

RA 5812 – Digital Models and Simulations Supporting Airworthiness-Related Decision-Making

Rationale

Modelling and Simulation (M&S) utilizes models, be they mathematical or logical representation of a system, entity, phenomenon or process, as a basis for simulations to develop data utilized for technical decision-making. Failure to appropriately assess the suitability of the M&S utilized may compromise Air System Airworthiness. It is to be demonstrated that the M&S utilized in support of Airworthiness-related decision-making (which include decisions on whether design requirements are met) have been derived from a credible source and are appropriate for their intended use.

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Regulation 5812(1)

Development and Assurance of Modelling and Simulation

5812(1) The Type Airworthiness Authority (TAA)¹ **shall** ensure that the development and Assurance of M&S used to support Airworthiness-related decision-making is appropriate for their intended use.

Acceptable Means of Compliance 5812(1)

Development and Assurance of Modelling and Simulation

1. To establish appropriate levels of development and Assurance of M&S, the TAA **should** assess the M&S Criticality based on the M&S level of influence and the consequence of Airworthiness-related decisions based on the M&S outputs.
2. Aligned to the 'Level' of M&S Criticality established, the TAA **should**:
 - a. Select recognized standard(s) / specification(s) to be used for development and Assurance of M&S and determine the applicability of their requirements.
 - b. Identify any additional Assurance and safety arguments that are required to mitigate the consequences of Airworthiness-related decision-making based on the M&S outputs.
3. The standard(s) / specification(s) to be used for development and Assurance of M&S **should** be based on the application to which the M&S is being applied.

Guidance Material 5812(1)

Development and Assurance of Modelling and Simulation

Background

4. As it is becoming increasingly viable to produce M&S that can provide sufficiently accurate information for Airworthiness-related decision-making, there is a desire to exploit the time and cost benefits (beyond traditional physical testing) they can offer. However, all M&S are abstractions and as such introduce uncertainty into the information they provide to the decision-maker. This RA provides the Regulations and non-exhaustive guidance on activities required to understand and communicate the Risk associated with the uncertainty such that informed decisions can be made.

¹ Where the Air System is ►not UK MOD-owned, Type Airworthiness (TAw) management◄ regulatory responsibility by either the TAA or Type Airworthiness Manager (TAM) needs to be agreed within the Sponsor's approved model ►◄; refer to RA 1162 – Air Safety Governance Arrangements for Civilian Operated (Development) and (In-Service) Air Systems or refer to RA 1163 – Air Safety Governance Arrangements for Special Case Flying Air Systems. Dependant on the agreed delegation of TAw responsibilities TAM may be read in place of TAA as appropriate throughout this RA.

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M&S Criticality

5. Similar to Safety Risk (which is a product of likelihood and consequence of failure), M&S Risk is determined as a product of the level of influence and the consequence of Airworthiness-related decisions based on the M&S outputs (ie the consequence of an incorrect decision being made). The 'Level' of M&S Criticality is a measure of this M&S Risk.

6. Level of Influence. M&S level of influence estimates the degree to which M&S results impact the Airworthiness-related decision under consideration. This is predicated on the amount and quality of other (non-M&S) information available and how it was to be used to support the impending decision. It is recognized that a M&S may initially have been designed for a low (negligible or minor) impact on Airworthiness-related decisions and then be proposed for a higher level of influence (moderate or significant). Although this approach is typically very challenging and, therefore not recommended, historical assurance evidence may offer a suitable alternative to reverse engineering model development. Where the final level of influence is unknown at the beginning of a programme, it is prudent to develop a strategy that includes routes to higher levels.

7. Consequence. Consequence classifications assess the impact of a M&S-influenced decision on Airworthiness (or Air Safety). It is recommended that the consequence categories (of Airworthiness-related decisions) are aligned with the severity categories in the Defence Aviation Hazard Risk Matrix (HRM)², or Defence Contractor Flying Organization equivalents as appropriate.

8. An example of developing an appropriate M&S Criticality Matrix is provided at Annex A. This example is not the only acceptable means of establishing model criticality; other standards / specifications may be used with suitable evidence supporting their appropriate adaptation (where required).

