FSA Methodology Workshop 1
08/11/2023

AST

AST Commercial Space Transportation

Federal Aviation Administration

Introduction & Questions

- The purpose of this workshop is to provide more insight for applicants as to what should be provided in a methodology description "in accordance with § 450.115(c)"
- Three sections:
  - Context for § 450.115(c) requirements
  - Explanation of § 450.115(c) elements, with examples
  - Checklist for descriptions of method, with example for § 450.131

- Q&A Session will be held after each section.
  - Participants should use the Q&A function to ask questions.
  - We will answer as many questions as time allows.
  - Any unanswered questions will be answered after the workshop in a written Q&A document or at a future FSA Office Hours.

AST Commercial Space Transportation

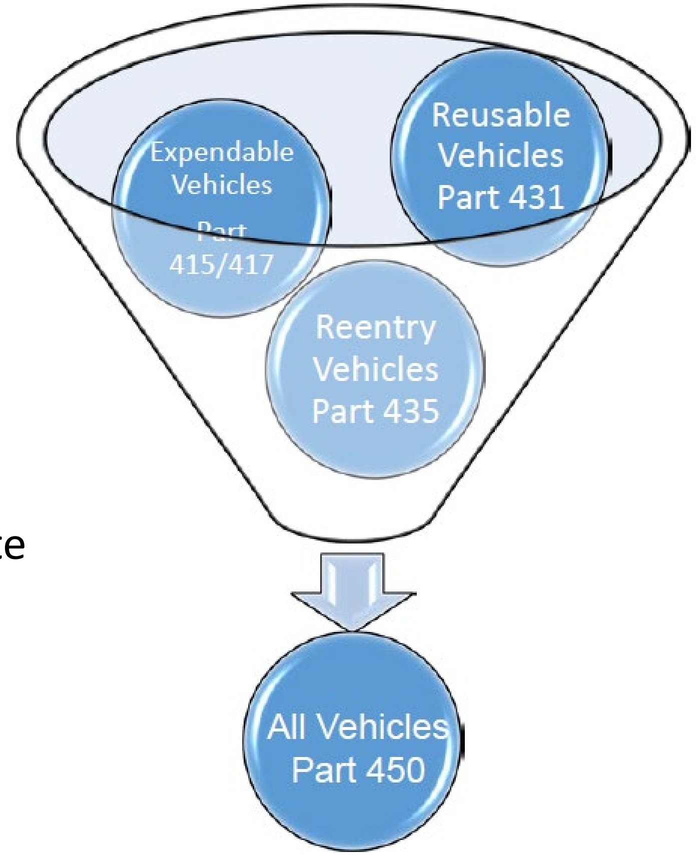
Section 1: Context for 450.115(c)

Federal Aviation Administration

Part 450

- Part 450
  - Consolidates multiple regulatory regimes into one set of requirements for all vehicle types
  - Performance-based requirements utilizing flexible means of compliance
  - Single license may authorize operations at multiple sites

- Shift from a focus on products to a focus on methods
  - Flexibility in the approaches and level of effort for an analysis
    - If methodology approaches and the applicant’s process are still valid a license modification would not be necessary for a new flight azimuth or a new launch site
      - ➢ Process accounts for any updates to the analysis as result of variable inputs
        - ✓ Probability of failure
        - ✓ Wind profiles
        - ✓ Exposed population
        - ✓ Variable flight rules, etc



450.35(a) Compliance (1 of 2)

For the purpose of § 450.35(a), the FAA has identified six types of acceptable MOCs

- **Type 1 – A current Advisory Circular**
  - Must be followed precisely; some Advisory Circulars provide guidance and include options so an applicant would need to tailor for their use (and becomes type 5 below)

- **Type 2 – A standard that has been accepted by the FAA**
  - FAA Accepted Means of Compliance that are publicly available are maintained on the FAA website at: https://www.faa.gov/space/streamlinedlicensingprocess/part-450-means-compliance-table/
  - Must be followed precisely, otherwise an applicant would need to tailor for their use (and becomes type 5 below)

- **Type 3 – Services provided by an *approved* federal entity (e.g. SLD-45)**
  - In accordance with § 450.45(b), the 'FAA will accept any safety-related launch or reentry service or property provided by a Federal launch or reentry site or other Federal entity by contract, as long as the FAA determines that the launch or reentry services or property provided satisfy this part'
  - Applicant is responsible for complying with requirements not provided by the federal entity
    - No entity performs all of FSA, for example

450.35(a) Compliance (2 of 2)

- **Type 4 – A Safety Element Approval (SEA), § 450.39**
  - An SEA can include "vehicle, safety system, process, service, or personnel"
  - An SEA has an approved scope - extent to which it satisfies requirement(s) and scenarios for which it applies
  - There are not yet any SEAs for part 450 FSA requirements

- **Type 5 – FAA approved applicant-specific descriptions of methods**
  - Can be a tailored version of Type 1 or 2
  - Usually takes weeks to months for iteration between applicant and AST to get to compliance

- **Type 6 – Actual mission data being used as representative**
  - Restrictive to the mission profile and conditions analyzed
  - Evaluation would occur via an independent safety analysis and the FAA may require additional products for this purpose per 450.45(e)(7)

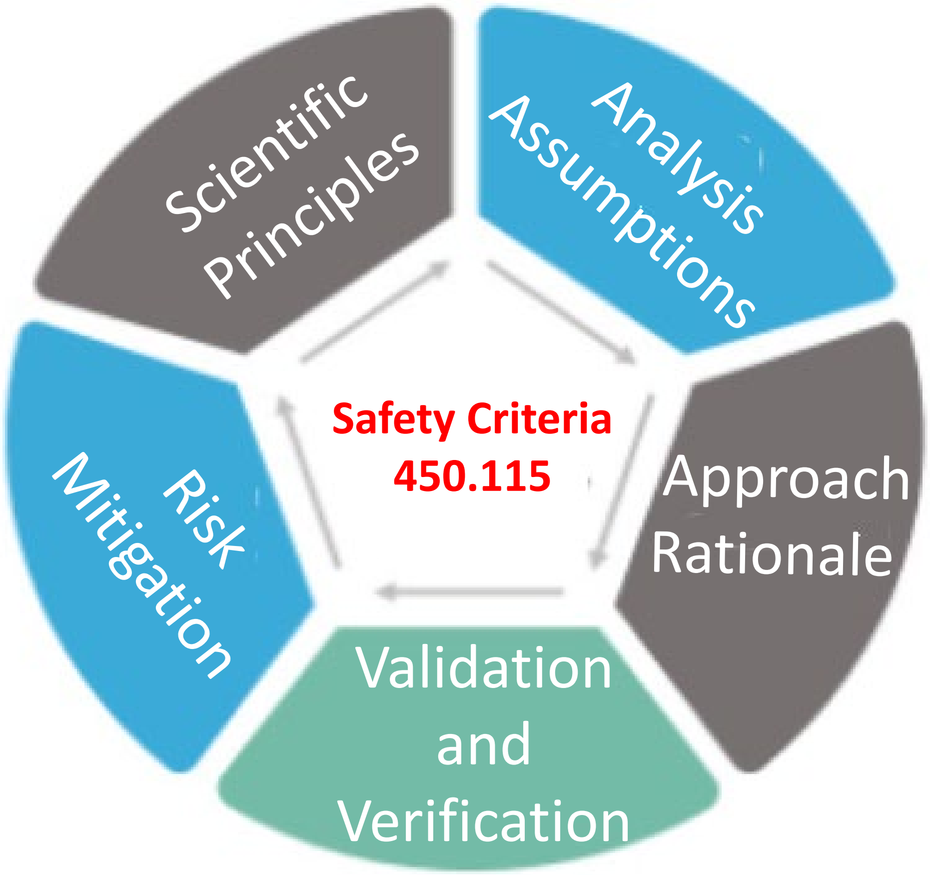
- **FAA determines:**
  - If an applicant can legitimately use a previously accepted MOC based on consistency with all the conditions relevant to the previously accepted MOC
  - If the current application demonstrates a method that exactly follows an accepted MOC

