AST Commercial Space Transportation

FAA AST Workshop: AC 450.109-1

Advisory Circular (AC) for Flight Hazard Analysis

Christopher Vance
Bhavyakumar Dave
25 August 2021

Federal Aviation Administration

Background on Advisory Circulars

Advisory Circulars (ACs) are being used to supplement streamlined regulations by the Federal Aviation Administration (FAA), Commercial Space Transportation (AST).

Their goal is to assist license applicants in two ways:

1. Further explain the meaning of the regulatory text and its intent/goal
2. Provide **a** means of compliance

The ACs are guidance, not a regulation, and compliance is voluntary

To demonstrate compliance using an AC, the entire AC must be implemented. This means all "should" statements must be accomplished if an AC is used.

Regulation § 450.109 Flight Hazard Analysis

(a) ***Applicability.*** This section applies to the use of a flight hazard analysis as a hazard control strategy to derive hazard controls for the flight, or phase of flight, of a launch or reentry vehicle. Hazards associated with computing systems and software are further addressed in § 450.141.

(b) ***Analysis.*** A flight hazard analysis must identify, describe, and analyze all reasonably foreseeable hazards to public safety resulting from the flight of a launch or reentry vehicle. Each flight hazard analysis must—

1) Identify all reasonably foreseeable hazards, and the corresponding failure mode for each hazard, associated with the launch or reentry system relevant to public safety, including those resulting from: (i) through (x)
2) Assess each hazard's likelihood and severity.
3) Ensure that the likelihood of any hazardous condition that may cause death or serious injury to the public is extremely remote.
4) Identify and describe the risk elimination and mitigation measures required to satisfy paragraph (b)(3) of this section.
5) Document that the risk elimination and mitigation measures achieve the risk level of paragraph (b)(3) of this section through validation and verification. Verification includes: (i) Analysis; (ii) Test; (iii) Demonstration; (iv) Inspection.

Regulation § 450.109 Flight Hazard Analysis (Cont.)

(c) ***New Hazards****.* An operator must establish and document the criteria and techniques for identifying new hazards throughout the lifecycle of the launch or reentry system.

(d) ***Completeness Prior to Flight****.* For every launch or reentry, the flight hazard analysis must be complete and all hazards must be mitigated to an acceptable level in accordance with paragraph (b)(3) of this section.

(e) ***Updates****.* An operator must continually update the flight hazard analysis throughout the lifecycle of the launch or reentry system.

(f) ***Application Requirements****.* An applicant must submit in its application the following:

1) Flight hazard analysis products of paragraphs (b)(1) through (5) of this section, including data that verifies the risk elimination and mitigation measures resulting from the applicant's flight hazard analyses required by paragraph (b)(5) of this section; and

2) The criteria and techniques for identifying new hazards throughout the lifecycle of the launch or reentry system as required by paragraph (c) of this section.

AC 450.109-1: Flight Hazard Analysis

SECTION 1: PURPOSE.

- This Advisory Circular (AC) provides guidance for an operator to apply a systematic and logical hazard analysis to identify, analyze, and control public safety hazards and risks associated with flight, and phases of flight, for a launch or reentry vehicle (hereafter referred to as system) in accordance with § 450.109.

- This AC presents one, but not the only, acceptable means of compliance with the associated regulatory requirements. The FAA will consider other means of compliance that an applicant may elect to present.

SECTION 2: APPLICABILITY.

- The guidance in this AC is for launch and reentry vehicle applicants and operators required to comply with 14 CFR part 450.

SECTION 3: APPLICABLE REGULATIONS AND RELATED DOCUMENTS.

SECTION 4: DEFINITIONS OF TERMS.

- No new terms. Terms and definitions from § 401.7 apply.

SECTION 5: ACRONYMS.

AC 450.109-1: Flight Hazard Analysis

SECTION 6.0: OVERVIEW

Section 6.1: Objective of Flight Hazard Analysis.

- A flight hazard analysis (HA) identifies key system design and operation data, documents the overall system safety risk to the public, and determines the necessary hazard controls (mitigations) to ensure the residual risk meets acceptable criteria.

- System safety risk documented in the flight HA is typically expressed in qualitative terminology; however, there may be sufficient operational history and subsystem analysis to express risk in quantitative terms.

AC 450.109-1: Flight Hazard Analysis

SECTION 6.0: OVERVIEW

Section 6.2: A Flight Hazard Analysis differs from Flight Safety Analysis.

