationship to Services and Goals (as suggested by Jackson) was not carried out in detail. Consideration of this was excluded from the Case Study in order to retain a manageable scope - largely because an approach to this already existed in the industrial setting in Praxis Critical Systems' REVEAL<sup>®</sup>[9] approach.

Scope of the Case Study. For practical reasons, the scope of the case study was limited to the investigation of the key aspects of the approach. This inevitably left a number of other areas under-examined, and many of these have since arisen as issues in the implementation. These, and other issues arising to date, are discussed in Section 4 once the project on which the approach is being implemented is described below.

### **3. The Future Centres Project**

NATS' long term intent is to provide the main Area Control Service through a Two-Centre Strategy, with Air Traffic Control Centres located at Swanwick and Prestwick. The first phase of this work was the successful transfer of the London Area Control Service to Swanwick in January this year. The Future Centres Programme will continue this by achieving the transfer of additional control services to the Swanwick site. The project includes the requirements to: procure new equipment from which to deliver the services; revise operational concepts and tasks; and successfully transition the service to the new platform.

Aware of the existing COTS based systems in the ATC domain, NATS is keen to capitalise on the economies of scale available from the procurement of a product based system. However, NATS recognises the challenges of COTS based procurement, in particular that:

- It is important to ensure that requirements are based on available capability [6] remain malleable [7], and that a balance of mutability [5] is maintained between requirements and COTS adaptation.
- Traditional serial approaches to procurement are not likely to be successful, but that they should be iterative. [5,8]
- Selection should be based on rigorous, measurable criteria.

In addition, some of the important requirements (particularly safety or HCI issues) will not be met from COTS, but must still be achieved. NATS will need to overcome this problem with a 'Buy and Adapt' approach [8]. The project has identified that a practical RE approach will need to meet the needs of COTS; hybrid; and custom build aspects, and that traditional NATS approaches to defining requirements are not suitable for this task. In order to address these, the project is bringing together aspects of a number of different approaches to Requirements Engineering. These include:

A 'Total System' Approach to Requirements. This involves the agreement with supplier of a relatively small number of high-level capabilities and performance levels for the total system (people, machines and procedures), and the co-operative refinement (with the selected supplier) of these into specifications allocated to people or equipment.

A Rigorous Approach to Solution Analysis. The project has chosen to adopt a rigorous approach to the analysis and rationale of potential solutions to the requirements. To this end, significant use is being made of the REVEAL<sup>®</sup> approach of Praxis Critical Systems Ltd [9]. The most important aspect of this is the introduction of 'Satisfaction Arguments' around the solutions, based again in the work of Jackson [4].

A Goal Based Approach to Requirements. Binding these aspects together is the Goal Based approach developed by NATS/UCL. As described in Section 2, the Case Study had only partly addressed the involvement of 'Assumptions' in the knowledge of the existence of the more rigorous approach of REVEAL<sup>®</sup>. This meant that the integration with this approach was comfortable and convenient. Similarly, the conceptual fit between the progressively increasing detail obtained by Goal Refinement, and the refinement of high level capabilities into low level allocations embedded in the Total System approach was very easy to merge. In addition, the NATS/UCL approach provided its own features (described in Section 2 above) which contributed strongly to the meeting the specific needs of COTS based procurement described earlier in the Section).

#### **4. Implementing the Goal Based Approach.**

Significant challenges were expected in the 'industrialisation' of the foundational research, and we were not disappointed - both in the areas that the Case Study had identified, and in others. The live project is in a very early stage, and any evaluation of the benefits of the approach in this setting would be premature. Nonetheless, significant lessons have already been learned.

It was important to be willing to **Adapt The Results** of the research when it was about to be applied. Extant procedures and particular ideas (specifically the Whole System approach, and the use of REVEAL<sup>®</sup>) in the project team required changes to our approach. We were able to achieve this for a number of reasons: firstly, we had a good understanding of the principles underlying the approach, and so could argue the case for what was core; secondly, our approach was aimed at correcting recognised weakness in the NATS approach, and we had worked at publicising both the weaknesses and the solutions; and finally, we had drawn heavily on sound innovations in the RE domain and these proved also to be key concepts underlying the approaches we needed to merge with.

