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Engineering Simulation Maturity Assessment: An Introduction

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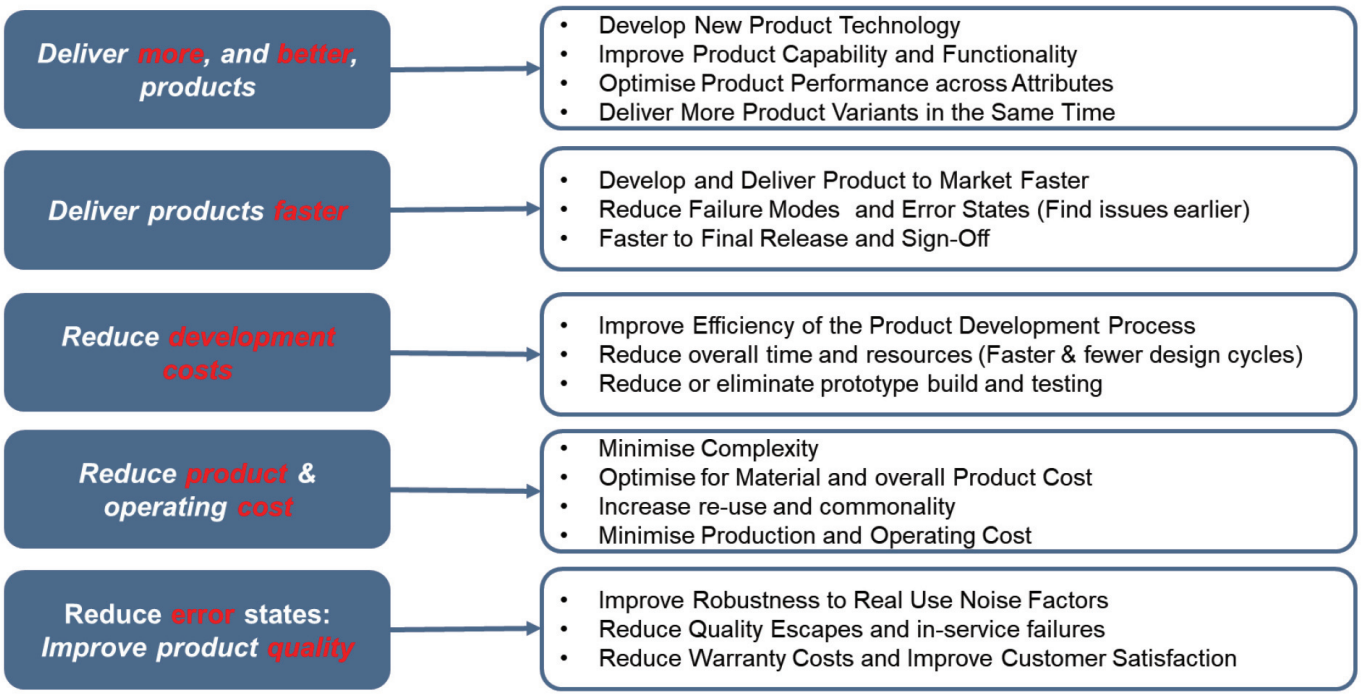
Performance data from engineering simulation enables engineers to develop, refine, optimise, and deliver their products. Organisations must be able to trust their simulation results to make critical engineering decisions about their designs. Engineering simulation is also an essential part of the business to improve the speed, efficiency, quality, and reliability of the overall product development and delivery process.

We can break down the goals organisations often have for their engineering simulation into five categories:



Organisations need capable, effective, fast, efficient and reliable engineering simulation to achieve these goals. This is even more important as organisations consider how to benefit from the latest techniques offered by artificial intelligence (AI) and machine learning (ML), as engineering simulation is a crucial source of reliable physics-based data necessary to train their AI/ML models.