- Risk as stated in the flight HA is different than as stated in the flight safety analysis (FSA).
- Flight HA and FSA are somewhat interrelated but intentionally independent analyses that are both integral to the overall hazard control strategy.
- A flight HA must ensure that the likelihood of any hazardous condition that may cause death or serious injury to the public is extremely remote in accordance with § 450.109(b)(3).
- The objective of the FSA is to characterize the overall risk to the public caused by the operation as a whole in consistent quantitative terms.
- Compliance with § 450.101 risk criteria does not relieve the operator from completing the flight HA.

AC 450.109-1: Flight Hazard Analysis

Section 6.3: Flight Hazard Analysis Methodology.

- The flight HA methodology must be defined per § 450.103(b)(1). Per the guidance of AC 450.103-1, *System Safety Program*, this should be accomplished by the documented system safety program.
- The data documented in the flight HA is utilized to ensure public safety as defined by the documented system safety program.

AC 450.109-1: Flight Hazard Analysis

Section 6.4: Aspects of a Flight Hazard Analysis.

- Flight HA may be utilized as a hazard control strategy but is also mandated by § 450.107(c) for a flight, or phase of flight, if the public safety hazards cannot be mitigated adequately to meet the public risk criteria of § 450.101(a), (b), and (c) using physical containment, wind weighting, or flight abort.
- This use of a flight HA to derive hazard controls provides flexibility that does not currently exist under the prescriptive requirements of Part 417 but is broadly consistent with Part 431 and Part 435.
- In accordance with § 450.109(b), a flight HA must identify, describe, and analyze all reasonably foreseeable hazards to public safety resulting from the flight of a launch or reentry vehicle.
- The flight hazard analysis should be performed early in system development and operation conceptualization to define the system safety risk to the public in order to positively influence design and operation decisions.
- Flight hazard analysis products must continued to be maintained throughout the lifecycle of the launch or reentry system, in accordance with § 450.109(c) through (e).

AC 450.109-1: Flight Hazard Analysis

AC 450.109-1: Flight Hazard Analysis

Section 6.5: Formal Traceability of System Safety Hazards.

- Formal tracking methods should be established to show direct connections between all aspects of system safety hazards to the public.

Subsystem and Component Level

Subsystem(s)	Component(s) / Item(s)	Functional Failure ID(s)	Failure Description and End Effect	Possible Cause(s)	Risk Before Mitigation Measures			Risk Elimination / Mitigation Measures	Risk After Mitigation Measures			Verification Evidence
					L	S	R		L	S	R	
Avionics	Main Computer	TBD	Main computer [Function TBD] during [Mission Phase TBD] fails [Failure TBD], possibly resulting in loss of vehicle control, break-up, or [End Effect TBD]	**C1** Board Failure **C2** Electro-Static Discharge (ESD)	Initial or no da	TBD	TBD	**C1.M1** – Specific to mitigation of board failure (design, test, manufacturing process, etc.)	TBD	TBD	TBD	**C1.M1.V1** – Documented evidence specific to performed **C1.M1** mitigation **C1.M1.V2**, and so on…

System and Mission Level[1]

Hazard to Public[1]	Risk Elimination / Mitigation Measures[1]	Risk After Mitigation Measures[1]			Verification Evidence[1]
		L	S	R	
H1 Off-nominal trajectory **H2** Abort Debris	**H1.M1** - Specific to mitigation of **H1** [Flight Safety System (FSS), operational restrictions, clear areas, etc…] **H1.M2**, and so on…	TBD	TBD	TBD	**H1.M1.V1** – Documented evidence specific to **H1.M1** mitigation **H1.M1.V2**, and so on… **H1.M2.V1**, and so on…

[*The template of*] **Table A-1** shows the types of information that an applicant should provide to demonstrate traceability.

AC 450.109-1: Flight Hazard Analysis

Section 6.6: System Safety Hazards and Software Safety

- In accordance with § 450.141(a), if the flight hazard analysis identifies software or data utilized in a subsystem or the integrated system as potential hazard sources or hazard controls, then the applicant should perform a software hazard analysis to identify computing system safety items and assess their level of criticality.
- Per the guidance of AC 450.141-1, software hazard analyses identify potential software faults and their effects on the computing system and the system as a whole, as well as mitigation measures that can be used to reduce the risk.

AC 450.109-1: Flight Hazard Analysis

Discussion

Floor open for questions/comments
Either verbally or via comments

AC 450.109-1: Flight Hazard Analysis

SECTION 7.0: PERFORMING A FLIGHT HAZARD ANALYSIS.

Identify Hazards with Traceability (b)(1)

Section 7.1: Identify Hazards.

