Requirements Degradation for the Creation of a First Prototype

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Abstract—The requirements engineering process is typically executed, irrespective of the process model chosen, for the final commercially viable system. The system requirements generated are for a system deployed and used in its final form and function. However, the first prototype that is generated is typically representative of a minimum viable technology, and represents a degraded set of the initial system requirements specification. Typically, a first prototype is used as a technology demonstrator, and its failure or success will determine the continuation of the project, with success triggering the allocation of additional financial and personal resources. This paper explores techniques for requirements degradation that can be used to form the system requirements specification for the first prototype. A requirements Engineering methodology is proposed based upon a survey of literature. It takes into consideration the characteristics of the project, i.e. a market driven, technology implementation research project with limited budget and a flexible timeline executed in an academic environment. The techniques must take into cognizance the main risk items, and core requirements, that need to be demonstrated in the minimum viable technology to secure the future of the project. The degradation cannot undermine or jeopardize the future success of the commercially viable system in determining the subset of requirements for the minimum viable technology.

I. INTRODUCTION

This paper explores the use of Requirements Engineering (RE) practices in a case study for new product development in a research environment that is based upon a market driven scenario (as opposed to a bespoke case). The essence of this work is to develop the RE process, including the exact tools and methods to be used, for elicitation, analysis, documentation and verification for a case study of the development of an Unmanned Aerial Vehical (UAV) for use in underground mining. The case study is to focus on the degradation of the requirements identified in the RE process to determine the functionality desired in the first prototype.

A. Minimum Viable Technology vs a Commercially Viable System

During the elicitation process, all parties typically envision and discuss the final product capability and functionality, in this text to be referred to as the Commercially Viable System (CVS). These requirements include the functionality of the complete installed final system as identified at project outset. It is inevitable that they will change as the project is executed, and this process is managed by the Requirements Management (RM) process.

However, in order to design and develop the first prototype, a subset of the requirements is required to determine the functionality and capability of the prototype. In this text, this will be referred to as the Minimum Viable Technology (MVT). There are a number of reasons for the MVT development

- to demonstrate the minimum deliverable that would still be useful
- to mitigate any technological risk that is identified at the project outset
- to show capability with a reduced resource (financial and schedule)
- to clarify the problem by using a prototype and refine the requirements of the CVS
- to gain a better understanding of the requirements of the CVS and thus be able to plan and cost the development better.

The MVT represents a degraded subset of the CVS require- ments. It could be that some of the requirements are identified as not needed at all, while others may only be needed at a reduced performance or capability.

For example, the MVT might never run as long as the CVS, and therefore the battery requirements and data storage requirements will not be as ownerous in the first prototype as they will be in the final system. The MVT might also never be used by the operator, and only be used and demonstrated by the developers, therefore the training and documentation, as well as many of the non-functional requirements would fall away.

It is noted that this scenario bears a parallel to the marketing equivalent of ”minimum viable product” in the entrepreneur- ship literature, which characterizes an approach where a business idea is reduced to core features that are tested in a prototypical way. This is however not explored in this research, but rather reserved for future work.

B. Research Method

The focus of this work is to identify the techniques available from within the RE framework to achieve a degraded subset of requirements. The strategy that has been selected is to execute a literature survey to identify suitable techniques, given that this is a new product development project with a potentially significant research risk component. This project is a market driven need, as opposed to a bespoke system. While methods and techniques from software engineering and business analysts might apply, it is the systems engineering based literature that is most relevant.

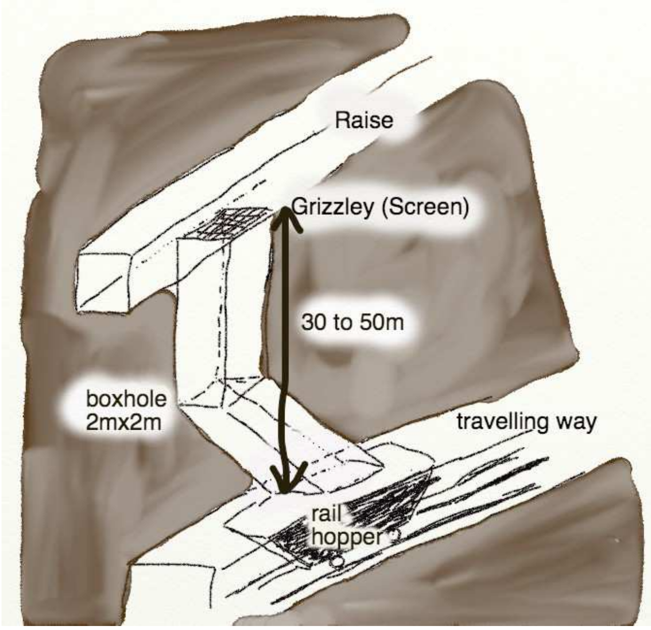

Fig. 1. Diagram of a box-hole structure and dimensions.