We were greatly aided by our approach being **Implemented In Established Tool Sets**, as this often provided a common grounding between complementary approaches. We found further benefits of using established RM tools: firstly, because we were bringing forward an approach that advocated tool use we found a receptive audience among those seeking the rigor they provide; and secondly, it would have been highly unlikely that NATS would have committed to any approach based in a custom built tool set, particularly when it had little pedigree and was largely unsupported. However, the price for this (highlighted in the Case Study) has been significant effort in tool customisation to hide complexity and facilitate ease of use. The graphical editing and presentation capabilities so valuable to a Goal Based approach are still not available to the project and this slows the work of the analysts.

We face a significant challenge in **Supporting The Implementation** of the research. Expertise in the approach was gained in the development and analysis activities of the Case Study, and only a very small number of people were involved. There is now a mismatch between the available expertise and the resource needed to support and mentor the new practitioners. Our original solution to this issue (a

gradual introduction of the approach and the production of comprehensive process guidance in advance of large-scale use) was thwarted by the earlier than expected demand for implementation. In some individual aspects of the approach (for example Goal Based Requirements, Stakeholder Involvement; Handling Assumptions), we are able to identify alternative sources of mentoring and support.

The lack of **Control over the Timing of the Take-Up** alluded to above has also prevented the full development of graphical goal editing and data entry - another area we had identified as important in the Case Study. We have had to address this through outsourcing the development of some of these aspects, in order to deliver them quickly; and through the use of non-integrated tools - which is less than satisfactory. Further development of both of these aspects will be required as the Future Centres Project progresses.

In hindsight, we were perhaps a little limited in the **Scope of the Validation/Evaluation** in the Case Study. The organisational weaknesses in some areas of RE practice (e.g. Metrics and Reviews) emerged too late to be included, and the early take up of the approach overtook the intended follow-on project which was to address those aspects we had deliberately excluded. Addressing these issues in the implementation stage compounds the difficulty of providing supporting to the implementation with the limited expertise available. In future R&D projects, greater emphasis needs to be placed on the less glamorous 'process' aspects, as these become vital elements of the fielded solution.

In implementing this work, the researchers have often called to take on a role of technical evangelist to a sometimes-**Sceptical Audience** of prospective practitioners. As the researchers have been close to the work, have a unique knowledge and understanding of the underlying concepts. We have sometimes been guilty of being over technical and academic with our audience - particularly where theoretical and academic arguments carry little or no weight. We have found it useful to have critics available in most of our meetings, able to provide feedback (either in the meeting or afterwards) on the appropriateness of the level of discussion that had taken place.

## 5. Further Work

This paper has presented the research work involved in the development of an improved approach to Requirements Engineering in NATS, and highlighted some early experiences in the adaptation and extension of the approach in the early stages of implementation. No doubt, further experiences will emerge, and better approaches to dealing with those reported here will become evident over time. Significant further work also remains in evaluating the benefits of the approach itself as more work is done over the next 2-3 months in identifying and describing requirements.

## 6. References.

- [1] "Effective Requirement Engineering in Practice." Internal NATS Report, 1998.
- [2] "Requirements Elicitation for Complex Safety Related Systems." David Bush and Anthony Finkelstein, London Communications Symposium, Sep 2000.
- [3] "An Analysis of the Requirements Traceability Problem." O. Gotel and A. Finkelstein, Proceedings International Conference on Requirements Engineering 1994.
- [4] "The World and the Machine". M. Jackson. Proceedings 17th International Conference on Software Engineering 1995.
- [5] "Software Package Requirements & Procurement." A. Finkelstein, G. Spanoudakis & M. Ryan :
- [6] B Boehm reported in Proceedings of the SEI/MCC Symposium on the Use of COTS in Systems Integration, Ed Alan W. Brown, David J. Carney & Maureen D. McFalls CMU/SEI Special Report CMU/SEI-95-SR-007, 1995
- [7] "Workshop on COTS-Based Systems", Ed. P. Oberndorf, L. Brownsword E. Morris, C. Sledge. CMU/SEI Special Report CMU/SEI-97-SR-019, Nov 1997
- [8] "COTS Software Integration: State of the Art.", M.R. Vigdar, W. M. Gentleman and J. Dean Technical Report 39198, National Research Council of Canada, January 1996.
- [9] <http://www.praxis-cs.co.uk/htmlcontent/our-core-services-2.htm> 19<sup>th</sup> July 2002