FSA Methodology – What is an FSA Methodology?

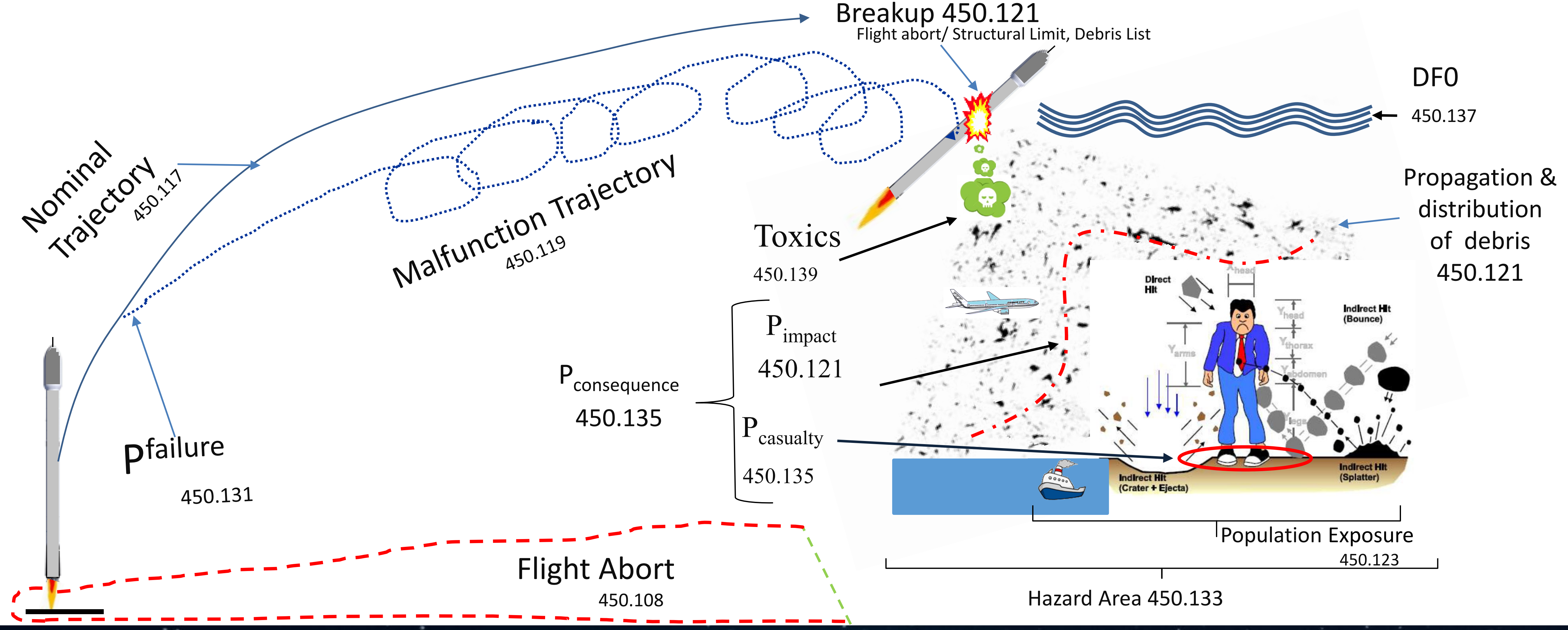
- An FSA methodology refers to the systematic, planned, structural and repeatable operating procedure an applicant performs to achieve a level of fidelity in flight safety analysis sufficient to demonstrate that any risk to the public satisfies the safety criteria of § 450.101, and should include:
  - Input data development and scientific principles
  - Analysis assumptions and justifications
  - Rationale of the proposed approach
  - Validation and verification of results
  - Risk mitigation development

- Refer to in the regulation as "description of the methods" use to demonstrate compliance with the FSA sub-analysis
  - Typically preceded by constraints and objectives
  - Typically followed by data requirements

- FSA methodology should address each of the requirements of 450.115(c) over the lifecycle of the proposed license activity



Components of FSA



Relevance of 450.115(a) & (b) & 450.101(g)

450.115(a) requires that an operator's FSA method account for all reasonable failures of safety-critical systems during nominal and non-nominal launch or reentry that could jeopardize public safety

