Using A Systems Engineering Approach to Expedite the Development of Professional Engineers

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Research and Development (Electrical Systems)

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Abstract Transnet Engineering's new Research and Development division is currently designing a world class training programme for new graduate employees using a Systems Engineering approach. This article outlines the conceptualisation of the need, the problems encountered with existing Transnet training programs, and the skill categories envisioned to cultivate exceptional talent. Furthermore, a brief overview of functional units is presented to achieve these skill pillars for accelerating the development of professional engineers.

Problem Statement

In July 2012, Transnet Engineering embarked on an ambitious venture to start up its own Research, Development and Innovation facility. After numerous strategic workshops with international experts, it was recommended that the facility should start with 80-100 engineers/researchers in the first year and then ramp resources up to a staff compliment of approximately 400 over a 5 year period.

The initial requirement of 80-100 engineers seemed idyllic on paper, but quite arduous to execute with the current skills shortage in South Africa. Research and Development requires the epitome of the best, and companies tend to retain their top performers zealously. Hence, even with an audacious recruitment drive, Transnet Engineering might only be able to lure 10 to 20 experienced experts from industry, but would have been forced to settle for average, or even below-average performers to fill up the compliment. Initial strategies entailed an aggressive recruitment drive at University level, attracting the cum-laude engineering and top performing postgraduate students from across South Africa. Though one is guaranteed to attract prime students, the unfortunate reality is that they possess minimal practical experience and would require intense on-the-job training to really be able to contribute effectively.

Further complicating the problem is the inability of the established training programme to produce Research and Development leaders and experts within a very short space of time. Historically, most of Transnet Engineering's programs focused on improving existing products, processes and maintenance practices as well as orientating staff to rail specific knowledge. Because of this, traditional methods which were orientated around only achieving ECSA accreditation (ECSA 2003) had to be modified and modernised to ensure rapid leadership development and skills retention for the new millennial generation.

Customer Requirements

With the issues outlined in the problem statement above, Transnet Engineering mandated a pilot training program designed to develop and retain skills within the new Research and Development division. This program necessitates expediting skills development to achieve ECSA recognition, development of rail specific knowledge as well as expediting the natural path to professional behaviour and thought patterns. Currently, with only 12 ECSA accredited Professional Engineers within the Transnet Engineering division, it was hoped that a program be designed to facilitate the professionalisation of candidates as efficiently as possible.

For the purposes of internalising Research and Development and for the goal of Transnet Engineering becoming an Original Equipment Manufacturer, component level experts have to be separated from system level specialists at some point during the program, to mentor and develop the two different skills groups. Finally, in line with the existing structure of a 2 year engineer-in-training program, it is hoped to evaluate the candidates in training and track their competencies continuously. This is for the decision of whether to permanently employ and where to position the candidates after the evaluation period.

Gap Analysis

Existing Transnet Graduate Program The existing graduate program employed within Transnet Engineering utilises a rotation scheme, whereby each engineer in training must rotate every 3 months to another division within the Product Development group. This methodology intended to provide the engineer-in-training with a holistic view of the opportunities within the organisation, allowing each individual to make up his/her mind on where he/she would fit best in the long run.

Unfortunately, a maximum of 3 months within any division is not a significant enough period for any person to get settled and/or contribute meaningfully towards any project deliverables. In many cases, senior engineers are also over-committed on their project deliverables and the net-effect is that most candidates do not receive the attention he/she deserves. Over time, this has resulted in a lot of uncertainty in what is expected from the new employee; with a lack of vision, context, and proficient skills development occurring. Because of this, dissatisfaction amongst some employees has existed, who are often left to their own devices. The lack of adequate leadership and enthusiasm building has led to a negative turnover of younger staff in previous years. Coupled to this however, are also the qualms of employees who feel inadequate responsibility is often granted, with a general sentiment that freedom for inspired projects are mired in corporate restraints. With the lack of a renowned orientation and work program, it has historically proven difficult to attract talent from industry without direct intervention.

With these factors subtasks were designed to tackle these more implicit aspects of the working environment, as well as to foster growth of the individual to maintain enthusiasm and commitment. Furthermore, as a major employment driver and strategic key to Government's economic renewal strategy, Transnet had to place special focus on activities to grow future community and social leaders.

