



Air Traffic Safety  
Oversight Service

**SOC**

Safety Oversight Circular

U.S. Department  
of Transportation  
**Federal Aviation  
Administration**

**SOC:** 07-05A

**DATE:** Feb 14, 2013

**Subject: Guidance on Safety Risk Modeling and Simulation of Hazards and Mitigations**

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**1. Purpose:** To clarify expectations concerning Modeling and Simulation (M&S) studies submitted with safety risk management documents (SRMD).

**2. Audience:** All elements of ATO involved in the Safety Risk Management (SRM) process.

**3. Where Can I Find this SOC:**

[http://www.faa.gov/about/office\\_org/headquarters\\_offices/avs/offices/aov/policies\\_forms/](http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aov/policies_forms/)

**4. Background:**

a. FAA Order 1100.161, Chg. 1 defines AOV responsibilities regarding safety oversight of the ATO. These responsibilities include monitoring compliance with safety standards and the ATO SMS; approving controls for initial or current High Risk Hazards (HRH) changes to the National Airspace System (NAS), and waivers or changes to handbooks, orders, and documents when those pertain to separation minima.

b. ATO requests AOV approval or acceptance of NAS changes through Safety Risk Management Documents (SRMD). These SRMDs may include M&S results as part of the safety case supporting the change. Often, unclear documentation compels AOV to request supporting information and can result in delays in processing the ATO request. The choice of a particular analytical approach will be determined by the unique conditions associated with each particular NAS change. Therefore, proactive early and continuing communication with AOV about planned M&S activities is essential, particularly when an initial HRH mitigation is involved.

**5. Guidance:** Risk is usually conditional on factors or conditions particular to the location(s) and situation(s) where a change is desired. Modeling and simulation can provide information to decision makers about the risks associated with possible adverse outcomes associated with a proposed change to the NAS.

This requires a commitment of time and resources for each request by both ATO and AOV. Similar to the process described in SOC 07-02, ATO may obtain agreement at specified phases

of the modeling process before submission of a completed SRMD. It is assumed that if ATO seeks AOV agreement with respect to the M&S development, then ATO also will seek agreement with respect to the SRM process as a whole. In the context of an SRMD, the primary objective of the M&S activity is to provide information concerning the risks of adverse outcomes associated with the proposed change, conditional on factors or conditions that apply at locations where the change is being implemented. AOV is prepared to provide agreement at the conclusion of each of the following identified M&S steps. AOV recognizes that the actual M&S process may not be in the order described below, so the sequence of agreements may require consultation between AOV and ATO.

## 6. Modeling and Simulation Considerations:

a. **Components:** A model is a construct distinct from its simulation. As defined, a model is a symbolic representation of a system; simulation is a manipulation of the model. Considering them separately increases the clarity with which each can be described, used, and reported.

b. **Methodology:** Base risk assessments on structured, generally accepted procedures and techniques for constructing a model and conducting its simulation.

c. **Data:** When possible, rely on quantitative data rather than qualitative data, e.g., for determining severity, likelihood, adverse outcomes, and risks. The benefits gained from using quantitative data include the capability to objectively and statistically compare quantitative results from simulations between simulation scenarios, as well as with the initial level of risk. Additionally, levels of confidence can be obtained for each comparison to assist decision makers.

d. **Results:** Compare the predicted effects of implementing the mitigation with the outcomes obtained from its simulation.

e. **Record Retention:** M&S records should be kept in accordance with SMS guidelines for record retention. For example, a report record for the M&S supporting an SRMD would be kept at one location, would include statements of purpose, copies of related reports, and other supporting documents noting assumptions, inputs, and other relevant data.

f. **Reporting:** Include in a request to AOV necessary and sufficient information about the model, the simulations, the results and their interpretation, and the rationale for the mitigation requested. This would generally be expected to expedite and facilitate AOV evaluation of a request. Any report of results will be expected to include the following items.