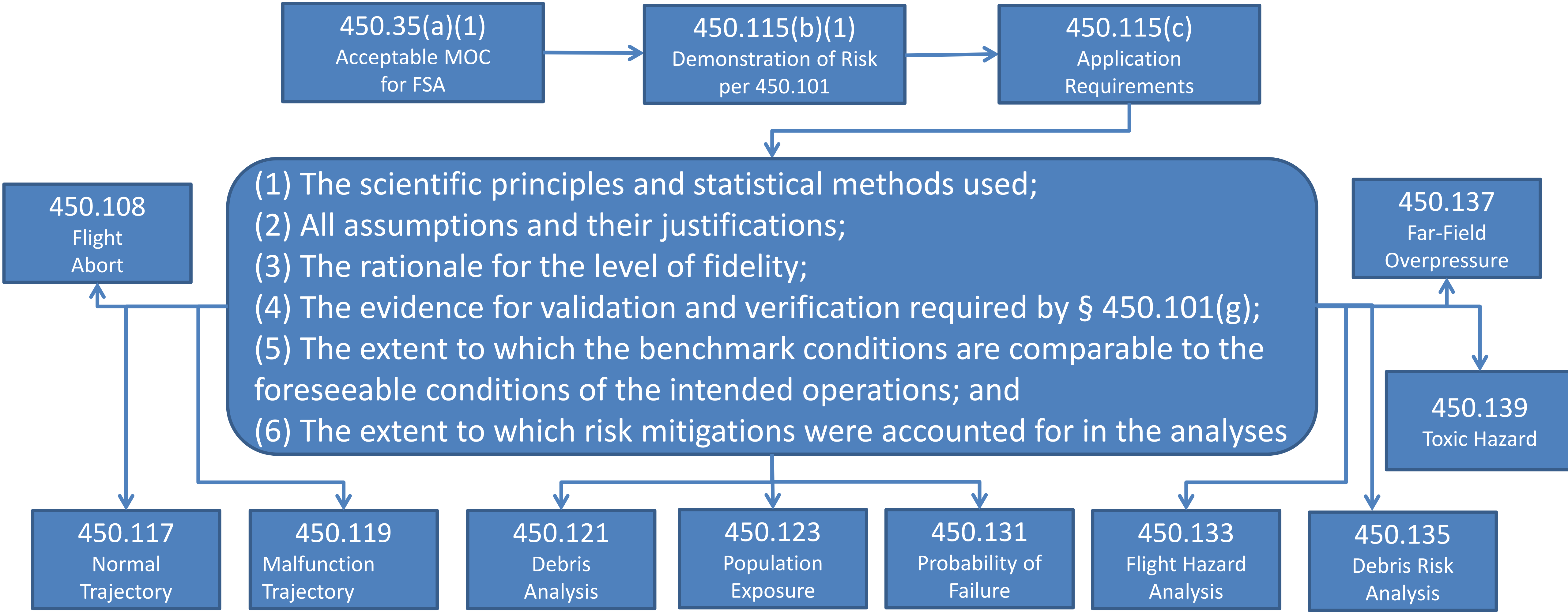
- Sets standard of analysis scope
    - Identify, describe, and analyze all reasonably foreseeable hazards and hazardous event to public safety
        - Foreseeable means that the failure event is identifiable and derived from a functional hazard analysis

450.115(b) specifies the necessary fidelity and resolution of any FSA

- Demonstrate risk satisfies 450.101
    - Accounting for all known sources of uncertainty
    - Identify the dominant source of each type of public risk
- Include use of mitigations
- Use accepted methodology per 450.35(a)(1)

450.101(g) notes that any analysis used to demonstrate compliance with 450.101 must use accurate data, and accepted scientific principles and the analysis must be statistically valid abd produce results consistent with or more conservative than the results available from previous mishaps, tests, or other valid benchmarks, such as higher-fidelity methods

Description of Methods per 450.115 (c) - application requirement



FSA Methodology Overview

Content

- Address each element of the subject sub-analysis (e.g. constraints, objectives, and application requirements)
- Cover each element of 450.115(c) for each topic
- Describe the intended usage and limitations

Rigor

- Logic is clearly described
- Based on generally accepted approaches
  - With specific references
- Mathematics are complete
- Evidence presented and analyzed

Depth/Definitiveness

- Verifiable: possible to reproduce consistent results and draw consistent conclusion using the same input data
- Inspectable: statements could be unambiguously supported by evidence upon request
- Repeatable: Two different engineers would not interpret in a meaningfully different way.

Example of content, rigor, depth

Unacceptable submission:

Debris impact locations are calculated using a 3DOF propagator that incorporates air density and wind using our in-house tool.

Acceptable submission:

Standard 3DOF computational simulation is used to compute trajectories for uncontrolled, unpowered objects. Input data are the initial position and velocity in ECI coordinates, the object's ballistic coefficient as a function of Mach number, and the specification of a 3-D atmospheric model (e.g. a Global Forecast System forecast). Equations of motion appropriate for a rotating Earth are used to determine the flight path of an object using a 3DOF simulation approach [ref 1]. The equations are integrated with respect to time using a Runge-Kutta method with the Adams-Bashforth predictor-corrector in ref 2 with an initial timestep of 1E-6s. Earth parameters through J2 are from WGS84 [ref 3]. Extraction and transformation of air density, speed of sound, and wind data are discussed in ref 4. The output is the trajectory (time, position, velocity) of the object in ECI coordinates from the initial state to impact with the Earth's surface at the interval of the integration steps.

1. Weiland*, Three and Six Degree of Freedom Trajectory Simulations, ch X*.
2. Press et al., *Numerical Recipes in C, 2nd Edition,* ch 16.
3. Department of Defense World Geodetic System 1984
4. XYZ Company, *Atmospheric Data Application Programmer's Interface Reference, version 6.1.*

This is an extremely brief version compared to some documentation we have seen on this topic.

End of Section

Q&A

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Section 2: Explanation of § 450.115(c) elements, with examples

We will explain (c)(1-3) then show an example fictional submission, then (c)(4-6) with a different example

Note: We have found that assumptions & justifications per § 450.115(c)(2) makes more sense to be discussed before scientific principles and statistical methods per § 450.115(c)(1).

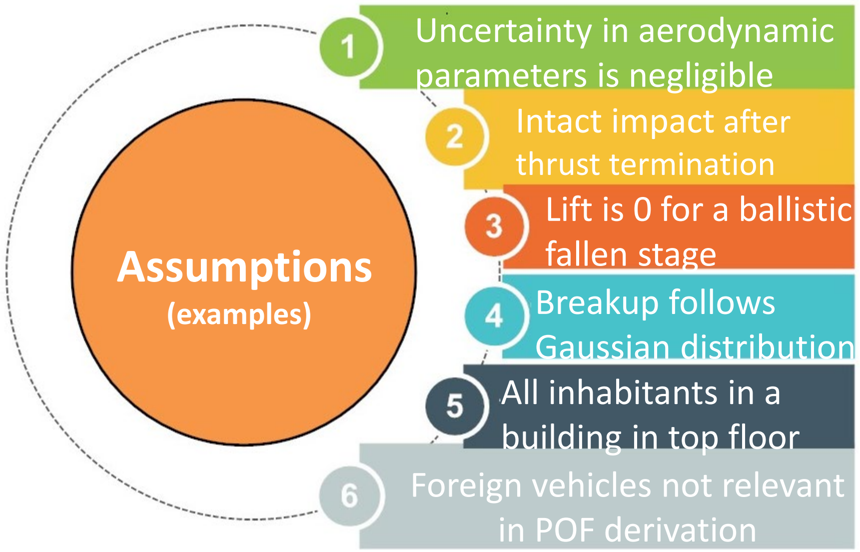
Federal Aviation Administration

450.115(c)(2) All assumptions and their justifications

Assumptions are things that are accepted as true or plausible and are often necessary to simplify problems and set limits to analysis

There are three types of assumptions in a methodology:

- The scope for which the methodology is intended to cover (and not cover)
    - Methods and procedures are allowed
- The physical phenomena which are relevant to the modeling
    - Is it a rigid body code?
    - Assumptions about the physics included in the code that limit the applicability of the simulation?
- Statistical selection and distributions
    - Normal distribution?
    - Uniformity?