However, achieving capable, effective, and efficient simulation is not trivial. Typical questions that business leadership may ask about the organisation's engineering simulation capability are;

- Is our simulation capability operating effectively, efficiently and reliably?
- Why does it take so long to get results, and can I even trust those results?
- Why can't we address more of our requirements and use cases with simulation?
- Can I eliminate the testing of physical prototypes?
- Why didn't simulation predict this quality problem?
- Where are our capability gaps, and what do we need to do to close them?
- Engineering simulation is expensive- what value and benefit does it deliver?
- Where should we prioritise investment?
- What do we need to do to benefit from the use of AI/ML in engineering?

An engineering simulation maturity assessment can help answer these questions.

What Is a Maturity Assessment?

A maturity assessment is a structured evaluation that measures an organisation's capabilities and processes against predefined criteria. It helps identify strengths, weaknesses, and areas for improvement across various business functions.

The key points from this definition are that;

- It is *structured* and follows a comprehensive framework
- It is an *evaluation* of an organisation's *capabilities* against predefined *criteria*
- It helps identify *strengths* as well as *weaknesses*
- It enables the identification and prioritisation of appropriate improvement actions.

The Core Components of Engineering Simulation

Engineering Simulation is like a complex machine made up of many components. At the highest level, we can place these in 7 categories:

CORE COMPONENTS	DESCRIPTION
PROCESS	***Efficient*** processes that define the simulation workflows and ***aligned*** to the overall development processes.
METHODS	***Capable*** and ***effective*** methods to define how to model the specific physics required to deliver the product requirements.
TOOLS	***Capable*** and ***connected*** tools to model the correct physics accurately.
MODELS	***Representative*** and ***accurate*** models that reflect the latest design intent
DATA	***Appropriate*** and ***reliable*** technical data to define material properties, technical specifications, modelling parameters, and use cases.
PEOPLE & ORGANISATION	***Skilled*** and ***experienced*** people with product knowledge and experience of the tools and methods, organised effectively to maximise collaboration and efficiency.
COMPUTE INFRASTRUCTURE	***Sufficient, reliable*** and ***flexible*** computing infrastructure and resources to execute the complex and large scale simulations.

These components make up the overall system, and each one must work at the optimum level and in harmony with the other elements to achieve capable, effective, efficient and reliable simulation. Indeed, a weakness in any of the components will affect overall performance.

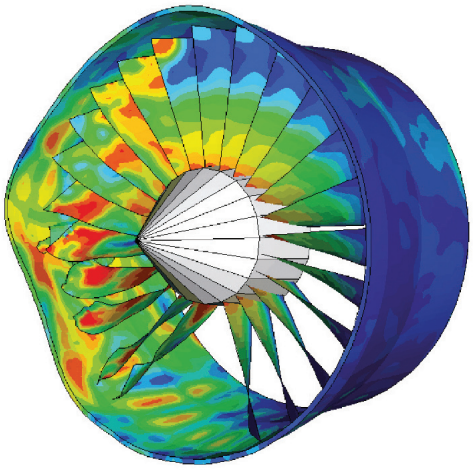
Starting with their goals — the product physics, the specific requirements, and the use cases they need to deliver — organisations must evaluate what is required from each component and how these need to work together. Next, they need to assess the current status of each component and identify areas of strength and where improvement is required. This is best achieved through a structured and comprehensive evaluation of the whole simulation capability using an established framework.

Different Types of Maturity Assessment

Over the years, organisations have developed different frameworks to assess the maturity of their engineering simulation. Many of these frameworks have been necessary where accuracy and trust in simulation results is critical, for example, where it is impossible, dangerous, or costly to verify solutions via physical test.

'Use Case Specific' Maturity Assessment

For aerospace applications, NASA developed the 'Credibility Assessment Scale '(CAS) [1]. In the Nuclear Industry, Sandia Labs developed the 'Predictive Capability Maturity Model' (PCMM) [2]. Jean-Francois Imbert and William L. Oberkampf created a survey and comparison of modelling and simulation (M&S) maturity assessment frameworks published by NAFEMS [3]. These are examples of *'Use Case Specific'* maturity assessments. The metrics obtained are for a specific product, requirement, and use case and are supported by rigorous verification and validation processes [4].