Evaluation of other industries' strategies It would prove fruitless not to take into consideration strategies undertaken by other high profile companies. Although satisfaction levels of employees are an entirely subjective matter, employee retention was taken as a merit

when considering other institutions' graduate training programs. With such, large corporations of the likes of GE, Microsoft (MS 2013), Google, PWC (PWC 2013) and FNB were considered amongst others, especially in line with their process to building new employees.

General Electric has an especially auspicious rail specific training program in place that focuses on technical and engineering skills generation (GE 2013). It has achieved great success through a mixture of extensive project involvement and rotation, as well as taking a modular and university style approach to achieving training. Beyond this, exposure is tailored across varying focuses to provide a broad overview of proficient business approaches. This program helps to distinguish generalists and specialists into their relevant areas of expertise.

As a generic base line the FNB Graduate Program (FNB 2013) was also considered. FNB provides special focus on training in both technical and soft skills. These include areas such as Networking, Performance Management, Project Management, Business writing, Self and Career Development that are presented very early on within the training program. Of particular interest within their programs was monthly knowledge sharing sessions held to further expand on different business sectors and strategies, as well as a graduate buddy system to provide support and advice on how to adapt to the corporate world. Google takes a specialised approach to achieving maximal interaction and collaboration, with everything from contriving queue lengths in cafeteria (IEEE 2013), to the position of recreational areas to foster creativity and interaction. What has proven especially helpful to their business model is the implementation of times where employees can explore their own creative projects and ambitions. In line with their business focus, this has substantially improved innovation and new project undertakings.

An overarching theme amongst the companies surveyed is that of extensive interaction sessions to foster team building and sharing. Another favourable component seen is continued development programs tailored in line with the graduate's envisioned career growth in the business.

Approach

The approach presents considerable complexities when the aim is to achieve a structured program able to orientate the majority of employees within the two year time frame. Due to variances between University program outcomes, economic and cultural backgrounds, personality differences and desired areas of expertise, consideration has to be given to categorise the tasks undertaken through a systems engineering approach. Such a dynamic system also presents problems relating to external dependencies on resources and precedent activities for certain tasks. As such, flexibility had to be built into the model for the purpose of sustainability as well as for the functional unity that exists between certain tasks.

Using the experience of senior employees, frustrations listed by the existing engineers-in-training, best practices used in employee orientation, as well as input from the body of knowledge on how to harness the strengths of the Millennial generation, requirements were generated to outline the activities needed to achieve maximum results within the 2 year period.

Due to the complexity of the needs to transform the entire group, the training program was constructed out as a dynamic system. In order to satisfy the complex interdependencies within the system (technical, emotional, cultural, company specific needs etc.) an attempt was undertaken to keep subtasks functionally distinct as to avoid excessive overlap of inputs and outputs. In realising the extent of this program being a system of systems, appreciable benefit is not as a result of individual tasks, but rather due to the interaction of the different activities. The tasking of activities also required the experiences of different personnel with regards to

how to order the tasks for the best outcome. Although complexity can be drilled down to a trivial level, appreciable abstraction of the tasks allowed better encapsulation to ensure the sub-systems outputs are met.

The main importance of the design lay in considering the larger picture, and creating a robust structured approach to designing subtasks. In line with this lies the Systems Engineering origin. Although existing material on structuring training programs through Systems Engineering is limited, generic Systems Engineering principles and practices apply. A similar approach to that of the V-model of (Buede 2009) was undertaken, with the current phase of development lying within the detailed design.

This necessitated the utilisation of University of Cambridge's Centre for Technology Management's strategy mapping techniques (Phaal 2010) designed to delineate and sequence identifiable phases. The different facets coupled to these phases were broken down into four attributes to be developed. These were identified under the following four development pillars:

- **Professional Development:** Refining the individual in line with (ECSA, 2003) and engineering standards to foster expert and responsible work.

- **Discipline Specific Development:** Developing specialist applicable knowledge either within systems development and deployment, or in line with specialisation in a particular discipline specific field.

- **Transnet Development:** Preparing the employee in line with the necessities required to undertake work efficiently amidst existing corporate strategic context, organisational structures, general policies & regulations, electrical and depot safety certification as well as aligning knowledge and training towards railway systems.

- **Leadership and Personal Development:** Fostering the growth of the individual with respect to strengthening character, leadership qualities, motivations, and professional behaviour.