1) The description of the model. For example, a written description of the corresponding real world components being modeled, such as facilities, weather conditions, staffing, equipment, etc.

2) The list of model parameters, assumptions, and sources, including variables used and their corresponding data sources and data values, as well as the value sets used for particular scenarios.

3) Results should be provided in a format that gives AOV the capability to review the effects of different analyses given a set of input assumptions. Examples of possible formats include Excel spreadsheets, charts, tables, etc. This includes results from simulated model runs, statistical and sensitivity analyses, and hazard-control analyses.

- 4) A discussion of any weaknesses in the modeling and simulation. These could include:
- a) Assumptions where there are uncertainties, e.g., due to differences of opinions from subject matter experts (SMEs).
  - b) Data variability/errors due to the conversion from qualitative to quantitative data.
  - c) Effects of sample size, e.g., effect on results of using a small sample size.
  - d) Scoping limitations imposed by placing boundaries on the system being studied (imposed by ATO).
  - e) Constraints on the process (outside control of ATO).

**7. Recommended Steps of the M&S Process:** The M&S process for the SRM process can be considered to consist of 8 steps (the term *steps* is used to clearly distinguish between these and the phases referred to in AOV SOC 07-02). A checklist is appended and shows the sequence.

a. **Step 1 -- ATO Development of a Safety Definition.** ATO completes a description of the system and its interfaces representing the changes being considered. This should include a preliminary hazard list (PHL) with the expected severity (Se) and likelihood (Li) of each hazard identified. The description and PHL are prerequisites for the next step in the design and development of an M&S process for the proposed change. AOV's feedback regarding the activities conducted during this phase may be solicited before continuing M&S work.

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided. Feedback from AOV may be accompanied by an initial agreement to proceed to the next step.

b. **Step 2 -- ATO Determination of Need for M&S.** Determination as to whether M&S should be used is based on severity and likelihood, each determined independently as defined by the ATO SMS Manual. M&S should be undertaken if preliminary evidence indicates that outcomes of the change made by ATO may take the form of (a) reduction in a separation standard, (b) reduction in ATC capability, (c) collision, (d) injuries or fatalities, (e) major, hazardous, or catastrophic severity levels. AOV feedback regarding the activities conducted during this phase may be solicited before continuing M&S work.

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided. AOV feedback may be accompanied by an agreement to proceed to the next step or agreement that M&S is not required.

c. **Step 3 -- ATO Identification of Adverse Scenarios to be Modeled Based on the PHL.** ATO identifies a set of adverse scenarios associated with the proposed change. A single change to the NAS may result in many different potential adverse outcomes. If so, the M&S should include these through the use of multiple scenarios. Detailed scenario descriptions define problem statements for the SME or analyst. Scenario descriptions should help determine which aspects of the NAS change (if any) require M&S. AOV feedback regarding the activities conducted during this phase may be solicited before continuing M&S work.

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided, including completeness and thoroughness of scenario descriptions. Adverse scenarios should take severity into account. AOV feedback may be accompanied by an agreement to proceed to the next step.

d. **Step 4 – ATO Determination of Appropriate Model(s).** If M&S is required and data are available, risk assessment should be based on objective quantitative statistical data (e.g., historical weather data, historical operational error data) or on observational data (e.g., SME watching radar display or SME reviewing audio/video recording). Where there is a lack of appropriate quantitative data to conduct a statistical assessment of risk, generally accepted methods, such as ranking, sorting, or SME judgment could be used to convert qualitative information into numerical values. However, it must be recognized that using transformed qualitative data severely limits the model design and resulting statistical analysis. At this step, there should be a complete identification, description, and discussion of the related assumptions, scoping, constraints, and other identified limitations. AOV's feedback regarding the activities conducted during this phase may be solicited before continuing M&S work.

