Systems Engineering in Transportation Projects
A Library of Case Studies

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Introduction

The Transportation Working Group has recognized that there is a need on the part of practicing systems engineers for a library of case studies of the application (or sometimes the lack of application) of systems engineering to transportation projects in order to learn from the experiences of others and to make a case for investing in systems engineering.

This document contains such a library. This library will grow over time as we add further case studies. We hope that, as it grows, clear themes will emerge which the reader may discern and turn to advantage on their own project, even if it differs in some significant respects from the projects described below.

In this issue, there are five case studies:

1. West Coast Route Modernisation Project in the UK
2. SkyTrain control center upgrade and expansion in Vancouver, Canada
3. Prestwick Air Traffic Control Centre in the UK
4. Docklands Light Railway Expansion in the UK
5. NETLIPSE, a European research project studying large infrastructure projects

This version of the library, prepared for the external web-site, contains only case study number 3 as an example to illustrate the full content. A full version of this document, containing all case studies, is available to INCOSE members on the INCOSE Connect server.

Each case study has been prepared either from authoritative documents in the public domain or by interviewing senior members of the project and checking the written case study with them. However, to ensure objectivity and a degree of harmonization, each case study was written up by a member of the Transportation Working Group who was not involved in the project.

The Transportation Working continues to seek further potential case studies. If you can suggest possible further case studies, or if you have any comments on this library, please contact Bruce Elliott, at bruce.elliott@arbutus-tc.co.uk.

Systems Engineering Case Study #3
NATS Prestwick Air Traffic Control Centre

Keywords: Requirements management; Integration; Verification; Validation; Project Control; Engineering Environment; Risk and Opportunity Management; Configuration Management; Information Management; Systems Analysis.

Background to the Project

NATS, formerly National Air Traffic Services, provides air traffic control (ATC) services to aircraft flying in UK airspace and over the eastern part of the North Atlantic. ATC had been provided through four regional Centres. In the late 1990's, it was decided to consolidate air traffic control into two Centres, with one at Swanwick, Hampshire, and one at Prestwick, Ayrshire. The Prestwick Centre was to incorporate the airspace managed by the Scottish and Manchester Centres. However, due to a falling demand in air travel, the Prestwick Centre Project was not started in earnest until 2007. The new Centre was completed and became fully operational in January 2010.

This case study concerns the design, implementation, test and commissioning, and acceptance of the Prestwick Centre. The Project was managed by NATS, who performed the systems integration task. Contractors were used for specific aspects.

This case study is drawn from an interview carried out in February 2011 with senior members of the engineering team.

Description of the Challenges faced

The major challenges were:

- A challenging and immutable deadline, driven by public commitments made by NATS;
- The need to achieve safety acceptance of the new system by the CAA, the UK regulator;
- Significant personnel issues arising from the need to relocate staff;
- Changes in scope during the project, for example, the incorporation of Oceanic control, which had been scheduled for a later implementation; and
- Uncertainties in costs, for example, the unexpected rise in the cost of some materials and labor.

Description of the SE performed

NATS had mature systems engineering processes but used IEC standard 15288, "Systems and software engineering -- System life cycle processes" as a checklist, to ensure that best SE practices were followed. System engineering practices and tools were employed comprehensively, including: detailed requirements analysis, detailed risk analysis and risk management, configuration management and information management working in tandem with Quality Assurance and Safety Assurance.

The stakeholder requirements were gathered and these comprised mainly strategic requirements of a business nature, for example, the requirement for a 30% system and operations expansion capability.

An ATC System is a system of systems, and so the Centre design began with the examination of the Centre architecture and data flow between the various systems. This was used to develop a logical model of the Centre using the Unified Modeling Language (UML). Business requirements were translated into requirements for both the facilities and the systems. Where possible, existing systems were re-used to reduce the project risks. Analysis of the Centre showed that certain functions were duplicated between the systems that NATS already used, and so by modification to certain systems, others could be eliminated.

A web-based document control system was employed whereby several hundred project documents were managed, and could be uploaded, controlled and accessed remotely. A web-based issues and actions system was also employed.

A requirements management tool was used to identify, allocate and manage system requirements through to verification and validation. Requirements were captured and traced only to the level necessary, for example where a legacy system was used without significant modification, then it was not necessary to go to the level of software requirements.

Testing included functional, overload and failure mode testing. Systems were tested in isolation before being combined into facilities before testing at the level of the Centre as a whole.

Proprietary tools were used for life-cycle modeling and to justify the required spares holding and to manage the configuration management for system parts and spares.

Risk management techniques were employed to identify and to mitigate risks as early as possible in the project, for example by the use of simulator tools to test individual subsystems and interfaces in the development environment.

The manner in which systems engineering processes were implemented took full account of human factors. For example:

- The High Level System Design Document was deliberately kept to within one hundred pages so that it would not only be easy to manage, but also so that it would be read and understood by all team members;
- Simple and regular communication channels between project leaders and team members were put in place;
- Regular meetings with senior management ensured that key decision makers were fully informed and involved throughout the project and could provide assistance where and when necessary; and
- Engineering management provided genuine leadership and ensured that all project decisions were fully informed by engineering considerations.

Outcomes

The project was implemented on time and £9M under budget. The new Prestwick Control Centre became fully operational without any interruption to air traffic control. A senior airline manager rang NATS to inquire when the switchover was due to occur only to be told that it had happened the previous week!

It had been planned to incorporate Oceanic control into the Centre after it had gone live but the project’s progress allowed this to be brought forward so that Oceanic control could be provided from the start.

NATS is now leading the way in Europe’s agreed strategy of concentrating ATC in a small number of large centres.

The logical model allowed the removal of at least three systems from the Centre resulting in significant savings in whole-life costs.

The project drew upon established NATS practices and improved upon them. It has advanced and continues to advance good practice within NATS

- NATS have developed Systems Architecture Development (SAD) processes, using UML, that will be applied to future system projects;
- NATS provides an Engineering Product Design Life-Cycle (EPDL), two-day, in-house training course to all engineers to ensure all engineering staff have a common understanding of the NATS processes and procedures for system projects;
- A lessons learned database has been established, whereby lessons learned can be captured to avoid recurrence of issues on future projects, and ensure best practices are developed and followed;
- Standard templates have been developed to ensure engineering documents follow a consistent and comprehensive approach from one project to another; and
- A "Coaching for Performance" process has been implemented to develop the "soft skills" of all staff involved in such projects.

Conclusion

This project was undertaken in an environment in which failure would have severely impacted operations, with implications of lost revenue and significant inconvenience to the public. Good application of Systems Engineering during initial design adequately identified all the requirements so that NATS, acting as System Integrator, was able to implement the project on time, within budget and to the level of performance required.