Defence Fuels Digital Twin

A proof of concept for Defence Fuels Enterprise (DFE)

MooD software

Ministry of Defence

CACI

Introduction

Improving your operations is essential to moving your organisation forward – but associated risks can make it hard to take the leap. Being able to model changes and predict the impact of any decisions provides substantial advantages.

CACI's Digital Twin capability offers just those advantages, with realistic and reliable data that offers a guiding path into the future. Serving as the real-time digital counterpart of any system, it offers a virtual representation of simulated situations. Actual data enables analysis, prediction and action. Decision makers can make improvements in cost and availability, resilience and performance, and compliance and safety.

The Digital Twin draws on our MooD software, a large-scale data visualisation platform that integrates systems to create a single working model for management and planning. Combined with the Digital Twin, it enables modelling of potential solutions, while ensuring all your stakeholders work to the same strategic and operational goals.

CACI's Digital Twin capability provides realistic and reliable data that offers a guiding path into the future

How are Digital Twins being used right now?

A Digital Twin was first practically used by NASA, and is most commonly applied to physical assets/like wind turbines, or a network of assets (such as the pumps and valves that control water distribution). The technology is now being applied to non-physical assets, like business operations, and federated to tackle larger problems, like the control of a 'smart city'.

An extremely flexible piece of technology, Time magazine has predicted that Digital Twins will 'shape the future' of multiple industries, from car manufacturing (including BMW's Regensburg factory) to healthcare (e.g. allowing surgeons to rehearse foetal heart surgery in advance). It's being used to trial responses of automated cars, and the impact of public transport changes across whole cities. In fact, it's hard to think of an area where Digital Twins would fail to provide a benefit.

First used by NASA, 'Time magazine' has predicted that Digital Twins will 'shape the future' of multiple industries

The Defence Fuels Proof of Concept

With such a thought in mind, CACI tested out the application of a Digital Twin design in collaboration with the MOD's Defence Fuels Transformation, focused on fuel movement within an air station. The aims were to understand the past, predict near and test distant future events.

We developed a Proof of Concept (PoC), which was able to define an appropriate architecture, implement a Digital Twin solution, show it can be built using available cloud tech and skills, and demonstrate a low-cost front end. It will provide decision support to numerous roles and enable future automation of decision making.

This PoC proved the ability to generate hundreds of thousands of pounds of savings (per month, per air base) and significant productivity benefits, offering faster, more objective and understandable information.

This Proof of Concept showed that hundreds of thousands of pounds could be saved every month and generate significant productivity benefits by offering faster, more objective and understandable information

Our Proof of Concept

Scoped to allow completion within a reasonable timescale (three months elapsed time), the project focused on fuel movement within an air station.

It identified three use cases of increasing sophistication that would give a broad coverage of the Digital Twin concept:

Understanding what's been happening

Identifying issues to do with efficiency of fuel holdings and asset utilisation.

Predicting the near future

Providing an 'early warning' of upcoming situations that could lead to issues.

Testing further-reaching change

Enabling changes to an air station to be made and tested as though these were happening for real.

The Solution

1. A **Front end** that allows operators to interact with it, to monitor or control what it does. In our PoC, we created a user interface that allows interaction directly with a visualisation of the structural model, including a representation of the decision processes.

2. Create **Structural Models** that act as the central definition for everything else the twin does. For instance, a 'Bill of Materials' of the system to be twinned could be created, laying out all components and connections.

   We used a particular unit, 'Royal Navy, RAF and Army Stations', which supply aviation fuel to aircraft. Our structural model starts with business data about the fuel tanks, vehicles, platforms and fuel at a unit.

3. A **Data Pipeline** that takes data from sensors or business systems. Ideally, every manual procedure, such as a person coming on shift, would be tracked and monitored through an app. Also, every automated procedure, such as transferring fuel, would be managed with the aid of real-time sensors.