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided. AOV feedback may be accompanied by an agreement to proceed to the next step

e. **Step 5 – ATO Building of Model.** Once the risk assessment/analyses are conducted, the mathematical model can be built to represent the system/subsystems, subject to the previously agreed to assumptions, scoping, constraints and other limitations. The model represents the real-world system and should be presented using mathematical formulations. The model should be quantitatively described by its inputs, components process and outputs. It is recommended that the qualitative inputs shall be converted to quantitative before the simulation. Changes from previous approved design should be completely documented and justified. AOV feedback regarding the activities conducted during this step may be solicited before continuing M&S work.

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided. AOV feedback may be accompanied by an agreement to proceed to the next step.

f. **Step 6 – ATO Run Simulation to Determine Baselines.**

1) Using the model, the outcomes should be evaluated based on mathematical analysis

of an event or outcome. Consequently, the uncertainty of values (i.e., probabilistic or stochastic) are introduced as appropriate to better account for the complex nature of the system being simulated. Simulations should reflect the system of interest and provide outcomes that communicate the probabilistic nature of the system. Results should be accompanied by the statistics reflecting outcomes from the various hazard controls. Statistical evaluation provides indicators for confidence judgments about the results of the simulation. ATO should provide AOV with the outputs obtained from the simulation. Note that simulation results are probabilistic and should be presented as such using results from probabilistic methods rather than deterministic (e.g., a range of values rather than just a point estimate).

2) A baseline should be established by a simulation of the model without using the proposed hazard control. An example methodology is as follows: the first simulation establishes a baseline representing normal operations. In Step 7 (below), a second simulation would represent operations in the presence of the hazard of interest. A third simulation would represent operations in the presence of the hazard of interest and the mitigation in place.

3) Baseline values can then be compared to outcome values from the simulation run with a hazard control included. Using baselines helps decision makers in both ATO and AOV to assess potential effects of proposed controls. ATO should provide the baseline information and results to AOV. AOV feedback regarding the activities conducted during this step may be solicited before continuing M&S work

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided. AOV feedback may be accompanied by an agreement to proceed to the next step.

**g. Step 7 – ATO Runs Simulation with Mitigations.** Simulation permits manipulation of operational conditions and situational assumptions to show the effect of mitigation. For example, a range of each variable can be simulated. Inputs can be controlled and systematically manipulated as needed to increase the clarity of comparison with the baseline. Inputs to the simulation should be selected so that the outcome from those inputs can be statistically compared to the baselines to demonstrate the effect of the mitigation. Such comparisons, which are based on a range of predetermined input sets, yield a range of risk estimates and thus can be a means to assess effects of the proposed mitigations on the hazard. Such systematic simulation may reveal and achieve the desired mitigation. The ATO should provide the simulation methodology and results to AOV before continuing M&S work

AOV Response: Review the materials and provide feedback regarding the completeness, relevance, and accuracy of the materials provided. Feedback may be accompanied by an agreement to proceed to the next step.

**h. Step 8 – ATO Complete Statistical Analysis and Sensitivity Analysis of Results.** The results of the M&S should be analyzed to provide appropriate statistical information and the sensitivity of the results to changes in the environment and/or assumptions.

AOV Response: Determine if the statistical analysis and sensitivity analysis are properly

designed, completed, documented, and presented. Based on proper completion of this process, AOV will approve the M&S process as conducted, contingent on the remaining parts of the SRM being conducted without changes to the hazard list, assumptions, limitations, and other related concerns.

**8. Definitions:** These definitions are consistent with definitions in other AOV and ATO SMS documentation.

a. **Cause:** An event that results in a hazard or failure. Causes can occur by themselves or in combinations.

b. **Data:** Qualitative or quantitative facts or evidence. Qualitative data may be converted to quantitative format using generally accepted methods.

c. **Hazard:** A condition that could foreseeably cause or contribute to an accident

d. **Hazard Control:** The means by which the resulting risk associated with a hazard is mitigated or reduced to an acceptable level.

e. **Hazard Risk:** An estimation of the potential outcome of a condition based on the condition's predicted severity (Se) and likelihood (Li).