- The hazards referred to in a flight hazard analysis are the system safety hazards to the public that occur from a system failure.
- The starting point for identifying system safety hazards to the public is the functional hazard analysis as required by § 450.107(b) that decomposes the system functions and assesses the end effect of their possible failures on system operation.

Hazard Traceability

Traceability ensures proper identification of system safety hazards to the public for § 450.109(b)(1) and should be demonstrated from:

1. Subsystem and component functional failures to their causes; and

2. Subsystem and component functional failures to respective system safety hazards to the public at the system and mission level.

AC 450.109-1: Flight Hazard Analysis

Section 7.1: Identify Hazards. [CONTINUED]

Identify Hazards with Traceability (b)(1)

Data from/beyond the Functional Hazard Analysis.

- System failures leading to system safety hazards to the public should include all applicable failures identified in the functional hazard analysis.
- Other possible failures not in the functional hazard analysis should be included if new ones are uncovered when considering public safety.
- An operator should use decomposition of systems beyond what is in the functional hazard analysis to identify the causes of system failures. Beyond the functional hazard analysis, supplemental data routinely utilized to identify system failures and their causes include Fault Tree Analysis (FTA) and Failure Modes and Effects Analysis (FMEA)
- There will likely be multiple potential causes for each system failure.
- Each potential cause of a failure should be specified to a level of detail (down to a subsystem or component level) in accordance with § 450.109(b)(1)(ii) where it is possible to apply a mitigation.

AC 450.109-1: Flight Hazard Analysis

Section 7.2: Assessing Likelihood and Severity of Each Hazard.

Identify Hazards with Traceability (b)(1)

- The likelihood and severity of each system safety hazard to the public must be assessed, in accordance with § 450.109(b)(2), in order to determine the associated system safety risk.
- The characterization of each system safety risk allows for determining the necessity, and proper application, of any additional mitigation actions.

<u>Resources for System Safety Risk Assessments</u>.

- To satisfy § 450.109(b)(2), suitable assessment severity categories and likelihood levels criteria should be determined for each specific program. AC 450.103-1, *System Safety Program*, provides guidance on assessing and documenting system safety risk, including severity categories and likelihood levels.
- The risk assessment with respect to system safety hazards to the public generally utilizes qualitative statements; however, there may be sufficient data to utilize quantitative terms.

AC 450.109-1: Flight Hazard Analysis

Section 7.2: Assessing Likelihood and Severity of Each Hazard. [CONTINUED]

Assess Severity and Initial Likelihood (b)(2)

<u>Utilizing a Systematic Assessment Process</u>.

- The FAA encourages, but does not require, the utilization of a systematic development process that allows for a baseline assessment of pre-mitigation risk for each hazard.
- The FAA recommends that applicants who choose not to utilize a pre-mitigation risk assessment strategy discuss the appropriateness of their development process and any risk assessment assumptions during pre-application consultation. This strategy may not be acceptable with all programs.
- Irrespective of the applicant's development process, post-mitigation risk assessment should be performed to determine the residual system safety risk to the public.

AC 450.109-1: Flight Hazard Analysis

Section 7.2: Assessing Likelihood and Severity of Each Hazard. [CONTINUED]

Assess Severity and Initial Likelihood (b)(2)

Utilizing a Systematic Assessment Process. [Continued]

- For § 450.109 (b)(4), risk assessment should be performed at the appropriate levels, primarily the: (1) subsystem and component level and (2) system and mission level. Risk assessment at these levels allows for greater insight into the effectiveness of mitigations and verifications specific to each cause of each functional failure resulting in a system safety hazard to the public and appropriate application of component, subsystem, system and mission mitigations and verifications.

Risk Assessment Traceability.

- Traceability ensures proper assessment for § 450.109(b)(3) and should be demonstrated from subsystem and component level risk assessment to system and mission level risk assessment.

AC 450.109-1: Flight Hazard Analysis

Section 7.3: Mitigate Risk to Acceptable Levels.

Check Compliance with Acceptable Criteria (b)(3)

- Risk elimination or mitigation measures must be implemented to reduce risks to the acceptable level of § 450.109(b)(3).

Proper Risk Mitigation Process.

- Mitigating risk does not change severity of the hazard, only the likelihood. If there is a change in severity, it should be documented as a new risk.

Developing Risk Acceptance Criteria.