Assumptions should be stated clearly at relevant points within the narrative

- Often helpful to summarize key assumptions and their justification in a matrix

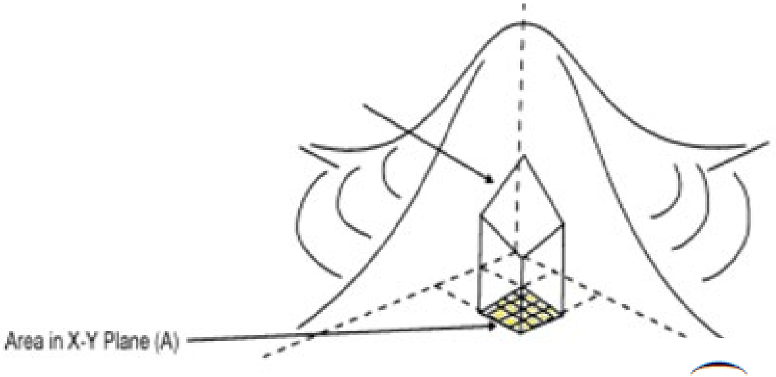
450.115(c)(1) Scientific Principles and Statistical Methods

- This discussion typically begins with an overview that describes integration of different elements of the modeling (sub-models)
  - Diagrams and flowcharts are often helpful, especially data flow diagrams
  - The link between the overview and the documentation of the elements should be clear

- Each sub-model should be based on established scientific principles, standard statistical methods, and/or empirical data
  - Scientific principles refer to knowledge based on the scientific method, such as that established in the fields of physics, chemistry, and engineering
  - A statistically valid analysis is the result of a sound application of mathematics and accounts for the uncertainty in any statistical inference due to sample size limits, the degree of applicability of data to a particular system, and the degree of homogeneity of the data.

- The depth of the detail should include equations and/or examples, but not algorithm implementation.
  - Standard mathematics (e.g. linear algebra, calculus) can be assumed
  - For off-the-shelf engineering software, provide references to technical manuals. AST may request applicants' assistance in obtaining them

$$Cov(X,Y) = E(XY) - E(X)E(Y)$$



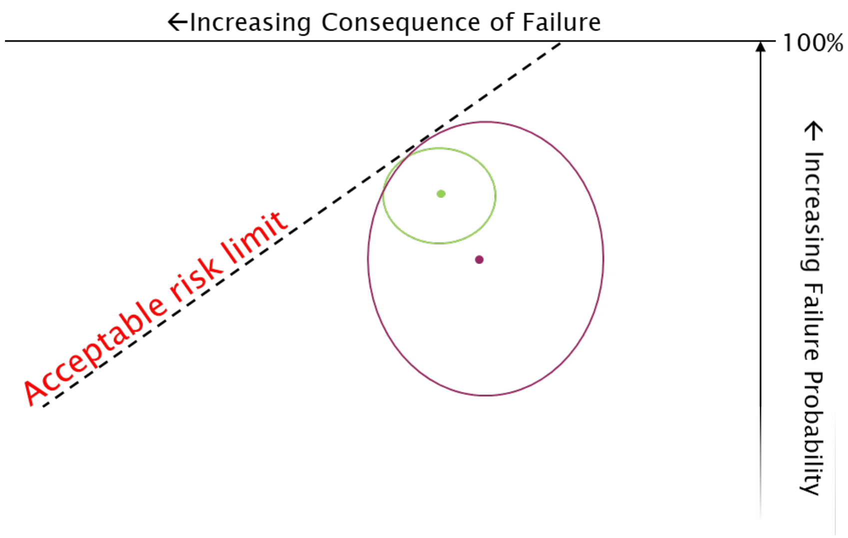
$$\varphi(t) = C(1 - \int^{t} \varphi(x)dx)$$

$$E_{C_{ij}} = P_{I_{ij}} \left(\frac{N_{P_j}}{A_{P_j}}\right)\left(N_{F_i} A_{C_i}\right)$$

$$\begin{Bmatrix}\ddot{x}\\ \ddot{y}\end{Bmatrix} = -\frac{g}{W}\begin{bmatrix}\cos\alpha & -\sin\alpha\\ \sin\alpha & \cos\alpha\end{bmatrix}\begin{Bmatrix}D\\ L\end{Bmatrix} - g\begin{Bmatrix}0\\ 1\end{Bmatrix}$$

$$P_I = \frac{1}{\sqrt{2\pi}\sigma_x}\int_{x_A-\sqrt{A}/2}^{x_A+\sqrt{A}/2} e^{-\frac{x^2}{2\sigma_x^2}}\,dx \times \frac{1}{\sqrt{2\pi}\sigma_y}\int_{x_A-\sqrt{A}/2}^{x_A+\sqrt{A}/2} e^{-\frac{y^2}{2\sigma_y^2}}\,dy$$

450.115(c)(3) The rationale for the level of fidelity (1 of 2)



- Fidelity means the degree of exactness of the approach as compared to the real-world.
  - Per 450.115(b) the method needs to have sufficient fidelity to establish compliance with the safety criteria, considering uncertainty.
  - Fidelity is measured by bias (e.g. conservatism) and uncertainty
- Documentation should discuss
  - At the level of **each sub-model and input data**
  - Explanation of how this fidelity was found
    - Quantitative: Has data to support bias and uncertainty, such as by comparison to a higher fidelity model or data. This typically comes from models that have been simplified to run more quickly or require less analysis.
    - Qualitative: Bias/uncertainty which does not have supporting data within the analysis, but instead has an estimate based on outside knowledge or on engineering judgment, e.g. we have evidence that the prediction over-estimates the value 90% or 99% or X% of the time
  - How it affects the fidelity of the overall results the context of risk analysis

450.115(c)(3) The rationale for the level of fidelity (2 of 2)

Choice of fidelity is an operator decision: It is a cost-benefit analysis

- Higher fidelity approaches are usually more costly
  - More work for applicant to develop
  - More work to develop input data
  - More effort for FAA to evaluate
    - True for even for a “simple” mission – there are more things to go awry with a more complex approach
- Lower fidelity approaches usually result in more operational restrictions
  - Lower-fidelity introduces assumptions that add conservatism into the answer
  - Restrictions include larger hazard areas, limited visitors, etc
    - The surroundings may make some restrictions not practical

Note: one can compare the fidelity of two approaches, but there is no such thing as an absolute metric for fidelity.