II. PROBLEM BACKGROUND

The chosen application of box-hole inspection in underground mining, is the inspection of a vertical ore chute used to transport ore from the mining area to the rail transportation, which then takes it to the central shaft for transport to surface. the basic structure of a foxhole is shown in figure 1. The box-hole is typically about 2mx2m square, with an upper vertical section, and a lower section angled at about 50 degrees to reduce the kinetic energy of the falling ore. The top is capped by a screen (grizzley) with 30cm x 30cm apertures, and the lower end is capped by a box end, used to control the flow of ore into the rail car (hopper). This is a dangerous environment, and people cannot safely gain access to it. The box-hole can periodically block, causing production delays, and there are recorded incidents where miners have perished while inspecting such blockages [25], [10].

The possibility of inserting a sensor set into the void in order to measure and monitor the conditions has been proposed. This opportunity/possibility needs to be explored further to determine its viability. Hence the execution of this project.

At a conference on Mine Emergency Preparedness and Rescue Innovation [10], a workshop on possible robot deployments was held. During the workshop, a number of possibilities were narrowed down to three promising cases. The outcome of that workshop [11] indicated that there was a need for the ability to enter an area to acquire reconnaissance information, without sending in people, potentially with the use of a UAV that would not be inhibited by a cluttered floor, possibly in areas where the roof had caved in. This rescue scenario was then extended to include the more everyday activities of production, where such a capability would be useful, namely the inspection of box-holes and ore-passes. The business case for a rescue robot is limited due to the limed number that would be needed to meet the potential demand. The deployment of such a system would be seldom, and one unit would be able to service many operations. However, a similar system deployed regularly in a production environment would have a much bigger market. Also, it it was deployed correctly, it would negate some of the circumstances that would require the rescue system deployment, by preventing the rescue incident from ever occurring.

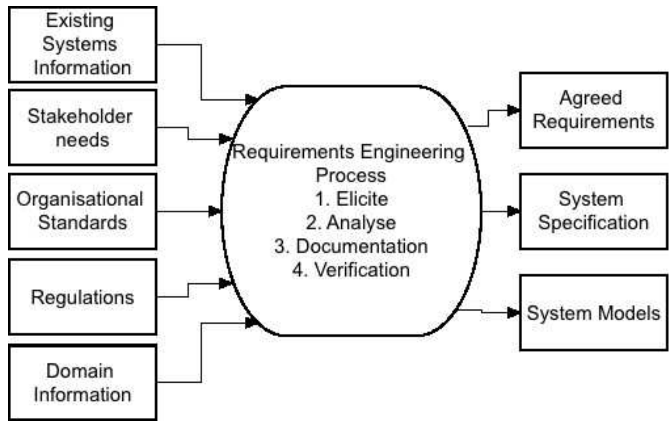

Fig. 2. RE process.

III. REQUIREMENTS ENGINEERING IN NEW PRODUCT DEVELOPM ENT

A. Requirements Engineering

Getting the requirements right is a fundamental step in ensuring a successful research project execution. Multiple input sources are interrogated to understand the need, which is then analyzed, documented and verified with the stakeholder to create an agreed set of deliverables, the System Requirements Specification (SyRS) [19] [20].

In new product development (and system development) the RE process is the same as it is for software engineering and business analysis, as in figure 2. The four steps of:

1) elicitation
2) analysis
3) documentation
4) verification

are common across disciplines, however, the techniques employed vary amongst the project types. There are many books written about the subject [23] [17] [33], but what follows is a relevant commentary for this context.

In [28] the product development process is described as in figure 3. The requirements engineering process maps to the concept development phase, combining the steps of identify customer needs through to set final specifications.