f. **High Risk Hazard (HRH):** A hazard that is associated with high risk as defined in the ATO SMS Manual. High risks are unacceptable risks and must be mitigated so that the risk is reduced to a medium or low level."

g. **Likelihood (Li):** The estimated probability or frequency, in quantitative or qualitative terms, of a hazard's effect or outcome

h. **Mitigation:** A means to reduce the risk of a hazard.

i. **Model (Modeling):** A symbolic representation of a system or subsystem, that may or may not be based on quantitative data. A model approximates a real or hypothetical system or subsystem for the purpose of imitating (reflecting) characteristics and/or relationships of interest. A model is usually described by its inputs, components, processes, and outputs. These can be expressed as events, conditions, and controls (cf. Scenario and System). Conceptual models are qualitative and are useful to help to develop more complex models. Interactive models can be manipulated to demonstrate key elements of a system. Analytic models use mathematical expressions to characterize system elements and are most useful to identify patterns and relationships. For information on the use of quantitative and qualitative data refer to the ATO SMS Manual.

j. **Modeling and Simulation (M&S):** A summary term often used to refer to activities related to both a symbolic representation (model) and its manipulation (simulation). Representing these activities quantitatively and using mathematical functions has several benefits. Results can be statistically analyzed, precision of estimations can be calibrated, and

specific levels of confidence in the results can be known.

k. **Outcome:** Result or consequence. With respect to M&S it is the result from simulating a model. Adverse Outcome: An unwanted real world consequence, e.g., collision, loss of air traffic control capability, increase in flight crew workload, etc.

l. **Risk:** The composite of predicted severity (Se) and likelihood (Li) of the potential effect of a hazard.

m. **Scenario:** A set of particular events, conditions, and controls resulting in an outcome. The presence or absence and order of events, conditions, and controls can be important to understanding potential causes, outcomes and hazard risk; e.g., one set order (e.g., A, B, C, D) may produce a different outcome than a different set e.g., (A, C, D) or set order (e.g., B, A, C, D). A scenario describes a particular system state having certain conditions in which the system can exist. Adverse Scenario. A sequenced set of events, conditions, and controls which results in an adverse outcome.

n. **Severity (Se):** Impact associated with an outcome measured in terms of harm to persons, loss of capability, property loss, loss of function, etc. The measure of how bad the results of an event are predicted to be.

o. **Simulation:** Manipulation of a model with an intention to understand or predict behavior(s) of the system or subsystem being modeled. Simulation is usually done by inserting a range of values for each model parameter of interest given differing or specific data inputs. The quality of a simulation depends on the quality of the model and the choice(s) of the values selected to represent each parameter.

p. **System:** An integrated set of constituent elements that are combined in an operational or support environment to accomplish a defined objective. These elements include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets.

q. **System State:** An expression of the various conditions, characterized by quantities or qualities, in which a system can exist.

**9. SUMMARY:** To help complete the SRM process smoothly and quickly, the AOV evaluation of the SRMD will include consideration of the following items:

a. Rationale as to why the M&S approach used was selected instead of an alternative approach.

b. Structure of the model and the simulated scenarios used as compared to other possibilities such as other simulations or the real world.

c. Known limitations of the modeling and simulation, including assumptions, scoping, and constraints.

d. Types of data used to build the model and to conduct the simulation, i.e., qualitative, quantitative, objective, subjective, etc.

e. Sources for data used, e.g., operations databases, subjective assumptions, statistical and non-statistical sources, expert judgment, etc.

f. Verification and validation of any converted or transformed values used in the model or simulation.

g. Selection of analytical approach based on the unique conditions associated with each requested change or relevant aspects of the change

h. Analysis of the results, possibly including: confidence intervals, p-values, range of validity, and levels of confidence.

i. Sensitivity of results, for example, results from various input sets or alternative assumptions as demonstrated by tests of significance.