Use

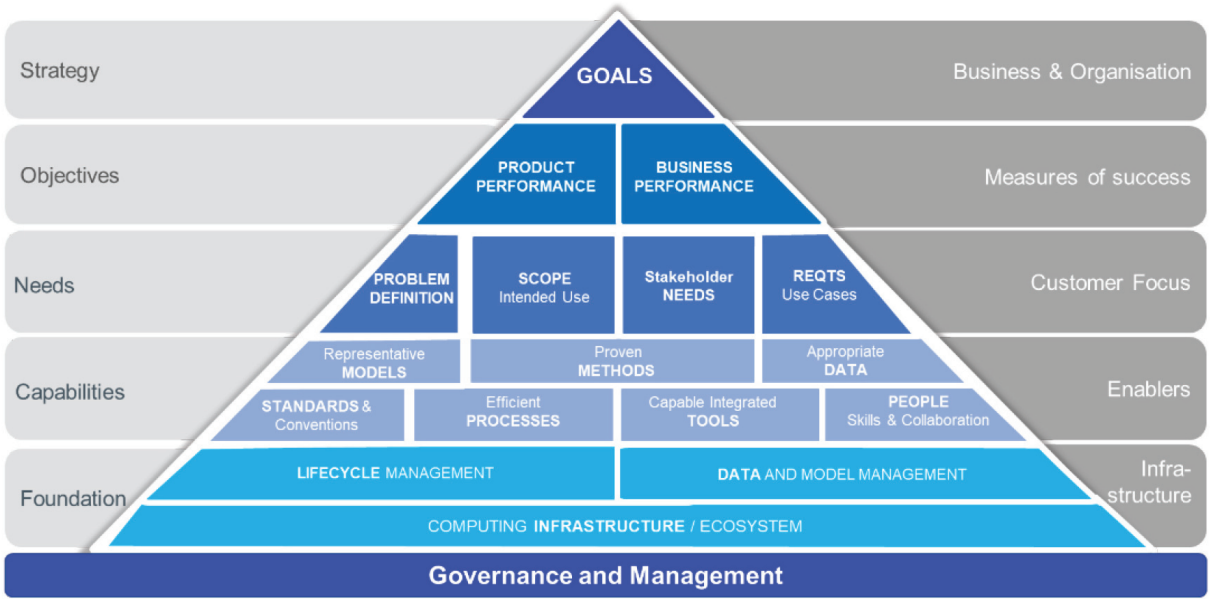
Case

Use Case Specific Maturity Assessment versus Organisation-wide Maturity Assessment

Organisation-wide Maturity Assessment

Organisations need a framework that addresses all of the core components to evaluate the overall capability, effectiveness, efficiency, and reliability of their engineering simulation. The Organisation Simulation Capability Maturity (OSCM) framework was created specifically to do this [5]. This framework enables organisations to identify appropriate improvement actions, create a roadmap, and provide a foundation for building a simulation strategy.

The choice of assessment– use-case specific and/or overall organisation capability– depends on organisational goals, requirements and circumstances.



The Engineering Simulation Strategy Framework.

The Organisation Simulation Capability Maturity Framework and Process

Critical Component	0	1	2	3	4
PROCESS	Insufficient Poor Confidence Limited Coverage (<25%) Ad-hoc No Plan No KPI	Needs Reviewed Low Confidence Partial Coverage (25-50%) Partially Applied Actions Identified Improvement Started	Comprehensive Medium Confidence Good Coverage (50-75%) Fully Applied Improvement Plan In progress - On track Established/Aligned	Embedded High Confidence High Coverage (75-90%) Fully Implemented KPI Monitored Actions Complete Goals Achieved	Systemic/Innovator Certification Level Full Coverage (90-100%) Maintained Continuously Improved Governed Futured
METHODS					
TOOLS					
MODELS					
DATA					
PEOPLE & ORGANISATION					
COMPUTE INFRASTRUCTURE					

The Organisation Simulation Capability Maturity (OSCM) metric.

The OSCM framework considers each core component and rates the organisation's performance using a rating scale of 0 (lowest) to 4 (highest).

To establish a rating, 10 key performance criteria for each component, derived from industry experience and best practice, are reviewed and assessed.