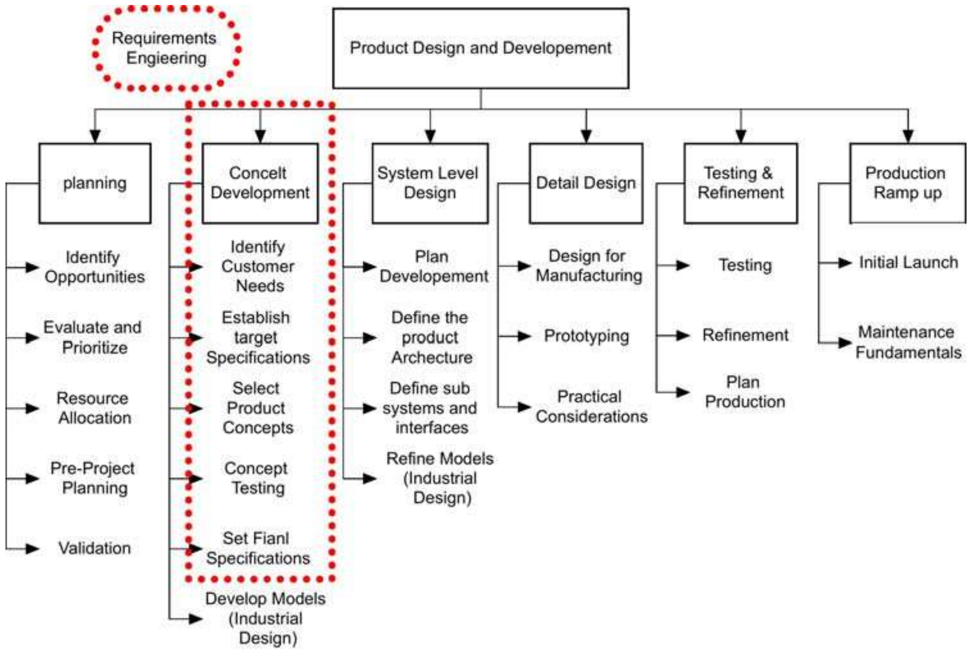

Fig. 3. New Product Development, and Requirements Engineering combined.

B. Life Cycle Models

[6] succinctly explains the evolution of systems engineering, and software systems engineering lifecycle models. The evolution started with a baseline model, or waterfall model, where there is some interaction between subsequent phases, but it is largely a linear process. However, the need to update the requirements after a period of time, as the problem/project/system is better understood, lead to the prototyping life cycle model. This iterative requirements definition phase lead to better requirements specification after the 'prototyping' of a number of the functions or subsystems, but it still represented a linear execution of the remainder of the project. The incremental life cycle model was a stepping stone to the evolutionary life cycle model, where multiple parallel development efforts exist. Outcomes and experiences from the initial work and deliverables feed back into the subsequent phases, resulting in evolving (and thus improved) requirements. The spiral life cycle model embodies all the other models, shown in Figure 4.

Each 360 degree rotation of the spiral represents a phase in the project. Each crossing of the -x axis represents a decision point. It is a potential termination point for the project after the evaluation of the previous phase and the planning (costing) of the subsequent phases with the new and additional information now available. The requirements specification would be the outcome of the 1st spiral of the model, or indeed only from the third or fourth spiral (Prototype life cycle). Each subsequent cycle then represents increasing project costs (distance from the origin) and the culmination of each phase would be a prototype of increasing commercial viability. Note that this is different from the prototype used in the elicitation phase, where only a function or subsystem is prototyped in an attempt to discover the true system requirements.

Figure 5 shows the spiral model of requirements generation. It links the 4 steps in a repetitive cycle, until there is agreement on the final step, thereafter the requirements are frozen.

A combination of models is chosen for this project. At least two layers of spiral will be used to determine the requirements prior to the design and development of the prototype. This process may involve the use of subsystem and graphical user interface (GUI) prototypes, as described in [18], as a tool for requirements elicitation. There will be a number of rounds of elicitation with the stakeholders, after which the gathered information is analyzed, scenarios compiled and subsystem prototypes developed for use in followup elicitation interviews. IDEO showed the success of rapid and repeated prototyping with close interaction with the stakeholders [27]. The requirements for the prototype representing the MVT will be the outcome of this subsequent spiral process, while an understanding of the CVS requirements will not yet have been completed.

C. Technology-Driven, Customer-Driven and Profit-Drive approaches to Design

The type of project informs the methods that would be suitable. This is a Technology driven project. There is no single customer, but rather a market segment identified as an opportunity to benefit from the implementation of technology solution, and it is driven by an academic institution, thus not profit driven. In [19], the different product development activities for a technology driven project are expanded as follows.