The model is presented on the next page and outlines the proposed system spread across 6 month interval "semesters". Extensive detail is excluded from this model to highlight the core aspects only. Although illustrated as four distinct processes, the concurrent execution ensured rapid development of the engineer-in-training's technical, job specific, leadership as well as professional skills. Dedicated sub systems were only developed in line with these themes to bring forth performance parameters for the sole purpose of tracking the individual's progress. Process mapping these tasks into applicable phases was then undertaken to reduce granularity and also to highlight interdependencies relating to timing of certain activities. Individual tasks/outcomes were outlined in functional sub-sets as to generate an adaptable model, stringent enough to ensure certain skills development against key milestones, whilst at the same time not miring the system or employees in rigidity.

From the functional breakdown of the system, 104 tasks of various granularities were synthesised. This presents a considerably complicated resource loading task on how to couple the interdependencies in line with their time allocations. Further refinement of themes and compatibilities proved the most effective method to improve system definition.

The result of the system development is shown in a top down approach in figure 1. Problems with the current model is that it does not cater well for employees coming in at irregular appointment dates, and for employees who have existing work experience or post graduate degrees. However, in line with the adaptable desires of this system model, flexibility

is granted by mentors and line managers to expedite aspects of the program for employees they deem fit in certain areas.

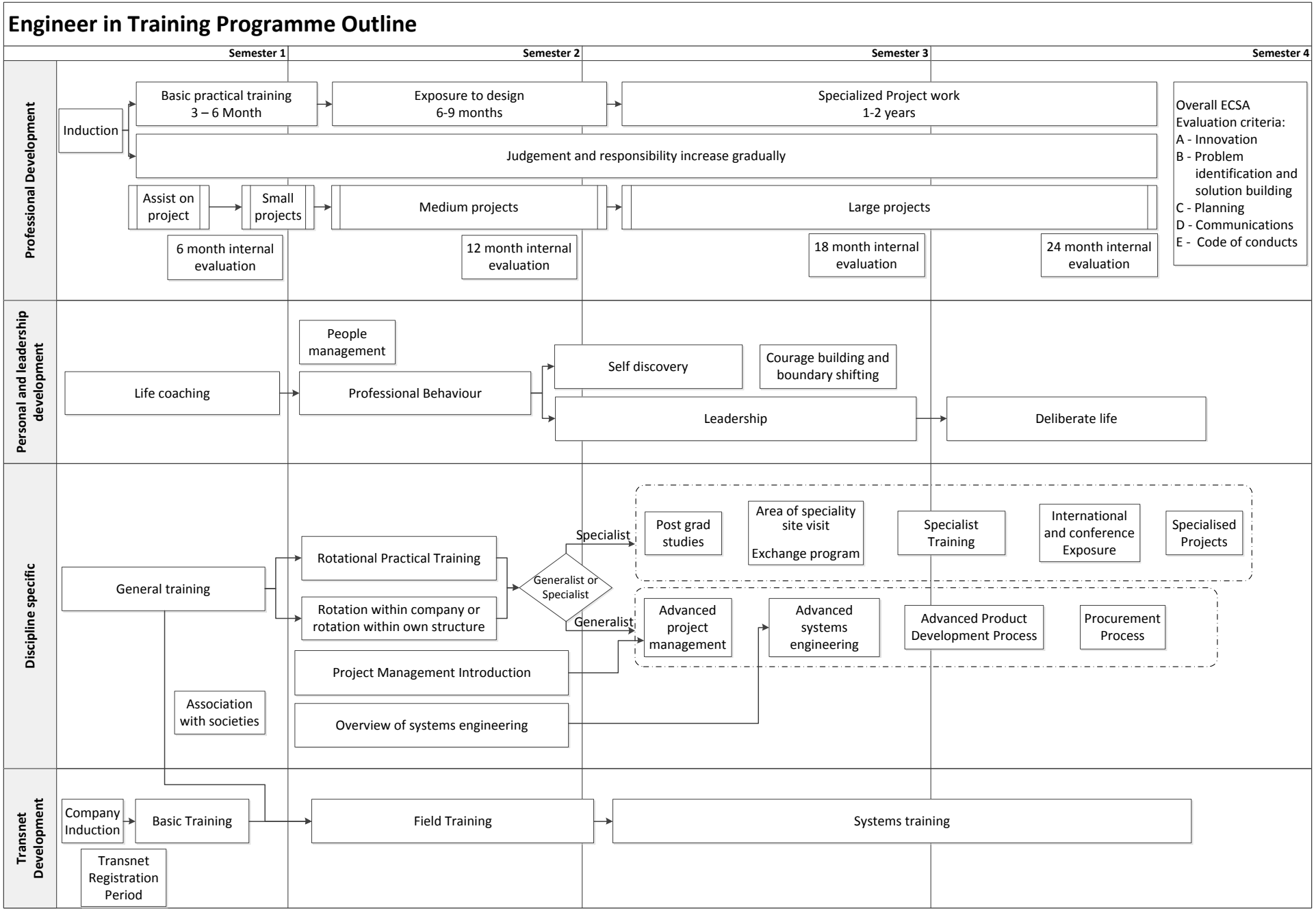

Figure 1: Systems diagram for Transnet Engineering's 2 year Engineer-in-Training program.