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<b>APPENDIX</b> <b>Modeling &amp; Simulation Checklist</b> (Use when ATO submits a document, e.g., SRMD, for AOV review)			
<b>Step 1 – ATO Development of Safety Definition</b>	<b>YES</b>	<b>NO</b>	<b>REFERENCE</b>
1a) Is a Preliminary Hazard List (PHL) included?	Continue to Step 1b	Obtain missing PHL from ATO	
1b) Does the Preliminary Hazard List (PHL) include the expected severity of each hazard identified?	Continue to Step 2	Obtain expected severities from ATO	
<b>Step 2 – ATO Determination of Need for M&amp;S</b>			
Is Modeling & Simulation (M&S) indicated?	Continue to Step 3	STOP M&S not needed	AOV SOC 07-02
<b>Step 3 – ATO Identification of Adverse Scenarios to be Modeled Based on the PHL</b>			
3a) Has ATO identified adverse scenarios?	Continue to Step 3b	Obtain missing information from ATO	
3b) For each adverse scenario, is a detailed description provided?	Continue to Step 4a	Obtain missing descriptions from ATO	
<b>Step 4 – ATO Determination of Appropriate Model(s)</b>			
4a) Are data available for the risk assessment?	Continue to Step 4b	Obtain data from ATO	
4b) Are objective quantitative data available?	Continue to Step 4d	Continue to 4c	
4c) Has objective qualitative data been converted to quantitative using SMEs expertise?	Continue to Step 4d	Obtain converted data from ATO	
4d) Is the selected model identified?	Continue to Step 4e	Obtain missing information from ATO	
4e) Is the selected model justified?	Continue to Step 5	Obtain missing information from ATO	

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<b>Step 5 – ATO Building of Model</b>	<b>YES</b>	<b>NO</b>	<b>REFERENCE</b>
5a) Is the model described?	Continue to Step 5b	Obtain missing information from ATO	
5b) Are all the parts of the model described	Continue to Step 5c	Obtain missing information from ATO	
5c) Is the model stochastic (probability based)?	Continue to Step 5e	Continue to 5d	
5d) Is the non-use of a stochastic model justified?	Continue to Step 5e	Obtain missing information from ATO	
5e) Are all assumptions in the model documented?	Continue to Step 5f	Obtain missing information from ATO	
5f) Are all assumptions in the model identified?	Continue to Step 5g	Obtain missing information from ATO	
5g) Are all assumptions in the model justified?	Continue to Step 6	Obtain missing information from ATO	
<b>Step 6 – ATO Run Simulation to Determine Baselines</b>			
6a) Have simulations been run using the model?	Continue to Step 6b	Obtain missing information from ATO	
6b) Were the simulations based on existing (baseline) operations/conditions (without the mitigations)?	Continue to Step 6c	Obtain missing information from ATO	
6c) Are the results of the simulations provided?	Continue to Step 7	Obtain missing information from ATO	

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<b>Step 7 – ATO Runs Simulation with Mitigations</b>	<b>YES</b>	<b>NO</b>	<b>REFERENCE</b>
7a) Were simulations run incorporating the mitigations?	Continue to Step 7b	Obtain missing information from ATO	
7b) Are the results of the simulations provided?	Continue to Step 8	Obtain missing information from ATO	
<b>Step 8 – ATO Complete Statistical Analysis and Sensitivity Analysis of Results.</b>			
8a) Has a statistical analysis of the results of both sets of simulations been completed?	Continue to Step 8b	Obtain missing information from ATO	
8b) Are results for the statistical analysis presented?	Continue to Step 8c	Obtain missing information from ATO	
8c) Was a sensitivity analysis of the results of both sets of simulations conducted?	Continue to Step 8d	Obtain missing information from ATO	
8d) Are results for both sensitivity analyses presented?	Continue to Step 8e	Obtain missing information from ATO	
8e) Does the SMRD discuss the results of the M&S to support the conclusion that the mitigation is effective?	M&S is deemed adequate	Obtain missing information from ATO	