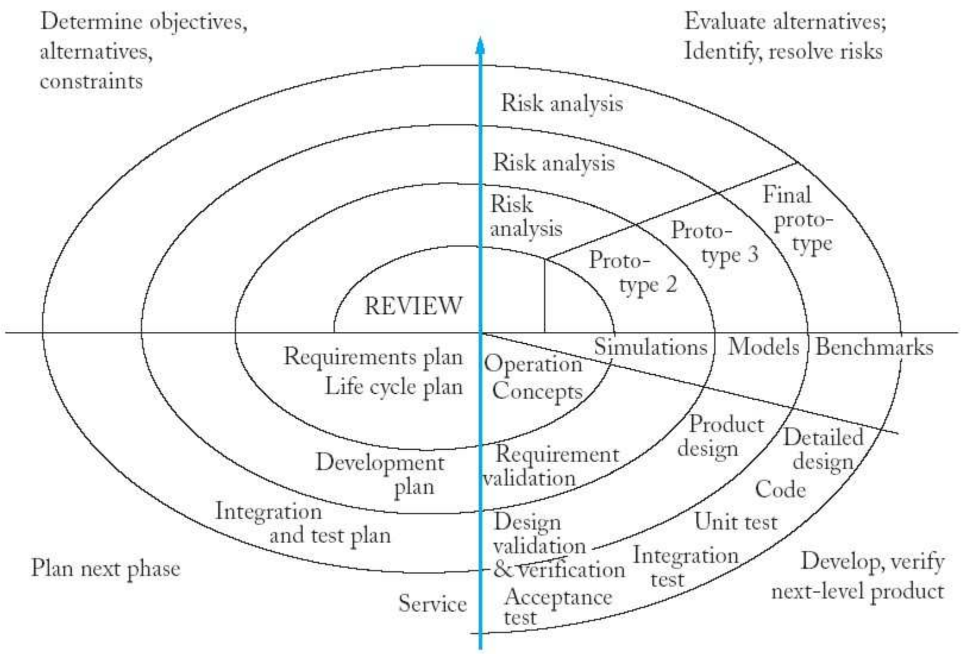

Fig. 4. Spiral life cycle (from [4])

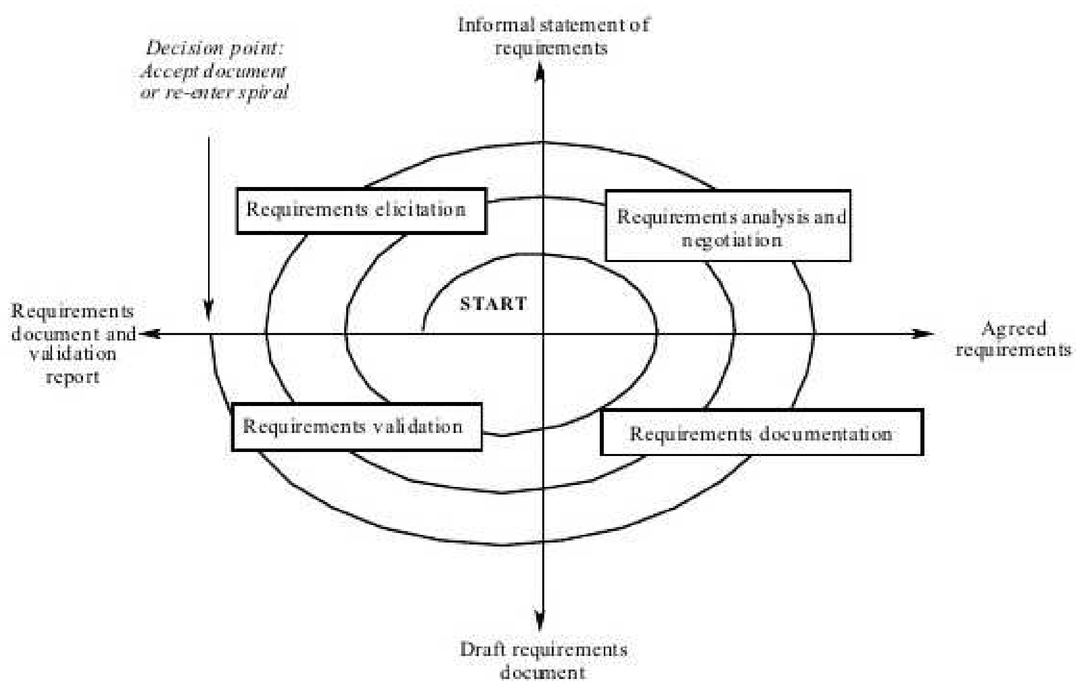

Fig. 5. Spiral Requirements Engineering (from [17])

1) Focus:

- Strong on sophisticated development technologies, develop technically complex new products.
- Scientific; Engineering; Operations; Marketing
- Product type

2) Identification of customer needs:

- Companies feel they can sense better than others what a market needs or what is possible in technical development and manufacturing.
- Customers are not involved, typically there is no market or customers for this product yet.
- Innovative, high risk products that offer unique features and benefits to customers.

3) Concept generations and selection:
- It is about the technology, user experience and marketing simply have to be good enough.
- Technical excellence is the building block often at the expense of usability and convenience.