Selection of Recognized Standard(s) / Specification(s)

9. There are limited application-specific standards / specifications relating to M&S available and the level of confidence that can be drawn from their use is variable. It is therefore necessary for the TAA to be confident that the chosen standard(s) / specification(s) will provide appropriate levels of development and Assurance. Where this is not possible, it may be necessary to propose a combination of standard(s) / specification(s) underpinned by processes and historical assurance data. Further guidance is as follows:

a. For software related M&S, the safety-related Programmable Elements approach defined in Defence Standard 00-970³ is applicable (ie the application of RTCA DO-330).

b. For non-software related M&S, where application specific standards are available, the following list details the minimum expected constituent components of appropriate standard(s) / specification(s). Depending on model criticality, tailoring of these minimum requirements may be permitted, see Annex A for a worked example.

- (1) Data and M&S input Verification, Validation and pedigree.
- (2) A mechanism for measuring compliance.
- (3) Verification and Validation for specific M&S.
- (4) Uncertainty characterization.
- (5) Sensitivity analysis.
- (6) Competence.
- (7) Methods for analysing and interpreting M&S results.
- (8) Change management processes.

² Refer to RA 1210 – Ownership and Management of Operating Risk (Risk to Life), Annex A – ADH Ownership, Referral and Defence Aviation Hazard Risk Matrix.

³ Refer to Defence Standard 00-970 - Certification Specifications for Service Aircraft.

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- (9) Processes for reporting results.
- (10) Best practices for user interface design.

c. Where no application specific M&S standard is available, or such a standard alone is deemed to be insufficient, a combination of standards, specifications, processes and historical Assurance evidence may be utilized to establish the minimum expected constituent components detailed above.

**Regulation
5812(2)**

Use of Modelling and Simulation to Claim Credit for Certification Evidence

5812(2) Where M&S outputs are intended to claim credit for Certification evidence, the TAA **shall** demonstrate to the MAA that development and Assurance of M&S is appropriate and present associated evidence at the relevant Phases of the Military Air System Certification Process (MACP)⁴.

**Acceptable
Means of
Compliance
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Use of Modelling and Simulation to Claim Credit for Certification Evidence

10. Where M&S outputs are intended to claim credit for Certification evidence, the TAA **should**:

- a. Include the general strategy for the development and Assurance of M&S in the Certification Strategy produced to support completion of the MACP.
- b. Produce Military Certification Review Items (MCRI) for each M&S (or group of M&S where the same approach is adopted) to demonstrate that appropriate levels of development and Assurance have been established and outline the manner of delivery.
- c. Ensure that the use of M&S outputs are clearly identified as a Means of Compliance (MC) in the Certification Programme (CP) proposed to the MAA at Phase 3 of the MACP and identify documents / evidence used to demonstrate M&S Assurance claims are included in the CP.
- d. Ensure that documents / evidence to demonstrate M&S Assurance claims are included in the Type Certification Exposition (TCE) submitted to the MAA to support compliance with the Type Certification Basis (TCB) at Phase 4 of the MACP.
- e. Where Certification evidence includes claims against ongoing M&S performance, such as where the M&S are Digital Twins (eg in a Health and Usage Monitoring System), it **should** include details of planning for ongoing model Assurance.

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Use of Modelling and Simulation to Claim Credit for Certification Evidence

MAA Review of M&S Development and Assurance.

11. Agreeing an MCRI with the MAA provides an independent review of the proposed approach, offering the Applicant confidence that the arrangements for M&S development and Assurance are appropriate for the intended use. This supports efficient progress through later stages of the MACP, removing Risk that Certification evidence will be rejected by the MAA on the basis that the development and Assurance of the M&S has not been demonstrated as appropriate. It also allows the TAA and MAA to develop an understanding of the level of uncertainty and hence Risk that may be introduced to decision-making by the M&S; this is key to ensuring that suitable mitigations are introduced through the MACP.

⁴ Refer to the Manual of Military Air System Certification (MMAC).