- Risk acceptance is determined by comparison of final assessed system safety risk against established acceptance criteria.
- Suitable risk acceptance criteria must be determined for each specific program and documented in the system safety program compliant with § 450.103 and utilizing the guidance of AC 450.103-1, *System Safety Program*.
- To ensure proper acceptance of risks associated with system safety hazards to the public for § 450.109(b)(3), the associated residual risk should meet the established acceptance criteria and the rationale for acceptance should be documented.

AC 450.109-1: Flight Hazard Analysis

Section 7.3: Mitigate Risk to Acceptable Levels. [CONTINUED]

Check Compliance with Acceptable Criteria (b)(3)

Baseline of Risk Acceptability.

In accordance with § 450.109(b)(3), the baseline standard for risk acceptability of system safety hazards to the public is to ensure the likelihood of any hazardous condition that may cause death or serious injury to the public is extremely remote as defined in AC 450.103-1.

As documented in AC 450.103-1, System Safety Program, extremely remote should be considered "so unlikely, it can be assumed occurrence may not be experienced, with a likelihood of occurrence less than 10^{-6} in any one mission."

Note: The standards for risk acceptability are intentionally strict to ensure protection of the public. Sufficient mitigation to control the hazard should be demonstrated.

AC 450.109-1: Flight Hazard Analysis

Discussion

Floor open for questions/comments
Either verbally or via comments

AC 450.109-1: Flight Hazard Analysis

Section 7.4: Identifying and Describing Risk Mitigation Measures.

Identify Mitigations with Traceability at Appropriate Level (b)(4)

- Risk elimination and mitigation measures must be identified and described for system safety risks to the public that are initially deemed unacceptable in accordance with § 450.109(b)(4). In accordance with § 450.109(b)(5), the risk elimination and mitigation measures must document reduction to the acceptable qualitative level of § 450.109(b)(3).

- Consideration should be given as to whether proposed risk mitigation measures introduce new hazards. To allow flexibility, the FAA has not mandated any particular mitigation approach. Selection of a risk elimination or mitigation measure is usually based on a number of factors, such as the type of operation, feasibility of implementation, effectiveness, and impact on system performance.

- Where possible, the FAA expects the utilization of existing industry standards for mitigations.

AC 450.109-1: Flight Hazard Analysis

Section 7.4: Identifying and Describing Risk Mitigation Measures. [CONTINUED]

Identify Mitigations with Traceability at Appropriate Level (b)(4)

Risk Mitigation Traceability.

Traceability ensures proper application of mitigations for § 450.109(b)(4) and should be demonstrated from:

1) Subsystem and component functional failures to their causes to respective mitigations;
2) Subsystem and component functional failures to respective system safety hazards to the public at the system and mission level;
3) Subsystem and component level risk assessment to system and mission level risk assessment; and
4) System safety hazards to the public at the system and mission level to their respective mitigations.

AC 450.109-1: Flight Hazard Analysis

Section 7.4: Identifying and Describing Risk Mitigation Measures. [CONTINUED]

Identify Mitigations with Traceability at Appropriate Level (b)(4)

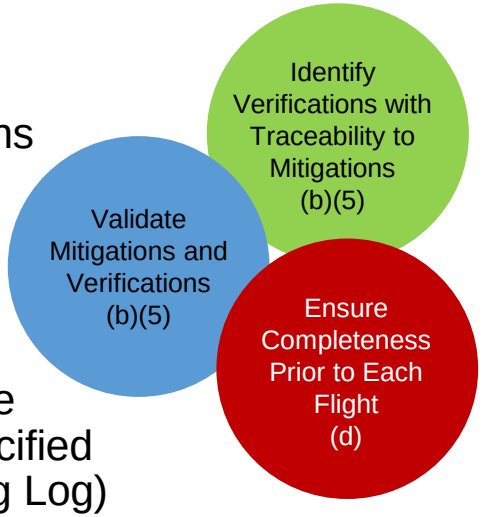
System Safety Design Order of Precedence

- MIL-STD-882E identifies the following mitigation approaches in order of decreasing effectiveness:
  a. Eliminate hazards through design selection;
  b. Reduce risk through design alteration;
  c. Incorporate engineered features or devices;
  d. Provide warning devices; and
  e. Incorporate signage, procedures, training, and personal protective equipment (PPE).
- The first priority should be to eliminate system safety hazards to the public through appropriate design selections or operational decisions.
- Unacceptable system safety risk to the public that cannot be eliminated must be reduced to acceptable levels.
- Potential risk mitigation methods include: design or operate for minimum risk; incorporate safety devices; provide warning devices; develop and implement procedures and training.

AC 450.109-1: Flight Hazard Analysis

Section 7.5: Validation and Verification.