Before starting, key stakeholders who understand the organisation, the product, the requirements, and all aspects of the engineering simulation capabilities must be identified.

The assessment process then commences by asking the stakeholders to complete a questionnaire and provide supporting example documents and key metrics covering each component criteria, following a defined high-level workflow.

Questionnaire

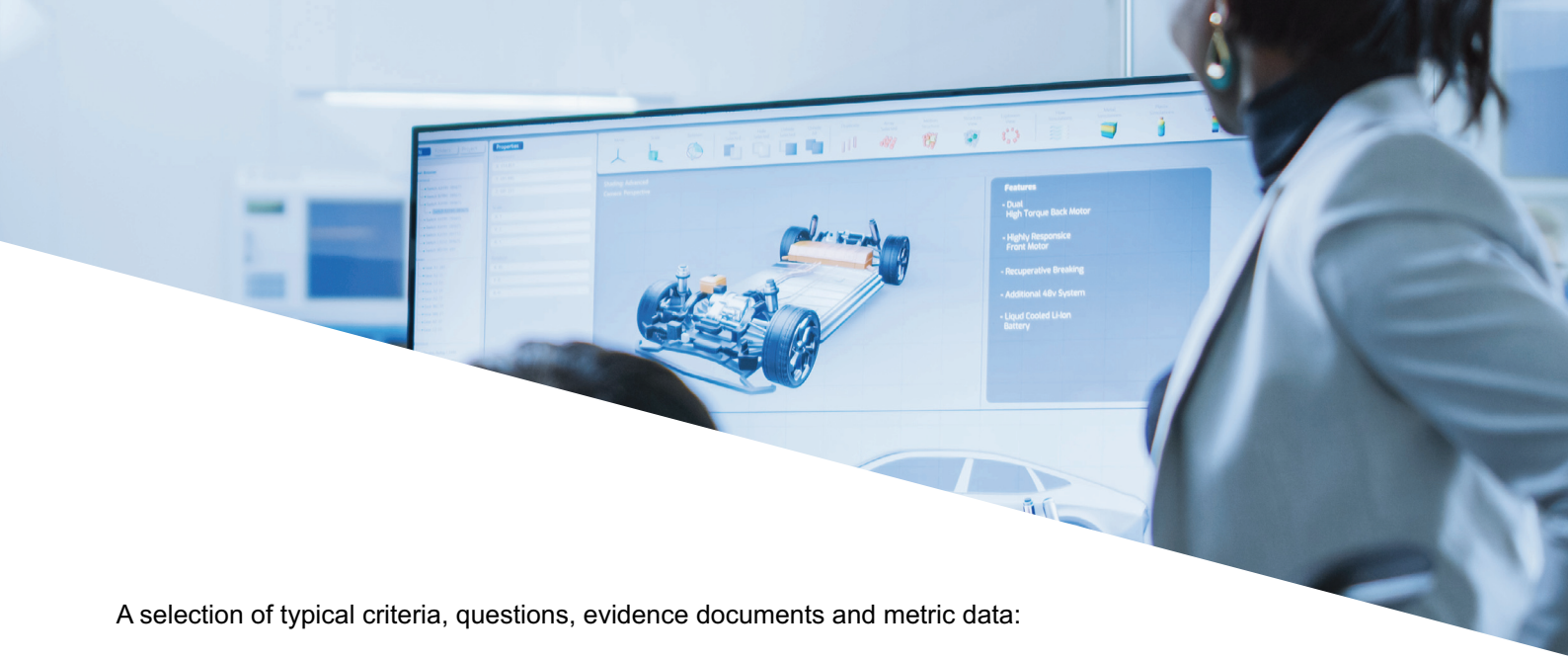
Sample Documents, Data and Metrics

Discussion Follow-up

Review and Assessment

Improvement Opportunities

High-level workflow for conducting a simulation maturity assessment.