   In our PoC, we wanted to show what could be achieved, just using declassified data from the Bulk Fuels Information System (BFIS) regarding fuel movements, and from Future Fuels Management Tool (FFMT) regarding stock holdings. The data pipeline architecture could evolve to accommodate future digitalisation.

*

We used a particular unit, 'Royal Navy, RAF and Army Stations', which supply aviation fuel to aircraft. Our structural model starts with business data about the fuel tanks, vehicles, platforms and fuel at a unit

4 **Predictive Models** that can learn from actual behaviour to predict what might happen next.

4a **Machine learning models for prediction**. We used a small sample of historical data concerning requirements for refuelling vehicles given a certain demand, allowing an 'early warning system' to be created.

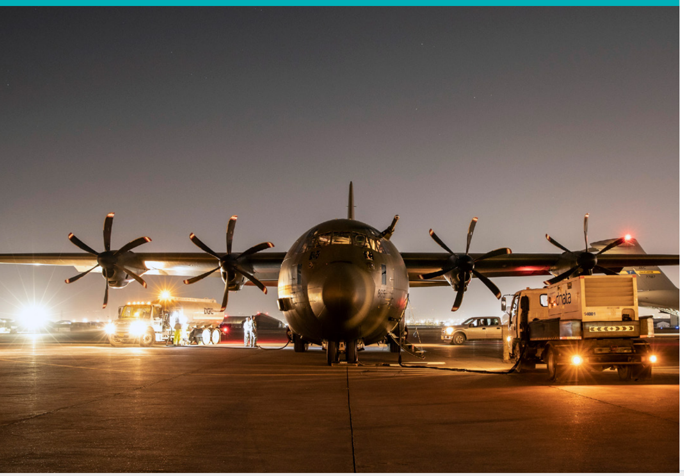
4b **Simulation models for testing the effect of change**. We adapted and integrated an existing Defence Fuels Enterprise simulation model, Fuel Supply Analysis Model (FSAM), to allow the testing of how a unit would operate given changes to the configuration of refuelling vehicles.

*

We used two kinds of predictive models: machine learning for near future and simulation for testing broader changes

Development Process

Our PoC was based on the UK's Digital Twin Hub toolkit, the Gemini Principles of Digital Twin development and CACI's DevSecOps methods



We used following principles:

- Selection of use cases and benefits, following the UK's Digital Twin Hub toolkit
- Proof of Concept follows the Gemini Principles of Digital Twin development
- Engineering follows CACI's DevSecOps methods, using readily available tech and services (MooD, common AWS services, Python toolkits)

The PoC was carried out over three months using Agile sprints. Five roles delivered this Proof of Concept: a Data Engineer, an Architecture and Modelling Engineer, a Business Analyst, a DevOps Engineer and a Cloud Architect. All worked to lightweight Agile processes in CACI's RAPID innovation team.

Should the Digital Twin be delivered, it is particularly important (even more so than with other technology projects) that MOD people play a strong role in ownership, due to its evolving nature and reflection of business structures. Development and on-going support for the Digital Twin should be under the guidance of an engaged set of stakeholders and domain experts.

Use cases

1 Understand what's been happening

Key roles at a fuel station need access to timely and insightful information about the processes at play– be that ordering and receiving fuel before issuing it to platforms, or monitoring and decision processes that manage risk. This first use case indicates how the components of a Digital Twin can come together to provide that information faster, more objectively and in a form that is understandable and challengeable.

Based on the model-based monitoring of assets, processes and data, it might include actual Days of Supply (DOS), or historical scenarios, for instance how the unit responded to changing demand in terms of utilisation of assets.

Through this capability, operators and those in command can view current level of risk and identify anomalies and inefficiencies over time, potentially enabling savings in assets and fuel holdings required. It allows the automation of monitoring processes, identifying anomalies in the volume or timing of fuel being ordered and issued, or in the utilisation of assets such as refuelling vehicles.