The reduction of system safety hazards to the public via risk mitigations applied at various levels (component, subsystem, system, or mission) must be validated and verified as required by § 450.109(b)(5).



<u>Validation of Risk Mitigations and Verification Methods</u>.

- Per § 450.109(b)(5), validation evidence must demonstrate that the risk elimination and mitigation measures achieve the risk level specified by § 450.109(b)(3). This documented evidence (e.g., V&V Tracking Log) must be provided to the FAA in accordance with 450.109(f)(1).
- Validation determines whether the implemented mitigation measures and their respective verification methods are sound.
- The validation effort ensures that each mitigation and verification is unambiguous, correct, complete, and consistent.
- The validation process evaluates that each mitigation measure and respective verification is well understood and operationally and technically feasible.

AC 450.109-1: Flight Hazard Analysis

Section 7.5: Validation and Verification. [CONTINUED]

Identify Verifications with Traceability to Mitigations (b)(5)

<u>Verifying Risk Mitigations</u>.

- Verification is the process of identifying and producing verifiable and measurable evidence for ensuring that the respective mitigation measures adequately support the documented reduction of system safety risk to the public.
- Where possible, the FAA expects verification of mitigation measures to utilize existing industry standards.
- Essential information for verification includes:
  - Identification of specific method(s) used to verify the mitigation measure;
  - Identification of specific evidence to be produced; and
  - Indication of closure based on successful completion of specified method with production of adequate, verifiable, and measurable evidence.

AC 450.109-1: Flight Hazard Analysis

Section 7.5: Validation and Verification. [CONTINUED]

Identify Verifications with Traceability to Mitigations (b)(5)

Verification Methods.

The FAA encourages discussion on proposed verification methods early in the licensing process. Four acceptable methods of verifying mitigation measures, in accordance with § 450.109(b)(5), include:

- **Analysis** – Technical or mathematical evaluation, mathematical models, simulations, algorithms, and circuit diagrams.
- **Component, subsystem, or system test** – Actual operation to evaluate performance of system elements during ambient conditions or in operational environments at or above expected levels to measure safety margins. These tests include functional tests and environmental tests.
- **Demonstration** – Actual operation of the system or subsystem under specified scenarios, often used to verify reliability, transportability, maintainability, serviceability, and human engineering factors.
- **Inspection** – Physical examination of hardware, software code, or documentation to verify compliance of the feature with predetermined criteria.

AC 450.109-1: Flight Hazard Analysis

Section 7.5: Validation and Verification. [CONTINUED]

Identify Verifications with Traceability to Mitigations (b)(5)

Verification Artifacts.

- Documented evidence can include design analysis, test data, and inspection reports
- Ideally, all mitigation measures should be validated and verified by the time of application submittal.
- The FAA recognizes that applicants may not have the ability to verify all mitigations prior to submission of an application.
- In those instances, an acceptable verification closure strategy should be documented with expected completion dates (which must be closed prior to licensed operation pursuant to any relevant terms and conditions of the license).
- This strategy should be provided to the FAA with adequate time to review the closure status of verification evidence prior to the initiation of the applicable licensed activity.

AC 450.109-1: Flight Hazard Analysis

Section 7.5: Validation and Verification. [CONTINUED]

Identify Verifications with Traceability to Mitigations (b)(5)

Verification Traceability.

Traceability ensures proper application of verifications for § 450.109(b)(5) and should be demonstrated from:

1. Subsystem and component functional failures to their causes to respective mitigations to adequate verifications;
2. Subsystem and component functional failures to respective system safety hazards to the public at the system and mission level;
3. Subsystem and component level risk assessment to system and mission level risk assessment; and
4. System safety hazards to the public at the system and mission level to their respective mitigations to adequate verifications.

Iterative Approach of Validation and Verification.

- The validation and verification (V&V) process is a comprehensive, closed-looped, iterative process to be used in all phases of the lifecycle of a launch or reentry system.
- Any mitigation that fails V&V cannot be relied on for elimination or reduction of system safety risks to the public.