A selection of typical criteria, questions, evidence documents and metric data:

Core Componnets	Criteria	Question	Documentation Evidence / Examples	KPI Metric
Process	Process Efficiency	Has M&S process efficiency been reviewed (e.g. VSM)? Has waste been identified & improvements been actioned?	Example efficiency review Example improvement actions taken	% Processes with Efficiency Measure % Achieve Efficiency Target
Methods	Method Confidence	Is a common objective Confidence Metric Used consistently? Does Method Confidence achieve target? Are simulation results presented with confidence interval?	Definition of Confidence Rating Metric Examples Confidence Assessment Example of Results with Confidence	% Methods with Confidence Rating % Methods at target confidence level
Tools	Verification Process	Is there an established and routinely applied process for tool verification and maintenance, with targets? Are routine test cases routinely used to verify tool updates?	Tool Verification process document Examples of tool verification. Example of tool maintenance	% Tools verified % Achieve target %Maintained on schedule
Models	Model Quality	How is model quality (representativeness/fidelity) defined, measured, checked, managed for the different models?	Model quality, fidelity, accuracy definitions	%Quality Defined %Checked %@Target
Data	Sourcing Applicability Pedigree	Are appropriate data sources clearly identified? Are data pedigree and applicability ensured? How is this recorded?	Data Sourcing Process and register. Applicability and pedigree checking process and examples	%Artifacts with defined source %Pedigree verified %Applicability verified
People and Organisation	M&S Organisation	Is there a consistent considered approach to organise M&S effectively: (e.g. centralised, integrated, matrixed, outsourced). What approach is used to ensure collaboration and sharing across the teams	Organisation approach definition Organisation Structure examples	Defined (Y/N) %Implemented
Computing Infrastructure	Compute Performance	Are compute resources configured and optimised for simulation? Does compute performamce meet reqts, including demand peaks?	Example of configuration and optimisation tailored to specific simulation application.	Job run time %Run time meets target

Extract of OSCM criteria questions, evidence requests and key metrics.

Once the questionnaires and document pack are complete, the assessment project leader holds discussions with the stakeholders to address any queries prompted by the information gathered. The project leader then assesses the organisation's status for each criterion to identify existing strengths, weaknesses, and gaps, enabling the team to establish appropriate improvement actions.

How Do Organisations Use Maturity Assessment Results?

Core Components	0 Insufficient Ad-hoc	1 Low Confidence Partially Applied	2 Medium Confidence Improvement Plan	3 High Confidence Actions Complete	4 Certification Level Continuously Improved
Process					
Methods					
Tools					
Models					
Data					
People and Organisation					
Computing Infrastructure					

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OSCM Metric Assessment results table- just one example of how assessment results can be recorded. The assessment results can be recorded in many ways. Here, the assessment results are shown against each core element's agreed target (based on goals and requirements). The metric will thus highlight strengths and the size of any gaps.

Improvement actions can be prioritised based on the scale, importance of gaps, and alignment with the organisation's goals.

Core Components	Opportunity Action	How	Benefit
Process	Conduct efficiency review. Identify critical path processes Identify bottlenecks. Implement improvement roadmap.	Review Value Add / Non-Value Add Tasks	Cycle Time (Speed) Resource Efficiency
Methods	Identify and implement an objective confidence metric	Agree a common metric. Establish assessment process	Quantify method availability, reliability, accuracy
	Assess Methods. Identify gaps and confidence shortfalls. Identify and prioritise improvement actions. Build a roadmap	Implement confidence metric. Quantify status v target	Improve coverage and confidence. Accelerate design, optimise
Tools	Survey tool requirements across organisation. Review performance status and identify improvement actions.	Community to review methods. Identify physics required and assess status	Identify and address capability shortfalls and toolchain issues.
	Review toolchains across all teams and workflows. Identify tool to tool interface inefficiencies and quality risks. Identify actions.	Map toolchains. Review interfaces. Identify issues and actions.	Reduce design cycle time. Improve efficiency & reliability
Models	Establish model requirements and build a plan per project and requirement	Establish modelling requirements Create a build plan Implement change mngmt	Ensure right model at right time. Maximise Sharing
Data	Implement Simulation Data Management	Catalogue data requirements. Introduce SDM. Agree data owners	Ensure right data, at right maturity at right time. Maximise process efficiency.
	Introduce a Data Maturity Metric	Implement appropriate metric. Establish process and ownership	Reduce errors from poor data Improve decision confidence
People & Organisation	Build collaborative community Review critical skills and optimum capacity v future requirements.	Identify stakeholders and experts. Build common interest groups Review skill requirements / method.	Maximise knowledge sharing. Align on best practice sol'ns Maximise skills * capacity
Compute Infrastructure	Conduct review of compute infrastructure needs and performance. Implement demand & capacity planning and futuring.	Review needs and status. Monitor key KPIs Implement capacity planning	Optimise performance Optimise investment efficiency