Analogy

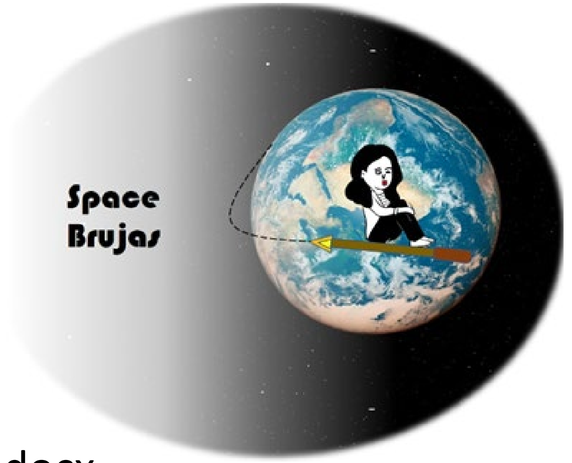
A hand saw can do everything a circular saw can do

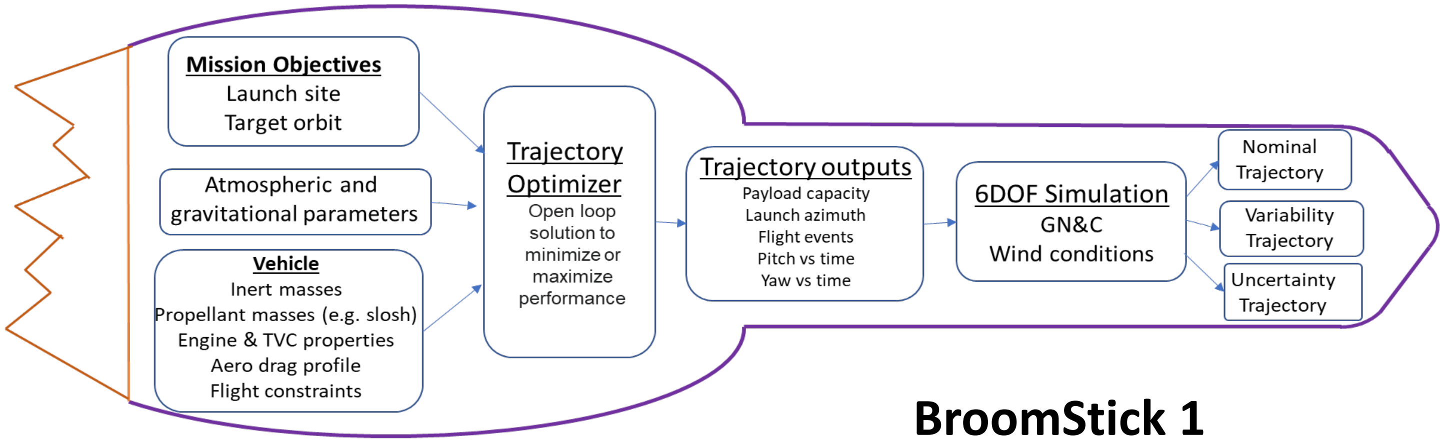
With a hand saw it’s hard to get a significant injury while using it. But it’s slow and tedious.

A circular saw is a lot more costly to build (including safety features and testing) and needs more caution when using, even for a simple cut.

Example of 450.115(c)(1)-(3)

- Fictious Launch provider, SpaceBrujas (SB) has submitted a Methodology description for 450.117 Normal Analysis Trajectory for their Launch Vehicle, BroomStick 1
- SB uses an in-house developed 6DOF called WIZARDSIM. This tool is coded in MATLAB and Simulink and is used to develop a full Guidance, Navigation, and Control (GN&C) software solution
- The closed-loop GN&C simulation consists of a collection of simulation models that represent the sensors, actuators, vehicle dynamics, and flight environments
- The high-level process for developing nominal and dispersed trajectories is shown below
- **One of the many sections** of SB's methodology addresses their propellant slosh sub-model per 450.115(c), the following is their submission: Launch 450.115(c)(1)-(3) Examples, SB_Slosh_model.docx





BroomStick 1

450.115(c)(4) *The evidence for validation and verification per 450.101(g)*

- Validation and Verification (V&V) evidence constitutes documentation of independent procedures that are used together for checking that a product, service, or system meets requirements and specifications and that it fulfills its intended purpose
  - Validation: the assurance that a product, service, or system meets the needs of the operation and reflects real world. It often involves acceptance and suitability with operation control needs and natural phenomena.
  - Verification: The evaluation that a product, service, or system complies with a regulation, requirement, specification, or imposed condition. It is often an internal process.

- Process V&V
  - Evidence that a process is capable of consistently delivering quality products
- Modeling and Simulation (M&S) V&V
  - Addresses simulation credibility
- User qualification V&V
  - Ensures that the right people with the appropriate training and expertise are using the process or software

Process V&V

Process V&V: Ensure that the structural and operating procedure achieves a level of quality, safety, and efficacy that is sufficient to be used for risk analysis, includes:

- A record of traceability from the input data's source through all aspects of its transmission, storage, and processing to its final form
- Systems to detect and manage process variability
- Each step is controlled to assure that the finished product meets all design characteristics and quality attributes including specifications
- Configuration Management that is applied over the process or product's life cycle to provide visibility into and to control changes to performance and to functionality and physical characteristic and include a well-controlled process for improving modeling based on flight experience like a Post-Flight Data Review
- Computing system safety items that meet the definition of ‘‘safety-critical’’ in § 401.7

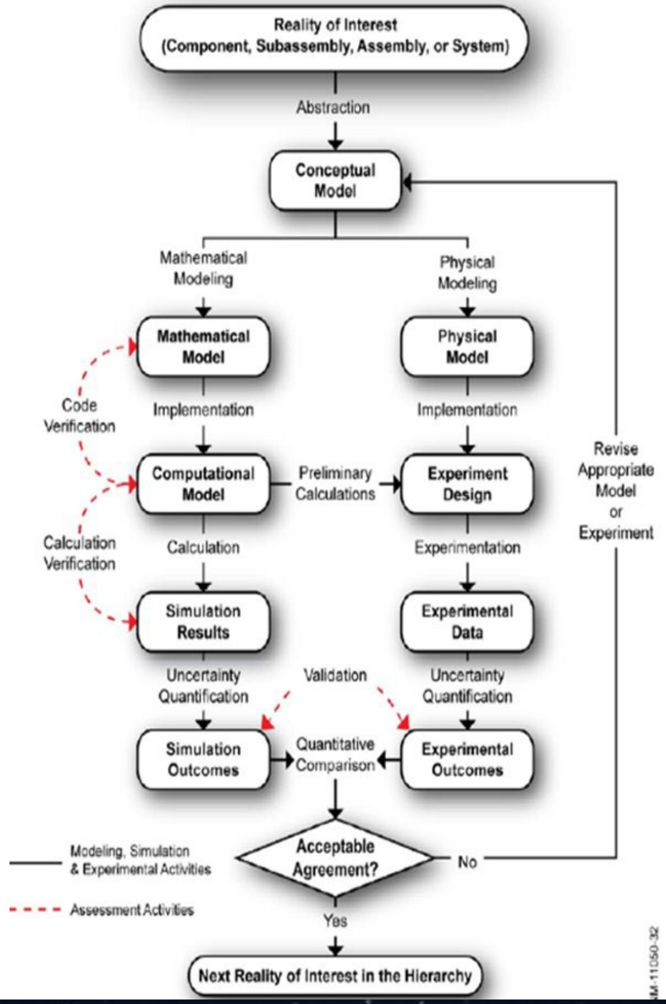
Reference

- Process Validation: General Principles and Practices (fda.gov)
- NASA Systems Engineering Handbook

Modeling and Simulation (M&S) V&V

Modeling and Simulation (M&S) V&V: Have we built the software right? Have we built the right software?