AC 450.109-1: Flight Hazard Analysis

Top-Level System [TBD]	Next-Level System [TBD]	Subsystem and Component Level												System and Mission Level[1]							
		Subsystem(s)	Component(s) / Item(s)	Functional Failure ID(s)	Failure Description and End Effect	Possible Cause(s)	Risk Before Mitigation Measures			Risk Elimination / Mitigation Measures	Risk After Mitigation Measures			Verification Evidence	Hazard to Public[1]	Risk Elimination / Mitigation Measures[1]	Risk After Mitigation Measures[1]			Verification Evidence[1]
							L	S	R		L	S	R				L	S	R	
		Avionics	Main Computer	TBD	Main computer [Function TBD] during [Mission Phase TBD] fails [Failure TBD], possibly resulting in loss of vehicle control, break-up, or [End Effect TBD]	**C1** Board Failure **C2** Electro-Static Discharge (ESD) **C3** Foreign Object Debris (FOD) **C4**, and so on…	Initial or no data	TBD	TBD	**C1.M1** – Specific to mitigation of board failure (design, test, manufacturing process, etc.) **C1.M2** – Specific to mitigation of C1 **C1.M3**, and so on…	TBD	TBD	TBD	**C1.M1.V1** – Documented evidence specific to performed **C1.M1** mitigation **C1.M1.V2**, and so on… **C1.M2.V1**, and so on… **C1.M3.V1**, and so on…	**H1** Off-nominal trajectory **H2** Abort Debris **H3** Reentry Debris **H4**, and so on…	**H1.M1** - Specific to mitigation of **H1** [Flight Safety System (FSS), operational restrictions, clear areas, etc…] **H1.M2**, and so on…	TBD	TBD	TBD	**H1.M1.V1** – Documented evidence specific to **H1.M1** mitigation **H1.M1.V2**, and so on… **H1.M2.V1**, and so on…
										C2.M1 – Specific to mitigation of ESD (design, test, manufacturing process, etc.) **C2.M2** - Specific to mitigation of C2 **C2.M3**, and so on…				**C2.M1.V1** – Documented evidence specific to performed **C2.M1** mitigation **C2.M1.V2**, and so on… **C2.M2.V1**, and so on… **C2.M3.V1**, and so on…		**H2.M1** - Specific to mitigation of **H2** [deorbit criteria, contingencies, established clear areas for NOTAM and NOTMAR, etc…] **H2.M2**, and so on…				**H2.M1.V1** – Documented evidence specific to **H2.M1** mitigation **H2.M1.V2**, and so on… **H2.M2.V1**, and so on…
										C3.M1 – Specific to mitigation of FOD (design, test, manufacturing process, etc.) **C3.M2** - Specific to mitigation of C3 **C3.M3**, and so on…				**C3.M1.V1** – Documented evidence specific to performed **C3.M1** mitigation **C3.M1.V2**, and so on… **C3.M2.V1**, and so on… **C3.M3.V1**, and so on…		**H3.M1** - Specific to mitigation of **H3** [abort criteria, mission rules, contingencies, established clear areas for NOTAM and NOTMAR, etc…] **H3.M2**, and so on…				**H3.M1.V1** – Documented evidence specific to **H3.M1** mitigation **H3.M1.V2**, and so on… **H3.M2.V1**, and so on…

DRAFT

Via Fault Tree Analyses; FMEA/FMECA; HEA Subsystem Hazard Analysis, etc.

Identify/Verify mitigations to specific causes of functional failures at the subsystem/component level (e.g., design, manufacturing, etc.)

Identify/Verify specific system/mission mitigations for residual system safety risk of public safety hazards (e.g., FSS, ops restrictions, etc.)

↓ Traceability ↑

AC 450.109-1: Flight Hazard Analysis

Top-Level System [TBD]	Next-Level System [TBD]	Subsystem and Component Level					
		Subsystem(s)	Component(s) / Item(s)	Functional Failure ID(s)	Failure Description and End Effect	Possible Cause(s)	
		Avionics	Main Computer	TBD	Main computer [Function TBD] during [Mission Phase TBD] fails [Failure TBD], possibly resulting in loss of vehicle control, break-up, or [End Effect TBD]	C1 Board Failure C2 Electro-Static Discharge (ESD) C3	

Data from Functional Hazard Analysis

Via Fault Tree Analyses;
FMEA/FMECA; HEA
Subsystem Hazard Analysis, etc.

AC 450.109-1: Flight Hazard Analysis

Risk Before Mitigation Measures			Risk Elimination / Mitigation Measures	Risk After Mitigation Measures			Verification Evidence
L	S	R		L	S	R	
Initial or no data	TBD	TBD	**C1.M1** – Specific to mitigation of board failure (design, test, manufacturing process, etc.) **C1.M2** – Specific to mitigation of C1 **C1.M3**, and so on…	TBD	TBD	TBD	**C1.M1.V1** – Documented evidence specific to performed **C1.M1** mitigation **C1.M1.V2**, and so on… **C1.M2.V1**, and so on… **C1.M3.V1,** and so on…
			C2.M1 – Specific to				**C2.M1.V1** –

Identify/Verify mitigations to specific causes of functional failures at the subsystem/component level (e.g., design, manufacturing, etc.)