A Digital Twin can provide current information faster, more objectively and in a form that is understandable and challengeable

2 Predicting near future

Again, this use case's primary goal is to provide faster, more objective and understandable information to the day-to-day-operators at a unit, and the command functions responsible for many units.

We used machine learning to create an early warning system based on past performance, alerting operators to upcoming issues like shortfall in asset capacity. The unit can use this to objectively manage risks and have greater confidence in capacity.

This use case has taken all the data that is exploited in the first use case, and provided this to a supervised machine learning (ML) algorithm. This uses an artificial neural network to learn the relationship between demand coming into a unit (the input, or parameters), and the response to that demand in terms of the utilisation of refuelling vehicles (the output, or results).

*

We used machine learning to create an early warning system based on past performance, alerting operators to upcoming issues

The resulting predictive model that relates inputs to outputs is then deployed to the Digital Twin front end. Here it can respond to new inputs that it hasn't seen before by giving guidance on what number of refuelling vehicles would be required, given the past behaviour of a unit.

It also takes an expected demand, for the next week, or month, and say whether this falls within the bounds of what the unit can cope with, to allow action to be taken in advance. This offers objective guidance and support to decision making.

It can answer questions such as:

- If demand doubles, does that necessitate doubling refuelling vehicles?
- If fewer aircraft arrive each day, but demand more fuel - how would that affect a response?

This approach opens the door to potentially automate a decision optimisation process. This could also integrate other information, like:

- Demand forecasts
- Maintenance records
- Weather
- Predictions from Digital Twins of refuelling vehicles concerning their likely availability

Additionally, learning can be a continuous process for the ML algorithm, drawing on new data on the success of recent optimisations to continually improve a unit.

*

The resulting predictive model gives guidance on what number of refuelling vehicles are needed.

3 Testing further reaching change

This, the most challenging aspect of a Digital Twin, allows decision makers to test alternative solutions using simulation models calibrated against existing data. Models informed by practical realities enables testing with greater speed and confidence, before committing to change.

The Digital Twin provides insight into how broad structural changes might affect unit performance

This includes:

- Investing in 'just in time' options for supply
- Alternative fuel and energy strategies
- Alternative policies and procedures for fuel movements
- Revised configuration of assets at a unit
- Optimisation of these in conjunction with other units

For this proof of concept, we adapted an existing DFT simulation model, FSAM, to show in principle how a simulation according to the Digital Twin pattern would work. Functions have been coded in a regular programming language to mimic the structural model, and to mimic the kinds of behaviour that is evidenced through the data pipeline. As a result, we are able to make changes to these functions that we can easily understand as corresponding to changes in the real world.

This use case allows experimentation concerning not just new situations, as with the second use case, but with different ways of organising a unit, or collection of units. We specifically focused on the configuration of the refuelling vehicle fleet and how that would impact operations. However, myriad different questions could be answered through this capability, depending on what aspects of the model are changed.

Decision makers can rapidly and confidently test alternative solutions using simulation models calibrated against existing data

Results

We were able to demonstrate benefit around all three use cases and how they supported the human decision maker. We implemented a technical architecture for a Digital Twin design pattern appropriate for the Defence Fuels enterprise, along with a process for development and sustainment.

The project had a number of achievements:

- It defined the architecture of a 'Digital Twin of the enterprise' appropriate for the Defence Fuels enterprise
- It implemented a Digital Twin solution to give a 'simplest possible' example for each of these use cases
- It showed that such a solution could be built using cloud technologies and skills readily available to MOD, based on models, data pipelines, machine learning and simulation
- It demonstrated a low-cost front end that provides decision support to a number of roles, and in principle provides an onward path to greater automation of decision processes

Contact us

For more information on our digital twin capabilities, our MooD software, or our other services, please contact our expert team today.

LinkedIn:

showcase/caci-information-intelligence-group

Website:

caci.co.uk/national-security-defence