- V&V of the Mathematical model that includes mathematical equations, boundary values, initial conditions, and modeling data needed to describe the conceptual model which is implemented into a computational/simulation model (code)
- The rigor of V&V depends on the level of criticality of the model (typically IV&V is not necessary)



- DoDI 5000.61 provides a good overview of V&V for modeling and simulation.
- NASA-STD-7009A and NASA-HDBK-7009A provides good description of accepted modeling and simulation practices
  - Link: NASA HANDBOOK FOR MODELS AND SIMULATIONS: AN IMPLEMENTATION GUIDE FOR NASA-STD-7009 | Standards

450.115(c)(5) *The extent to which the benchmark conditions are comparable to the foreseeable conditions of the intended operations*

- A benchmark is an independent ‘ good’ or acceptable standard against which comparison can be made to check that a product, service or system fulfils intended purpose

- Describe situations where the modeling approach has been compared to empirical data and/or other modeling approaches
  - Provides context and is a critical element of an analysis to identify best practices
  - Can help to identify issues and improvements in process and technical development of Sofware

- Conditions should be compared to the intended scope of the methodology, discussing the regimes where the model is closer to and further from the benchmarks
  - Benchmark should run in parallel with the methodology, bringing in standards and best practices from elsewhere, while the methodology preserves knowledge generated within the organization
  - If inappropriate benchmark are used the analyst may end up making erroneous conclusions

- A benchmark serves as evidence of compliance with § 450.101(g) which addresses the required accuracy and validity of data and scientific principles.

- SANDIA Verification and Validation Benchmarks, SAND2007-0853: https://www.osti.gov/servlets/purl/901974

450.115(c)(5) *The extent to which the benchmark conditions are comparable to the foreseeable conditions of the intended operations*

- No amount of benchmarking is sufficient to verify accuracy
  - Benchmarks increase confidence but cannot alone determine correctness

- Regulation includes “extent to which” is used as the FAA acknowledges that there could be cases that are so unique that relevant benchmarks are unavailable
  - Applicants are still expected to address and provide some reasoning to the extent to which benchmarks were used relying on the best available data.
  - In the lack of a benchmark an applicant may discuss the level of conservatism included in their approximations.

User qualification V&V:

User qualification V&V: ensures proper use of the process and/or M&S to reproduce the function or action of the product/service/system

- Operator qualifications and recertification
  - Qualifications & experience assessments of the people developing, testing, & using key elements related to the process or M&S, including, maintenance, operation, results analysis, training, and error reporting
  - Intended to identify personnel who are likely to perform the process successfully
  - Define roles and responsibilities
  - Description of the minimum requirements
- Includes safety-critical personnel qualifications (§ 450.149), especially those that perform countdown activities

- NASA Workmanship Standards: nasa-std-87396b.pdf
- Job Analysis (opm.gov)
- CompetencyDeliveryandImplementationGuide (nih.gov)
- User Requirements Analysis A Review of Supporting Methods: 978-0-387-35610-5_9.pdf (springer.com)

450.115(c)(6) The extent to which risk mitigations were accounted for in the analyses

- This describes how mitigations (e.g. flight safety system, hazard areas, launch commit criteria) are incorporated in the flight safety analysis process and methods

- Mitigations include those described in the functional hazard analysis (FHA)
  - Mitigations include redundancy of the design and conservatism used in the analysis
  - The FHA mitigations should be correlated to FSA elements

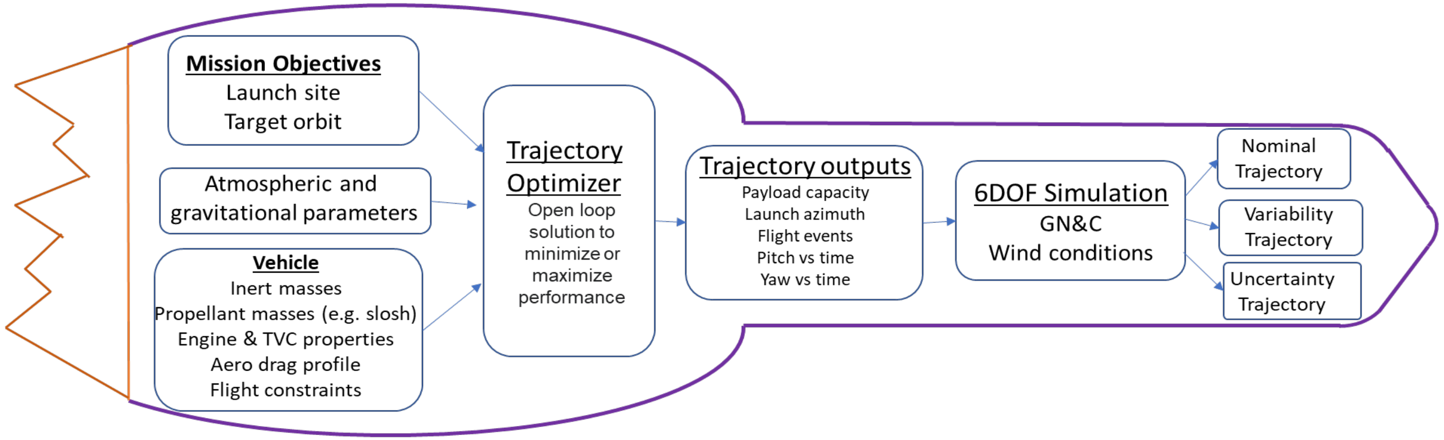
- FSA produces mitigations (e.g. flight safety limits, hazard areas) which are used in downstream analyses
  - Arguably these are the most important products of the FSA

- Regulation includes "extent to which", as the FAA acknowledges that there could be cases that are so unique that relevant mitigations are unavailable or applicable
  - Applicants are still expected to address and provide some reasoning to the extent to which risk mitigations were used relying on the best available data

Example of 450.115(c)(4)-(6)