AC 450.109-1: Flight Hazard Analysis

System and Mission Level[1]					
Hazard to Public[1]	Risk Elimination / Mitigation Measures[1]	Risk After Mitigation Measures[1]			Verification Evidence[1]
		L	S	R	
H1 Off-nominal trajectory **H2** Abort Debris **H3** Reentry Debris	**H1.M1** - Specific to mitigation of **H1** [Flight Safety System (FSS), operational restrictions, clear areas, etc...] **H1.M2**, and so on...	TBD	TBD	TBD	**H1.M1.V1** – Documented evidence specific to **H1.M1** mitigation **H1.M1.V2**, and so on... **H1.M2.V1**, and so on...
	H2.M1 - Specific to				H2.M1.V1 – Documented

Identify/Verify specific system/mission mitigations for residual system safety risk of public safety hazards (e.g., FSS, ops restrictions, etc.)

Traceability

AC 450.109-1: Flight Hazard Analysis

Discussion

Floor open for questions/comments
Either verbally or via comments

AC 450.109-1: Flight Hazard Analysis

Section 7.6: Identifying New Hazards and Updating the Flight Hazard Analysis.

Continuously Update and Capture of Any New Hazards (c) & (e)

- In accordance with § 450.109(c), criteria and techniques must be established and documented for identifying new hazards and updating a flight hazard analysis throughout the lifecycle of the launch or reentry system.
- In accordance with § 450.109(e), a process must be defined and implemented for continually updating the flight hazard analysis and system safety risk assessment to reflect knowledge gained during the lifecycle of the launch or reentry system.

AC 450.109-1: Flight Hazard Analysis

Section 7.6: Identifying New Hazards and Updating the Flight Hazard Analysis.

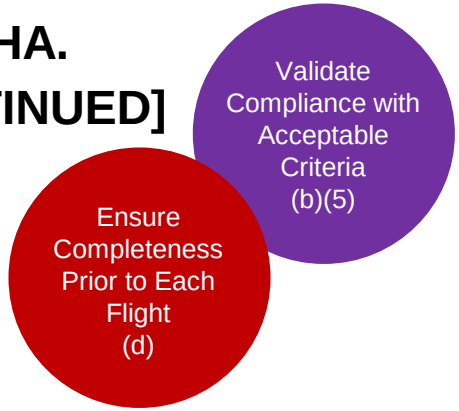
Continuously Update and Capture of Any New Hazards (c) & (e)

Updates from Lifecycle Data.

- Foreseeably, data gained during design, manufacture, test and operation, including the discovery of anomalies and faults, usually impacts a flight hazard analysis.
- Necessary data should be identified, and approaches should be implemented, to detect anomalies and failures in order to improve the flight hazard analysis.
- Additionally, information gained during assembly and operation of components, subsystems, and next-level systems contributes to the further understanding of the overall system and mission and may lead to additional updates to the flight hazard analysis.
- A process should be implemented to update the flight hazard analysis and residual system safety risk assessment to reflect knowledge gained during the lifecycle of the integrated system and mission.

AC 450.109-1: Flight Hazard Analysis

Section 7.6: Identifying New Hazards and Updating the Flight HA. [CONTINUED]



Accuracy via the System Safety Program.

- In accordance with § 450.103(b) and (d) and explained more fully in AC 450.103-1, *System Safety Program*, methods to detect flight anomalies and system failures and processes for evaluating post-flight data must be defined in the documented system safety program.
- The flight hazard analysis should adequately reflect the data gained from these methods and processes to ensure accuracy throughout the lifecycle of a launch or reentry system.

Completeness Prior to Flight.

In accordance with § 450.109(d), the flight hazard analysis must be complete and all system safety hazards to the public must be mitigated to acceptable levels, specifically that of § 450.109(b)(3), for every launch or reentry.

AC 450.109-1: Flight Hazard Analysis

Section 7.7: Application Requirements.

In accordance with § 450.109(f), an application must include:

(1) the flight hazard analysis data produced in accordance with § 450.109(b)(1) through (5), including the verification evidence for the risk elimination and mitigation measures; and

(2) (2) the criteria and techniques for identifying new hazards throughout the lifecycle of the launch or reentry system, as required by § 450.109(c).

