The Real-Time Data Company Ltd.

Introduction

This document is an attempt to present a succinct view of the digital lifecycle, also called 'digital thread', that leads to the digital twins required by defence policy e.g. DE&S 2025 Strategy. This is a developing area, particularly for the defence sector. Having a description such as this helps to facilitate discussions about implementation by ensuring that all stakeholders share the same view of the process and its outcomes. Importantly, it also allows differences in understanding to be shared and resolved, particularly with other sectors where the techniques are more mature. This document remains a 'work-in-progress' until it represents the de-facto views of the majority of interested parties. Identified alternative views are described in Appendix A. References to Appendix A are included in the text for anyone wishing to explore the wider aspects.

Scope

The descriptions here apply to all project models including waterfall, iterative, agile etc. The Systems Engineering and Project Management (SEPM) Joint Working Group - INCOSE/APM Guide to Life-cycles and Life-cycle Models issue 1.1 2017 identifies some 15 project models. A Systems Engineer would be able to map the digital thread and digital twin concepts onto each of these models to produce appropriate recognisable 'digital' products, outcomes and benefits.

The descriptions are also applicable to the specialist technical, engineering, quality and management disciplines normally found in commercial and military equipment implementation and support activities.

The Thread/Lifecycle

Requirements stage:- Using high-level executable software models to define requirements, replacing lengthy documents, is being advocated. The models will represent only the item (e.g. equipment) to be produced and will be independent of environment and other models (see Appendix A - **Synthetic Environment**). Scenarios aimed at demonstrating what is required of the new equipment will be prepared. A federation of models and the forthcoming Defence Synthetic Environment will be created to run the scenarios. The models will evolve into physics/mathematically accurate representations, at the early stages they would be more akin to training models being 'visual-only', as used in computer gaming. These are simpler to produce to achieve the main purpose of allowing users, and all other stakeholders, to participate in requirements' validation and so achieve their buy-in to the project.

Evolution during the lifecycle:- The intent is to add detail to the initially validated requirements' model as the project's design and development lifecycle rolls out. A key feature is that, at whatever lifecycle stage the scenarios are run, the same test and evaluation results should be achieved as those produced and validated by the original high-level model. This will make it easier for DE&S Project Managers to monitor project progress and to know if/when to call dstl (Design Authority) back to arbitrate. It is understood that 'the model' may actually be several models – sometimes called an eco-system of models. A typical eco-system would include supply chain information, stock availability, documentation database etc. that would be linked and interdependent using a common parameter database (see Appendix A - **One or more models?**). Many of these being shared between several projects so that re-using 'templates' from previous work becomes viable and highly cost-effective. A large amount of information and data sharing is implicit in this concept and a 'digital backbone' will facilitate these exchanges. The digital backbone is likely to comprise a cloud-based storage system with a complex networking infrastructure and resolving risks of cyber interference is a paramount concern.

Digital Twins:- The development's final testing stage would be part of acceptance before any real-world trials are undertaken – thereby further reducing risks and costs, as well as being more environmentally friendly. Taking it a stage further, a copy of the 'as built' model(s) would be delivered with each equipment. By a popular (but not unique) definition, at that stage, the model becomes a 'digital twin' of the delivered entity (see Appendix A - **When does a DT exist?**).

The digital twin will be used in parallel with the real entity (i.e. subjected to the same operating conditions see Appendix A - **What constitutes 'connected'?**) to assist with support functions, including identifying any need for preventative maintenance. For forthcoming engagement operational purposes, defined by further scenarios, the twin would be federated with other twins in a synthetic environment and the scenarios run, very probably with humans in the loop. In a multi-domain operation, such as required to respond to a civil disaster, the twins from all participating domains (e.g. Fire, Ambulance, Police, Water Supply and other Services) would feature in the scenarios, ideally (but not necessarily) in the same synthetic environment. The National DT Infrastructure would play a key role in such an event.

Feedback & Feedforward:- The introduction of digital twins offers a significant change to the quality and equipment availability delivered by in-Service support, as well as considerable potential improvement in the quality of strategic and tactical planning. A joined-up lifecycle also offers a mechanism to link learning from front-line in-Service usage, back down the supply chain to the design stages, for subsequent updates or to inform related projects. Involvement of users at a very early stage is built-in, so their experience and ideas can be incorporated at cost-effective points in the lifecycle, helping to improve their buy-in to the new project. It also promotes re-use, particularly of model components, even after the original equipment has been retired.

Summary

Balancing the extent of changes needed and the benefits, the digital approach leading to digital twins is thought to beneficial and worth doing. Initially, most benefit may be achieved in the specification, design and development stages, with post-delivery benefits being realised once a significant family of equipment twins have emerged.

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Appendix A Alternative Views

Synthetic Environment

Early entity-modelling included the environment as part of the model. It is more logical to separate the modelling of the environment from that of the entity to be evaluated because this allows the environmental model to be re-used. Some people may wish to retain the environment as part of the entity's modelling.

One or more models?

The complexity of what needs to be modelled will generally require the implementation to comprise several models. For example, a model to meet technical requirements may be supplemented by a physical model, other models may be required to represent environmental conditions (temperature, shock etc.). Failure rate, supply chain and other aspects specific to the entity being modelled and how it will be used can be met by further models. The set of models is sometimes referred to as an 'eco-system of models' and should be linked in order to achieve greatest benefit.

When does a DT exist?

Some would say that a digital twin exists at very early modelling stages if it is intended to be connected to a real entity. Here I have taken the definition that it exists when the model and real entity both exist and are connected, as this seems (to me) to be most intuitive.

What constitutes 'connected'?

Some would say that connection means a near real-time connection so that the model is in close time-step with the real entity. In some cases that is important (e.g. for real-time control and monitoring of the real entity by the model). The connection may be much looser in other cases, with updates over long periods (e.g. to capture fleet maintenance statistics). I have not specified a connected timescale because it does not materially affect high-level definitions.