- Space Brujas' WizardSim is coded in MATLAB and Simulink and is used to develop a full Guidance, Navigation, and Control (GN&C) software solution specially design for the Broom-Stick 1 launch vehicle
- Both the simulation software and GN&C software use a model-based approach, and the combined closed-loop GN&C simulation consists of a collection of simulation models that represent the sensors, actuators, vehicle dynamics, and flight environments including aerodynamics, mass properties, propulsion, earth model and atmosphere/winds
- SB provided an IV&V report of their 6dof simulation and benchmark of functional modules using POST2 and risk mitigation consideration in their trajectory design and simulation testing to comply 450.115(c)(4), c(5) and c(6)

Launch_FSA_WorkShop1_115c4_5_6_Example.docx



End of Section

Q&A

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Section 3: Checklist for descriptions of method, with example for § 450.131

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Complete Enough Checklist

- The FAA has compiled checklists for initial review of methodologies
    - Allocates the requirements of § 450.115(c) to each of the subject-specific performance requirements
    - Identifies the specific topics that are normally addressed for each subject-specific requirement

- The FAA uses this checklist to determine if a methodology submission is sufficiently thorough that it is ready for subject matter expert review
    - The FAA uses discretion when applying the checklists; these are an aid to our evaluation process. We recognize some topics may not be appropriate or may be covered in a different way for a particular approach.
    - The FAA expects to evolve and update the checklists as we learn from evaluations

- The FAA is in the process releasing the current version of the checklists

450.131 Checklist (1 of 3)
(determining comprehensiveness for evaluation)

Background	Y/N	Comments
Does the method define entry criteria for performing the analysis?		

For Flight Data Analysis [450.115(c)(1), 450.115(c)(2)]		Assumptions	Justifications	Logic Description
Data parameterization 450.131(a) and (b)	Categorization of flight phases / events			
	Categorization of vehicles			
	Categorization of flights			
	Categorization of failure modes			
	Categorization of outcomes			
Data load 450.131(a) and (b)				
Data selection 450.131(a) and (d)				

450.131 Checklist (example 2 of 3) (determining comprehensiveness for evaluation)

For Probability of Failure Calculations [450.115(c)(1), 450.115(c)(2)]		Assumptions	Justifications	Logic Description	Mathematics
Vehicle analysis 450.131(c) and (d)	Flight event/phase decomposition, including sequence and dependencies				
	Failure mode identification for each event/phase				
	Relationship to functional hazard analysis				
Data analysis 450.131(c)	Application of similar flight history				
	Application of subject vehicle/stage flight history				
	Incorporation of uncertainty (14 CFR 450.115(b)(1))				
Allocation 450.131(d)	Allocation of probability by failure mode				
	Allocation of probability of by event / phases				
Rate calculations 450.131 (e)	Calculation of conditional failure rates				
	Unconditional Rate calculations given conditional rates accounting for probabilities of past events				

450.131 Checklist (example 3 of 3) (determining comprehensiveness for evaluation)

Is there a discussion of:	Y/N	Comments
The level of fidelity of the analysis? [450.115(b), 450.115(c)(3)]		
The benchmarks used to demonstrate the validity of results? [450.115(c)(5)]		
Risk mitigations are incorporated in the analysis methodology? [450.115(c)(6)		

Is there evidence of verification and validation for all of the necessary software tools and processes? [450.115(c)(4)]	Verification	Validation	Configuration Control	Comments
<Software Tool 1>				
<Software Tool *N – list all*>				
<Process 1>				
<Process *N –list all*>				

End of Section

Q&A
on
checklists

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End of Main Workshop

- Next steps for AST
  - Edit and release today’s slides & examples
  - Finalize current version of checklists and release
- Additional questions?

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Backup

FAA FSA Methodology Evaluation

- When reviewing a unique means of compliance, the FAA will consider:
  - Past engineering practices
  - The technical quality of the proposal to demonstrate compliance with the intent of the part 450 regulations
  - The safety risk of the proposal
  - Best practice history

- Evaluate using a subject matter expertise the extent to which the methodology, the analysis
  - is comprehensive
  - lists assumptions and justifications
  - provides verifiable evidence
  - is a valid approach
  - satisfies 450.115(c)(1)-(6)
  - identifies and evaluates significant sources of uncertainty

FAA Methodology Evaluation Process

Submission

Acceptance

Feedback to Applicant

Applicant Response

Assessing Completeness

Ensure that the methodology covers all the expected topics of the analysis and regulatory requirements. If it does not, it is inefficient to perform a deeper review. It is performed using a checklist and when determines that it is complete, it is ready for an SME review.

SME review

The SME provides the in-depth review. Provides Specific comments on the documents indicating any questions, concerns, inaccuracies, unstated assumptions, insufficient clarity.

FAA Evaluation

The AST FSA Lead assignee performs the evaluation based on the SME review, understanding of larger scope of the applicant's concept of operations. The FSAL Lead produces is a preliminary determination on the methodology (which may necessitate discussion technical advisor, branch manager, and/or licensing team) with supporting evidence.

FAA FSA Methodology Evaluation

FAA/AST will provide to applicant:

- Specific comments on the documents indicating any questions, concerns, inaccuracies, unstated assumptions, insufficient clarity or detail, etc.

- A comment Matrix indicating the severity of each comment. The reference for severity is how much bias and/or uncertainty may be introduced by the issue to the products of the analysis

- A summary
    - of the extent to which the methodology has been found to meet the regulation
    - highlighting any significant issues related to safety
    - and include preliminary assessment to include FAA assessed methodology maturity (from 0 to 5)

- Support a reasonable number of technical interchange meetings (TIM) to answer methodology feedback (after feedback has been provided in writing)

End of Section

Q&A

Office Hours most common asked questions

Under what circumstance does an operator have to model degrade thrust?

In accordance with § 450.115(a) an operator's FSA method must account for all reasonably foreseeable events and failures of safety critical systems during nominal and non-nominal launch that could jeopardize public safety. This is to be accomplished with a sufficient level of fidelity [as per 450.115(b)] to demonstrate that any risk to the public satisfies the safety criteria of § 450.101, including the use of mitigations, accounting for all known sources of uncertainty. This applies to all reasonably foreseeable failure modes, including degraded thrust/performance scenarios.

- A key element of modeling this failure mode is the response of the guidance system to the reduced performance, as this is most likely going to result in a unique vehicle behavior and potentially hazardous event(s) that will need capturing in the FSA, pursuant to 450.115(a).
- The inclusion of degraded performance failures into a risk analysis computation may or may not be necessary. It would be necessary if the resultant vehicle response mode is not capture by other standard failure modes, such as RA, LOT and MT resulting in breakup states and debris not covered by other failure modes.