4) System level design:
- Pure technology function with little or no involvement from other functions.

5) Detail design:
- Once technology has completed product it will start looking at marketing, packaging etc

IV. ELICITATION

Elicitation is the process of learning, uncovering, extracting, surfacing, or discovering the needs of the customers, users, and other potential stakeholders [14], and thereby determine what is to be achieved in a project. This is recorded as functions, or requirements for the system to perform or deliver.

A. Classification

There are many ways of classifying (or grouping) requirements, and they are not mutually exclusive. For example, a stated requirement, given by the client, may well already be a real requirement about the systems safety. It would therefore be a non functional requirement. It will become a validated requirement once the requirements baseline is complete, and eventually it will be a verified requirement, once a proposed design is analyzed against the requirements. The classifications that are used are project dependent and are chosen during the elicitation phase by the stakeholders and Requirements Analyst (RA). Typically this will occur formally during the analysis phase, but cognizance must be taken of possible classifications during the elicitation process. Recording the source and justification for each requirement can assist in its classification later in the process.

B. Stakeholder Identification

1) Taxonomies: A Stakeholder is a group or individual that can affect, or is affected by, the system implementation. Identifying stakeholders must be done prior to the elicitation step, as the elicitation techniques to be used will be determined by the planed interactions with the identified stockholders. The 'soft' issues, as well as time and logistical constraints, will determine the type and duration of the elicitation function. It is possible to spend a large amount of time identifying the network of stakeholders, and it is a task with diminishing returns.

Understanding the stakeholders and their rolls is important when it comes to prioritization of requirements later in the process, which can be based upon the stakeholders viewpoints.

[32] gives the following types of stakeholders:
- Users: people who will actually use the system.
- Advisors: legal experts or regulators
- Customers: those who are paying for the work
- Developers: Those that will do the development work. Other taxonomies (from [24]) have been proposed:
- End-users, Managers, Engineers (developers), Customers, external bodies (Regulators).
- Internal to project, internal to organization (external to project), external to Organization.
- Users (direct and indirect) and Developers.
- Designers, financial interest, responsible for operation, those with an interest in its use.
- primary, secondary, external, and extended

Sharp [24] herself proposes a complex multi layer system of stakeholder classification and identification. Starting with a baseline group of stakeholders comprising of Users, Developers, Legislators and Decision makers, each of which is analyzed in a 4 step process to identify additional stakeholders, and understand their involvement in both the RE process and the final system implementation. Namely:

a) Identify the internal rolls of the stakeholder,
b) identify the suppliers who provide information or supporting tasks to the stakeholder,
c) identify the clients who process or inspect the product (or output) of the stakeholder,
d) Identify Satellite stakeholders interact in otherwise with the baseline stakeholder.

These steps are repeated with all new stakeholders, building a network model of the stakeholders and their interactions, until no new stakeholders are identified. This peeling the onion pro- cess can however be a tedious and lengthy process, and could be stopped when there are sufficient stakeholders to represent all the stakeholder groups, and thus complete the RE process. The process however does not formally recognize that there will, in all likelihood, be additional stakeholders identified during the system life-cycle process. It also fails to recommend a method of identifying which from the complete list of iden- tified stakeholders should be present in the elicitation process, as it is unlikely (due to limits in budget and schedule) that every stakeholder will be able to be consulted. The resulting stakeholder network is analyzed to determine stakeholder (and their viewpoint) priority. The higher linked stakeholders can be identified as higher priority, as can the central stakeholders. The identification of the important stakeholders that must be involved in the process is possible with such a network model. This is the approach that will be utilized in this project.

2) Market Driven vs Bespoke Systems: None of the above taxonomies take cognizance of the potential difference between the different project initiation sources. The project could either be a bespoke system (ordered by a customer), or a mar- ket driven system (identified by a supplier). This differentiation makes a difference to the process to be

followed, and the tools that can be, and are employed in the RE and RM processes [26] [9]. A bespoke system will likely start with a formal document like a Request for Quote (RFQ) or Scope of Work (SOW), or similar document presented by the client. A market driven project is internally identified based upon an identified opportunity in the market, or a problem that needs a solution.

3) classification: The stakeholder classification will be a result of the identification process, and groupings of those stakeholders that will take part in the RE process. The stake-holders identified to participate in the RE process will be a representation of the resulting taxonomy for the project, thus, it is important to complete the process satisfactorily and not simply go with what we have.