Conclusions

Without becoming embroiled in extraneous detail regarding the model or subtasks, a brief overview is presented before to introduce the system and strategy in place within Transnet's new Research and Development training initiative.

Of particular focus is the satisfaction index of employees. Underlying the desire to help develop respectable and moral leaders is the aim to help grow individuals into a purpose driven and motivated lifestyle. Significant resources are allocated for team building activities in conjunction with introspection opportunities. This is to help develop the key qualities, keep individuals motivated and promote the image of Transnet's employment strategies.

It was found during of initial stages of implementation that the majority of new graduates preferred to apply technical skills to engineering tasks immediately, as opposed to gaining soft skills first. Soft-skills were thus shifted later in the program to ensure greater context and appreciation.

The model will invariably be optimised and altered, through iterative incremental improvements focusing on time casting sub tasks. It was found in focus groups that the involvement of new graduates in designing and documenting such a model was beneficial to vision casting and mission, as well as to providing motivation and guidance for their program expectations. The systems engineering approach was found to be the most optimal method to encapsulating the envisioned sub tasks, with extensive timing process mapping undertaken to allocate such tasks.

As Transnet Engineering's Research and Development team embarks on this new initiative, it aims to set a precedence not seen before in Transnet, as it aims to create and retain the future stewards of the Rail Industry. It is envisioned that Transnet be transformed into a world class railway provider through the development of Professional Engineers beyond just technical facets. By imbibing a sense of family, cohesion and pride amongst new Transnet employees, this formulated model aims to sustain the training of graduates for the economic upliftment of Transnet and the South African economy as a whole.

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Biography

Andries Wilken: Andries attained his B.Eng (Electrical) at the University of Pretoria in 1998, whereby he was awarded the ABB Powertech prize for best Project 400 student. An avid learner, he then continued his astounding track record; continuously ranking in the top performers of his M.Eng in group in 2001 as well as MBL group of 2007. His passion for personal and leadership development was sparked in 2001 when he decided to participate in a Christian based GAP year where after he joined Transnet in 2002. His leadership abilities and expertise in embedded control allowed him to be quickly positioned as senior systems engineer in major international locomotive acquisition projects as well as senior developer in world-class locomotive control systems. He is currently the Executive Manager for Transnet Engineering's newly founded Electrical Research division; a team earmarked to take Transnet Engineering to the next level in its lifecycle.

Jonathan Gevers: Jonathan attained his BEng degree at the University of the Pretoria in the field of Electronic Engineering. Having held many teaching assistant and student mentoring roles, part of his passion is the orientation and training of personnel. His interests lie in control systems and holistic system designs. At an undergraduate level he received the Intel South Africa award for best project in Microelectronics for the system design of an integrated energy harvesting device.

Anri Marais: Anri is part of the Research and Development team of Transnet Engineering. She obtained her Industrial Engineering Degree at the University of Stellenbosch specializing in System Dynamic Modelling. Anri participated in a Post Matric gap year before she commenced with her undergraduate studies in which she obtained various outdoor, personal, leadership and business skills. She also enjoys travelling and broadened her world knowledge and insight in cultural interaction during her work vacation in the United States and outreach in Mozambique. She has a passion for the development of systems and impacting people's lives.

Mikail Ansari: Mikail has an MSc in testing Reluctance Synchronous Motors for providing traction in Electric Mine Shuttle Vehicles. He presented this research at the IEEE Conference on Electric Vehicles in Greenville, USA and SAUPEC in Cape Town, South Africa. He now works at the Research and Development division at Transnet Rail Engineering. He has lectured an introductory course on Electric Circuits at the University of the Witwatersrand, tutored students as part of his postgraduate studies and has an interest in the use of novel systems within Education. He also has a BSc from the University of the Witwatersrand, Johannesburg, South Africa and has participated in an Advanced Automotive Design Workshop from Motor City Europe, in Cologne Germany.