When using flight abort as a hazard control strategy, degraded performance trajectories would be crucial in determining limits of a useful mission, as there could be degraded performance trajectories that meet mission objectives (orbital insertion, etc). These trajectories should be used to guide an applicant in developing appropriate flight rules that ensure mission assurance and meet safety criteria

Office Hours most common asked questions

FSA required for carrier aircraft that acts as part of the launch vehicle only up to release?

Yes, a carrier aircraft is considered part of the launch vehicle under the definition of "launch vehicle" in 401.7. As such, an FSA should include the phase of flight of the carrier prior to and after release. Section 450.3(b)(3) refers to activities necessary to return the vehicle or component to a safe condition on the ground after impact or landing, this reference will include returning the carrier aircraft to a safe condition after impact or landing. However, per 450.113(b) An operator is not required to perform and document a flight safety analysis for a phase of flight if agreed to by the Administrator based on demonstrated reliability. An operator could demonstrate reliability by using operational and flight history to show compliance with the risk criteria in § 450.101(a) and (b).

Are passive disposals of sub-70 nmi perigee orbits ineligible to use the 450.101(d) disposal requirements?

Yes, ineligible. Disposal means the return or attempt to return, purposefully, a launch vehicle stage or component, not including a reentry vehicle, from Earth orbit to Earth, in a controlled manner. This passive 'disposal' does not meet the definition of *disposal* as it is not reentering from an Earth orbit; "orbital insertion" is defined as minimum 70-nautical mile perigee per 401.7.

Office Hours most common asked questions

Would a mission that plans the payload to complete orbital insertion on its own propulsion be cataloged as a ‘orbital mission’ when the launch vehicle does not achieve orbital insertion?

Section 450.113(a)(1) requires an operator to perform and document an FSA for all phases of flight, for orbital launch, from liftoff through orbital insertion, and through all component impacts or landings. In this circumstance, the payload is still considered part of the launch vehicle because it relies on the payload's propulsion to place the payload in outer space, consistent with the definition of "launch vehicle" in 401.7. Therefore, the FSA should be performed and documented through the payload's orbital insertion, consistent with 450.113(a)(1).

Regarding completing the analysis using extreme winds. Is there guidance on how best to determine what an extreme wind is? Is highest risk to population due to wind drifted debris?

Worst atmospheric conditions under which flight might be attempted per 450.117(d)(3) may include extreme winds under which flight be attempted. It is not just local effects placing debris over the Launch area that an operator should be concerned about. But also, extremes that would result in an increase in cross range IIP movement as well as up-range and downrange. The purpose of the inclusion of multiple wind scenarios is to guide the operator in reasonably maximizing coverage of their risk mitigation strategy.

Office Hours most common asked questions

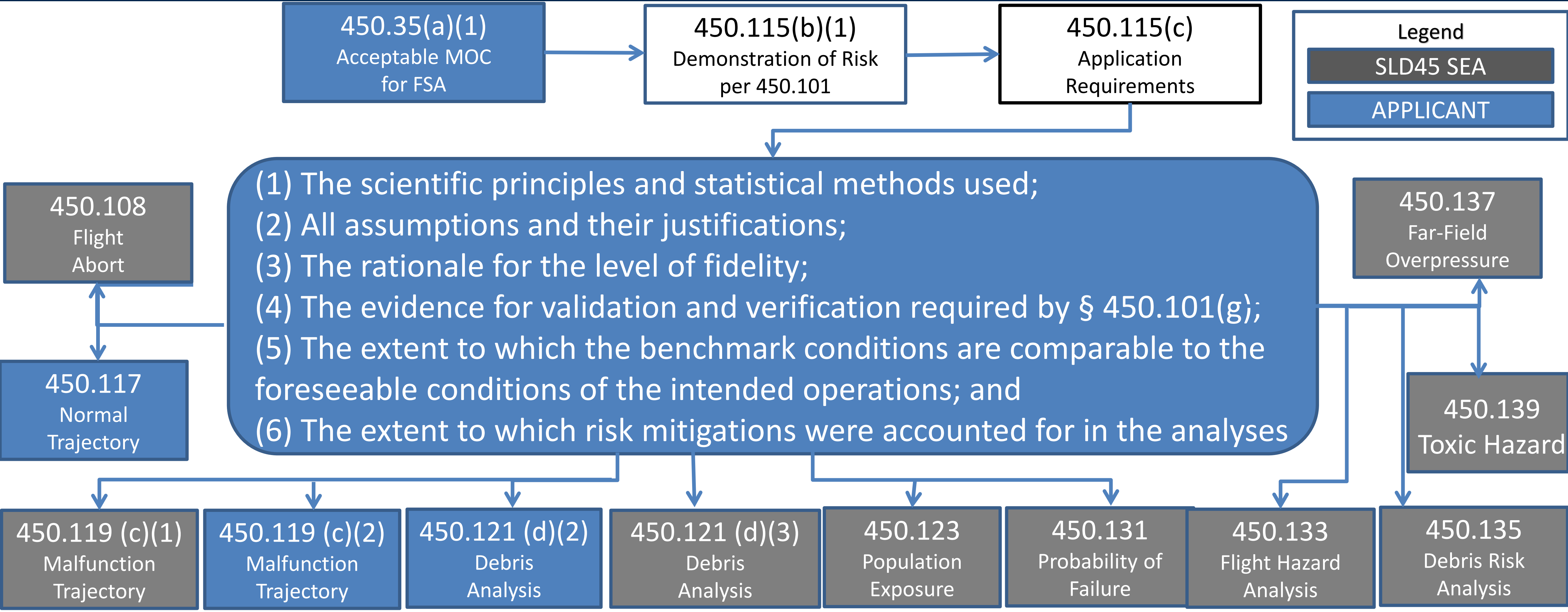
Should the limits of a useful mission trajectories be generated with 6DOF? Is there a requirement in 450?

Per 450.119(c)(2) a description of the methodology used to determine the limits of a useful mission is required, in accordance with § 450.115(c). Here, an applicant is giving the opportunity to describe their method for deriving LoUMs and why it is sufficient. LoUMS may include failures, such as tvc stuck nozzle and/or engine failure just after launch and those are best model in 6DOF with the guidance and navigation algorithms to aid in getting the vehicle to orbit.

Is it necessary to generate a new set of variability trajectory prior to launch for countdown analysis? The set of variability trajectories generated during the preliminary trajectory development step should be sufficient. During day of launch, the operator should only need to verify if the actual trajectory used for launch is within the variability set.

The variability uncertainty prior to launch decreases the closer to launch; therefore, a forecast prediction would have a better understanding of environmental conditions. An analysis with forecasted winds (<72 hours) would result in smaller risk contours for DOL risk calculations. An FSA closer to launch would increase mission assurance since using larger risk contours may result in unnecessary costly holds or scrubs by violators of hazard areas.

Methodology Requirements for an accepted FSA approach (e.g. SLD45)



End of Section

Q&A