Ways to identify suitable stakeholders are developed by Razali [22]. The process takes into account not only the roll and knowledge of the potential stakeholder, but also their interpersonal skills in being a valuable contributor in the RE process. The process starts with the identification of all stakeholders, under a taxonomy primary,secondary, external and extended. The stakeholders are then classified in a simple mapping as either:

a) Mandatory (for primary and some secondary),
b) Optional(secondary and external),
c) Nice-To-Have(extended and some external).

This is a relatively simplistic mapping, and in actuality, each stakeholder should be purposefully classified. Filtering based upon knowledge and interest is vague in the proposal, but the intent is to determine a way reduce the possible stakeholders to be consulted in the requirements elicitation process.

A stakeholders analysis template [31] is one possible method to use to record and analyze the possible stakeholders. It will be used in this project.

C. Choosing Elicitation Techniques/Methods

The choice of elicitation technique depends on resource availability, information required and types of problems to be solved.

In order to elicit the requirements from the stakeholders it was decided to use multiple rounds (as per the spiral model in Figure 5) of semi-structured interviews and brainstorming (using prototypes to generate discussion and ideas, and sce-narios to capture the intended deployment characteristics) and then developing of MVT prototype. As per ACRE framework developed by Maiden and Rugg [18] when developing a new system, which is the case here, rapid prototyping and scenario analysis is best suited technique to elicit the information from stakeholders. ACRE suggests that scenario analysis and prototyping more effective for acquiring requirements for new systems, the reason being that scenarios and prototypes are both simulations of the required system and its interaction with the environment, and hence provide more effective cues for recall of knowledge of stakeholders.

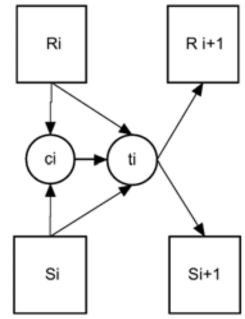

Fig. 6. Hickey’s selecting the elicitation technique based on the current Requirements and current project Situation

Hickey [14] explained in the unified model, that in actuality, the complete elicitation process cannot be preplanned prior to execution. The choice of an elicitation technique (ti), at time (i), is a function of the current requirements characteristics (Ri), and the current project situation (Si). A combination of Ri and Si will generate a set of possible techniques (Ti) that can be used, which is a subset of all possible elicitation tech- niques (T). A choice function (ci) the selects the appropriate technique (ti), from the subset (Ti) to execute, resulting in a function diagram as in Figure 6.

The requirements are thus updated with the new knowledge, to (Ri+1), and the project situation is altered by the execution of said technique, to (Si+1). The new requirements and situ- ation then give rise to a different set of applicable techniques from which the next elicitation activity is chosen. Figure 7 shows the entire elicitation process executed in ’n’ steps, until the requirements are deemed complete enough (Rn) and give rise to the project situation (Sn).

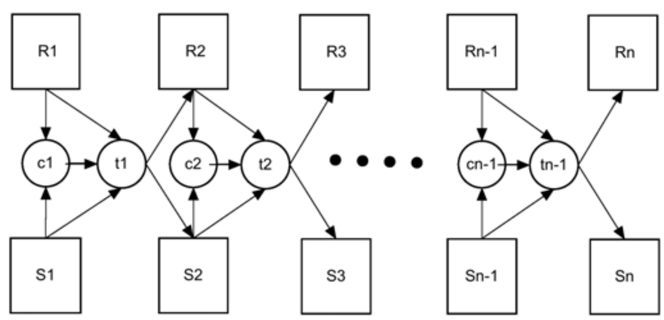

Fig. 7. Hickey’s complete, recursive elicitation process.

Unfortunately, the mapping of the project characteristics and the situation characteristics to the elicitation techniques is not available, and it is up to the RA to choose the methodology. I.E. the choice and order of elicitation techniques to execute in order to discover the requirements. [13] has identified 10 key dimensions that differentiate a large variety of the available elicitation techniques, and fifty situational characteristics that could influence the decision to select one or more elicitation techniques, encoded in Colorado Selector of Techniques for Acquiring Requirements (CoStar). [16] updated it and it was further published in [15]. It would seem to be more complex the initially anticipated, as there is no final literature published. Many techniques can be disqualified from application due to the projects' characteristics. There is no existing system that can be observed, thus any ethnographic or observation techniques will be unhellpful. i.e. apprenticing.

There is no specific customer that can participate in a Joint Application Development (JAD) process.

The stakeholder pool that is envisaged to be a result of the stakeholder identification phase, is not going to be geographically close to one another. Thus, any technique that requires a group to meet together will not be feasible, i.e. collaborative sessions beyond two or three persons (for small groups, technology can enable a number of locations to have a joint meeting), and Team building are not applicable.