Example improvement actions.

Benefits of a Maturity Assessment

The benefits of conducting an engineering simulation maturity assessment are broad and varied. Specific examples include the opportunity to :

- Optimise capability to deliver requirements and achieve business goals
- Provide a metric to quantify the current status of the core M&S elements
- Assess your organisation against key performance criteria
- Identify strengths, constraints, weaknesses, and opportunities affecting your M&S
- Target and prioritise investment and improvement actions and projects
- Build confidence in and grow your M&S capability
- Maximise team collaboration and best practice sharing
- Improve product development efficiency and speed
- Reduce development, tool, operations and product costs
- Prepare for changing future needs: product, technologies, and organisation
- Ensure readiness for new techniques, such as Data Analytics / Machine Learning / AI
- Measure impact and monitor implementation progress

Getting Started

The following are some practical steps to get started:

- Identify your goals and requirements
- Identify a champion to support the initiative
- Identify, engage, and organise your stakeholders
- Identify a project leader
- Identify who will be responsible for conducting the assessment

Who Should Conduct a Maturity Assessment?

Key factors to consider when deciding who should lead and conduct a maturity assessment project for an organisation include;

- Independence from vendors and neutrality to any internal interests
- Knowledge and experience of:
  - Product engineering and project delivery
  - Engineering simulation, strategy and leadership
  - Business and organisation
  - Delivering improvement initiatives
  - Communicating with business leadership

It is also important to consider whether or not the organisation has the time and motivation to provide dedicated focus to delivering the assessment in a containable timescale.

Conclusion

Engineering simulation is a critical capability in many organisations; at this technological juncture, it is becoming more important than ever. Organisations need effective, efficient and reliable simulation, but achieving this is complex and depends on the optimal, harmonious performance of all key components.

Organisations seeking to optimise their performance in this area must conduct a comprehensive assessment to identify their strengths and weaknesses, enabling them to prioritise improvement opportunities. The Organisation Simulation Capability Maturity framework was explicitly created for this [7].

Find out more about the NAFEMS Simulation Maturity Assessment service at:
nafe.ms/mas

References

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[4] NAFEMS Analysis Management Working Group (16 May 2014). *What is Verification and Validation?* A joint NAFEMS and ASME publication. [online] Available at: https://www.nafems.org/publications/resource_center/wt09/

[5] A. D. Richardson. (2022). *Organisation Simulation Capability Maturity Assessment* [online]. Available at: https://www.phronesim.com/maturity-assessment

About the Author

Andy Richardson is Founder and Director at PHRONESIM Ltd, a company providing independent advice to companies worldwide to help them maximise the efficiency and effectiveness of their engineering simulation. He is a Chartered Engineer and Fellow of the Institution of Mechanical Engineers. He has 30 years' experience at Jaguar Land Rover with 20 years in engineering senior management roles, including 10 years as Head of Simulation.

Andy also spent 2 years as Senior Manager for Airframe Methods and Tools at Airbus.

Andy delivers the NAFEMS eLearning course 'How to Implement a Simulation Strategy'. He is a member of the NAFEMS UK Steering Committee, Assess Business Theme, and Simulation Governance and Management Working Group.

Andy holds a BSc in Engineering (Coventry University), an MSc in Numerical Modelling (Aston University) and an MBA (Warwick University Business School).

If you would like to learn more about the Simulation Maturity Assessment, visit nafe.ms/maturity

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