AC 450.109-1: Flight Hazard Analysis Appendix A

Table A-1 conveys the types of data that should be provided by an acceptable system safety analysis, including a method for traceability between all aspects of system safety hazards to the public. It is intended as a guide to show what information should be provided within a flight hazard analysis. It also shows how logical tracking for each item can be used to show the relationships between the different pieces of information. A hazard analysis format conveying the information of **Table A-1**, such as similar tables or traditional worksheets, should be utilized.

TABLE A-1. System Safety Template for § 450.109 Flight Hazard Analysis

Top-Level System [TBD]	Next-Level System [TBD]	Subsystem and Component Level												System and Mission Level[1]						
		Subsystem(s)	Component(s) / Item(s)	Functional Failure ID(s)	Failure Description and End Effect	Possible Cause(s)	Risk Before Mitigation Measures			Risk Elimination / Mitigation Measures	Risk After Mitigation Measures			Verification Evidence	Hazard to Public[1]	Risk Elimination / Mitigation Measures[1]	Risk After Mitigation Measures[1]			Verification Evidence[1]
							L	S	R		L	S	R				L	S	R	
		Avionics	Main Computer	TBD	Main computer [Function TBD] during [Mission Phase TBD] fails [Failure TBD], possibly resulting in loss of vehicle control, break-up, or [End Effect TBD]	**C1** Board Failure **C2** Electro-Static Discharge (ESD) **C3** Foreign Object Debris (FOD) **C4**, and so on…	Initial or no data	TBD	TBD	**C1.M1** – Specific to mitigation of board failure (design, test, manufacturing process, etc.) **C1.M2** – Specific to mitigation of C1 **C1.M3**, and so on…	TBD	TBD	TBD	**C1.M1.V1** – Documented evidence specific to performed **C1.M1** mitigation **C1.M1.V2**, and so on… **C1.M2.V1**, and so on… **C1.M3.V1**, and so on…	**H1** Off-nominal trajectory **H2** Abort Debris **H3** Reentry Debris **H4**, and so on…	**H1.M1** - Specific to mitigation of **H1** [Flight Safety System (FSS), operational restrictions, clear areas, etc…] **H1.M2**, and so on…	TBD	TBD	TBD	**H1.M1.V1** – Documented evidence specific to **H1.M1** mitigation **H1.M1.V2**, and so on… **H1.M2.V1**, and so on…
										C2.M1 – Specific to mitigation of ESD (design, test, manufacturing process, etc.) **C2.M2** - Specific to mitigation of C2 **C2.M3**, and so on…				**C2.M1.V1** – Documented evidence specific to performed **C2.M1** mitigation **C2.M1.V2**, and so on… **C2.M2.V1**, and so on… **C2.M3.V1**, and so on…		**H2.M1** - Specific to mitigation of **H2** [deorbit criteria, contingencies, established clear areas for NOTAM and NOTMAR, etc…] **H2.M2**, and so on…				**H2.M1.V1** – Documented evidence specific to **H2.M1** mitigation **H2.M1.V2**, and so on… **H2.M2.V1**, and so on…
										C3.M1 – Specific to mitigation of FOD (design, test, manufacturing process, etc.) **C3.M2** - Specific to mitigation of C3 **C3.M3**, and so on…				**C3.M1.V1** – Documented evidence specific to performed **C3.M1** mitigation **C3.M1.V2**, and so on… **C3.M2.V1**, and so on… **C3.M3.V1**, and so on…		**H3.M1** - Specific to mitigation of **H3** [abort criteria, mission rules, contingencies, established clear areas for NOTAM and NOTMAR, etc…] **H3.M2**, and so on…				**H3.M1.V1** – Documented evidence specific to **H3.M1** mitigation **H3.M1.V2**, and so on… **H3.M2.V1**, and so on…

DRAFT

Note:

1 - "System and Mission Level" may be captured as shown or in a separate table or spreadsheet with traceability to "Subsystem and Component Level"

2 - "C1.M1.V1" is only an example; the key is to demonstrate traceability by a suitable method.

3 - L = Likelihood; S = Severity; R = Risk

4 - Typically within system safety: Likelihood (L) = Probability (P); Severity (S) = Consequence (C); L x S = R

AC 450.109-1: Flight Hazard Analysis

Discussion

Floor open for questions/comments
Either verbally or via comments

Where to Find Part 450 ACs

To ensure your comments and questions are considered in a future revision of the AC, please submit via the Feedback Form:

https://www.faa.gov/documentLibrary/media/Form/FAA1320-73.pdf.

Attachments to this form are welcome.

https://www.faa.gov/space/streamlined_licensing_process/