This project has characteristics that make the following techniques ideal, as described in each section.

D. Interviewing

One-to-one discussions with a stakeholder using unstructured or structured approaches [12]. Semi structured interviews are driven by a set of predefined questions, while ensuring some unstructured discussion to enable the capturing of additional new pertinent information. They are effective in collecting large amounts of information [33]. There is a dependency to generate the right questions for the right stakeholder [33].

E. Brainstorming

Brainstorming session is a gathering of interested people whose task it is to generate ideas [23]. It promotes free thinking, allowing for innovative/creative solutions [33], and is especially applicable for new product development. There is a dependency on participants willingness to participate.

F. Prototyping

A prototype is an initial preliminary version of a solution or system [17]. Two types of prototypes are used: throw-away (discard after development) and evolutionary (become part of final solution). During development of user interfaces a prototype enables stakeholders to play an active role in developing requirements. Prototyping can be expensive to produce in terms of cost and time, requiring preparation before any elicitation activity [33]. (Note that this is different to the MVT prototype that this the initial goal of this work.)

G. Scenarios

A storyboard which illustrates the sequence of interactions between user and system (covering who the players are, what happens, why it happens) [29]. Very useful to generate common understanding, validation and during test case development [33]. Useful when the problem is new and innovation is required/allowed [32]. Shows the functionality of a use case. And can capture a view point. The internal structure of the system is typically not addressed in a scenario [33].

H. Models

The application of modeling in the elicitation phase has broad application potential. Data Flow models, State Charts and time ordered sequences are some of the possibilities. It is unlikely that any elicitation process can successfully be executed without the use of models at some point. Typically this is in a collaborative environment [16], but it can also be a method of sharing ideas between stakeholders, or capturing the requirements justification for use in the validation phase.

I. UAV Development stakeholder identification strategy

This is a market driven project (as opposed to a bespoke system whose design is undertaken at the request of a specific customer for a specific need). There is no one specific client, and it is not feasible to interact with all possible clients. Also, it is a hypothetical implementation, thus the stakeholders that will be identified represent rolls, rather than individuals, as would be the case in a bespoke system. However, representation from such stakeholders needs to be taken into account in the RE process.

As a research project, there is no identifiable implementation team of the CVS. The product being developed has a number of possible commercialization paths, and each has its own implications (not discussed here). There is no group identified that will manufacture, sell and support the product, therefore there can be no stakeholder to represent that group. However, it is vital that the viewpoint of such a stakeholder is taken into consideration when executing the RE process. i.e. manufacturability, training and support requirements. These viewpoints will have to be hypothesized in a roll playing method to determine the requirements.

Thus an onion peeling approach will be employed starting with the existing project network to identify both the the roles of stakeholders, as well as potential individuals that can fulfill those roles.

Thereafter, once all possible candidates are identified, as with [22], a filtering process will be employed to based upon the stakeholders knowledge and interest in the project RE process. Finally, a prioritization process will be employed to identify the stakeholders that will participate in the RE process. An important verification step will be added to ensure that all the priority rolls are represented, and for those that are not, a hypothetical contributor will be used during the Elicitation process to ensure that the viewpoint is not missed in compiling the requirements.

V. ANALYSIS

Analyzing the information elicited from the stakeholders to generate a list of candidate requirements, often by creating and analyzing models of requirements, with the goals of increasing understanding and searching for incompleteness and inconsistency [14]. In actuality, this process starts with the utilization of requirements characteristics during the elicitation phase. Initial prioritization is recorded when the requirements is first recorded, and this is verified during discussions. The analysis phase validates these classifications, and adds more classifications to the recorded requirements. The requirements are classified into groups (i.e. functional vs non functional) and into subsystems.

In this project, one critical characterization of the requirements is if it would fall into the requirements for a MVT or a CVS. This differentiation is important and will be tracked from the outset during the elicitation process.

A. Prioritization

Also sometimes called requirements triage, is an analysis technique used in determining which subset of the requirements ascertained by elicitation and analysis is appropriate to be addressed in a specific release of a system [14], given the time and resources available [5]. In this case, it encompasses the the inclusion of, or determination of the level of performance of, a requirements characteristic as a MVT or CVS.

Firesmith [8] explores the exact meaning of priority and its impact upon the classification process, and expands 14 different axis upon which a requirements could be prioritized. [7] proposes an automated method of prioritization based upon clustering algorithms and the prioritization of the clusters, largely aimed at determining software improvements based upon 1000's of customer feedback requests. [1] is a relatively recent literature analysis of prioritization techniques. They are classified into one of 4 categories:

1) Ordinal: many techniques that create an ordered list of the requirements.
2) Nominal: requirements are grouped.
3) Interval: some information on the relative importance of the requirements is captured.
4) Ratio: comparitive matrix based systems that need some automated calculation system.