ANNEX A
M&S CRITICALITY

1. The purpose of assessing M&S Criticality is to support the appropriate development and Assurance activities so that M&S can be shown to deliver an equivalent level of confidence to the Assurance activity that is being eliminated, reduced or automated.
2. M&S standards / specifications generally permit a modulation of development and Assurance efforts based on M&S Criticality. M&S standards may not align with the severity categories in the Defence Aviation HRM. The following example shows how such an alignment may be achieved to underpin use of an existing M&S standard (NASA-STD-7009A⁵) to deliver AMC for this Regulation.
3. From the Risk table provided in NASA-STD-7009A Appendix D, a preliminary M&S Criticality Matrix has been developed at Table 1. The lowest NASA-STD-7009A decision consequence (Negligible) has been removed to align with the severity categories in the Defence Aviation HRM. The preliminary matrix adopts 3 x 'Levels' of M&S Criticality, based on the Red, Yellow and Green categories detailed in NASA-STD-7009A:
 - a. Red: The full set of requirements in the selected standard(s) / specification(s) must be applied. Equivalent to NASA-STD-7009A Red (R).
 - b. Yellow: Tailoring of the requirements from the selected standard(s) / specification(s) is permitted. Where M&S outputs are intended to claim credit for Certification evidence, the MAA must agree to the proposed tailoring via an MCRI (as required by AMC 5812(2)). Equivalent to NASA-STD-7009A Yellow (Y).
 - c. Green: Application of requirements from the selected standard(s) / specification(s) is discretionary and does not require MAA agreement. Equivalent to NASA-STD-7009A Green (G).
4. The M&S 'Level of Influence' on the vertical axis is aligned to NASA-STD-7009A 'M&S Results Influence'⁶. This makes sense in the context of M&S for design or Certification but may not for other applications of M&S, for example where the M&S is used to support software development. In such cases, the M&S would most likely fall under established RTCA DO-330 processes (as per RTCA DO-178C).

Table 1. Preliminary M&S Criticality Matrix (aligned to NASA-STD-7009A).

M&S Level of Influence	Controlling				
	Significant				
	Moderate				
	Minor				
	Negligible				
		Minor	Moderate	Significant	Catastrophic
		NASA-Std-7009A Decision Consequence			

5. Whilst it is credible to align the M&S Level of Influence with the descriptions of M&S results influence taken from NASA-STD-7009A, Appendix D, Table 2, it is also important to reconcile the 'decision consequences' from the definitions at NASA-STD-7009A Appendix D, Table 1 with the meaning of terms in the severity categories in the Defence Aviation HRM. A summary comparison between NASA-STD-7009A Decision Consequences and Defence Aviation HRM is provided at Table 2.

⁵ Refer to NASA-STD-7009A – Standard for Models and Simulations.

⁶ Refer to NASA-STD-7009A, Appendix D.3 for more guidance on M&S Results Influence.

Table 2. Comparison of MAA² and NASA Consequence Classes

MAA Class	Catastrophic	Critical	Major	Minor
Consequence	3+ fatalities engaged in the activity in question or a single fatality of a member of the public.	1 or 2 fatalities. A large number of specified injuries will also be included in this category	Specified or large number of reportable injuries	Reportable injuries
NASA Class	Catastrophic	Significant	Moderate	Minor
Consequence	Permanent disability or death	Severe injury or occupational illness	Minor injury or occupational illness	Minor detriment (first aid)

6. Based on this comparison, use of the NASA Decision Consequence will not deliver alignment with the severity categories in the Defence Aviation HRM. Table 3 provides a proposed update to the M&S Criticality Matrix with Risk levels 'left shifted' to account for variance in the consequence classes. This delivers higher M&S Criticality levels than originally proposed (for each severity category) and forces a new M&S Criticality Level (marked in blue) to be introduced at the top end of the scale⁷. It is necessary that additional development and Assurance measures are applied in 'Level A' to account for the fact that failure of the M&S could lead to increased consequences and the revised requirements become:

- a. 'Level A'. The full set of requirements in the selected standard(s) / specification(s) must be applied and Safety arguments developed to demonstrate that Risks associated with increased consequences of failure have been mitigated.
- b. 'Level B' to 'Level D'. As per Paragraph 3 (above), levels 'Red' through to 'Green' respectively.

Table 3. Proposed M&S Criticality Matrix (aligned to Defence Aviation HRM Severity Categories).

M&S Level of Influence	Controlling	B	B	A	A
	Significant	C	B	B	A
	Moderate	C	C	B	B
	Minor	D	C	C	B
	Negligible	D	D	C	C
		Minor	Major	Critical	Catastrophic
		Defence Aviation HRM Decision Consequence			

7. It is not within the scope of this Annex to propose what the additional Assurance activities might be required for 'Level A' M&S Criticality; these would be proposed via an MCRI (as required by AMC RA 5812(2)). However, examples might include:

- a. Specific benchmarks of acceptable uncertainty.
- b. The application of Data Safety standards.
- c. Where surrogate or reduced order models are used to reduce computational cost, demonstration that is possible to reconstruct (to a reasonable level of accuracy) the original model from the decompositions produced.

8. It will be noted this this is not the only acceptable route to delivering AMC; other standard(s) / specification(s) may be used with suitable evidence supporting their appropriate adaptation (where required) forming part of the AMC.

⁷ For consistency with DO-330 we also now label the levels as 'Level D' through to 'Level A'.

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