There are some powerful mathematical techniques that assist in determining the priorities by ranking characteristics against characteristics. Through normalization and matrix algebra, a ranking vector is calculated. These methods can however alien- ate the stakeholders to whom the method will be too complex and not understood, thus creating mistrust in the outcome. (it is seen as a black box). i.e. one of the most popular, (AHP) analytic hierarchy process is a pairwise comparison process, but doesn't scale well for larger number of requirements. Case based ranking, is another that faces scalability issues in requirements prioritization with machine learning [2]. Also, hierarchical cumulative voting - [3], which is an adaptation of AHP, and requires a specialized computational tool to execute.

It is interesting to note that many prioritization texts refer to only delivering the "real" requirements that are critical to the system/project success. However, in modern markets, there are often many competing systems and it is the differentiating capabilities that resolution in capturing the market share, and in the case of software systems, the 'added extra capabilities' can often be seen as not core to the system, but once to haves. In the context of this project, the core 'real' requirements are akin to the MVT capabilities, while the 'nice to have' functionality would be a possibility for the CVS functionality. i.e. pop up tool tips in the GUI to assist with usability in a CVS vs a comprehensive user manual, vs only commented code in a MVT.

As this is a technology development project, there needs to be realistic justification for the inclusion of a requirements in MVT vs CVS. Therefore methods like voting or $100 alloca- tion where stakeholders vote or assign value to requirements is not seen as feasible or useful. There must be agreement on the required functionality of MVT. Arbitrarily ranking the requirements and choosing a "cut-off point", is not viewed as useful either, as there must be scientific justification for the inclusion/exclusion of a requirement in the MVT or CVS.

It is not envisioned that there will be a large number of requirements, therefore an automated prioritization technique is not required. A simple classification into categories is proposed (based upon the KANO model, based upon discussion and justification to the following questions.

If xyz requirements was not delivered, would the system:

- be deployable?
- deliver any output?
- outcome still be useful?

Simplistically,The answer No implies MVT, and yes implies CVS. In reality however, the requirements analysis will be an iterative discussion process between core stakeholders and will be intimately intertwined with the elicitation activities., as opposed to a completely separately executed phase.

VI. DOCUMENTATION

The purpose of documenting the requirements (system behavior) is to enable the verification thereof, and provide a measure against which the final product (or interim design) can be measured, to determine success and/or completion (Validation) of the project. The requirements are recorded and distributed in ways suitable for the various audiences. There will likely be a variety of system depictions that are suitable for the various stakeholders. I.E. the developer needs the low level requirements and their classification and interactions, while the end user will only be interested in the system level requirements and outputs.

The use of a template is helpful in ensuring that there is nothing omitted from the process - The Volere template [30] is highly regarded by experts [16], and will be used for this project. It acts both as a guide for what should be recorded in a requirements specification, as well as a tool for recording all the relevant information [23].

It is clear that an automated requirements tool for tracking of the dependancies and tracing the requirements is invaluable in a RE process. Thus, such a tool will be utilized for this work. Currently Magic Draw [21] is under evaluation.

VII. VERIFICATION

From a time and energy perspective, this is a relatively short and easy step. The documented requirements are distributed to the stakeholders for confirmation that the classification and prioritization is acceptable to form the baseline for the project. If there is not agreement, then another lap of the spiral model of RE (Figure 5) is required to clarify the discrepancies using the most appropriate tools or methods for dealing with the errors, omissions, or conflicts.

From the point of agreement onwards (Freezing the base-line), it become critical to track the requirements using a re-quirements management tool, such that any changes that occur, or requirements that are added (or derived) are agreed and approved by all stakeholders, together with a record of such activities. It is well noted that scope creep is a major cause of project failure, as is the uncontrolled addition/alteration of project goals. Having a formal record and change process enables the expectations of all parties to remain aligned. This ensures that the final product is viewed as a success as it meet with the requirements, and thus all stakeholders expectations.

VIII. CONCLUSION

This paper has formulated a requirements engineering methodology for the development of an unmanned aerial vehicle (quadcopter) for the underground mining application of box-hole inspection. The methodology is based upon literature and the suggested methods matched to the project characteris- tics. It is a market driven, technology based, research project with distribute stakeholders, limited budget and a flexible timeline. The project will now be executed as per this plan, and the results of the process reported. The successes and failures of this plan during execution will be documented, and will provide feedback for the technique and method choice for requirements engineering of future such technology based research projects.

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