U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Physical Containment as a Hazard Control Strategy

Date: 09/27/2022 **AC No:** 450.110-1

Initiated By: AST-1

This advisory circular (AC) provides guidance for an operator to perform a physical containment analysis in accordance with Title 14 of the Code of Federal Regulations (14 CFR) 450.110. Section 450.110 applies to the use of physical containment as a hazard control strategy for the flight, or phase of flight, of a launch or reentry vehicle to meet public safety criteria. AC 450.107-1, *Hazard Control Strategies* provides further guidance for when a physical containment analysis may be used to demonstrate compliance with § 450.107(b).

The Federal Aviation Administration (FAA) considers this AC an acceptable means of compliance for complying with the regulatory requirements of § 450.110. This guidance is not legally binding in its own right and will not be relied upon by the FAA as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance is voluntary only and nonconformity will not affect rights and obligations under existing statutes and regulations.

If you have suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

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1 PURPOSE.

1.1 This advisory circular (AC) provides guidance for an operator to develop a physical containment analysis in accordance with § 450.110. Physical containment may be used as a hazard control strategy for launch and reentry in accordance with § 450.107(a). AC 450.107-1 *Hazard Control Strategies* describes how a functional hazard analysis is used to determine if physical containment is an acceptable hazard control strategy for a phase of flight.

1.2 As a hazard control strategy, physical containment is designed to be a simple method of protecting public safety by launching or reentering within an area that is cleared of public and critical assets, and within an area that contains hazards based on the potential energy of the vehicle. Physical containment is most likely to be used for low energy test flights, when a launch vehicle does not have sufficient energy for any hazards associated with its flight to reach the public or critical assets.

1.3 Section 450.110 applies to the use of physical containment as a hazard control strategy for a flight, or phase of a flight, for a launch vehicle to meet the safety criteria of § 450.101(a), (b), and (c). In accordance with § 450.110(b), to use physical containment as a hazard control strategy, an operator must identify and develop the flight hazard area in accordance with § 450.133; ensure that the launch vehicle does not have sufficient energy for any hazards associated with its flight to reach outside the flight hazard area; ensure the hazard area is clear of the public and critical assets; and apply any other mitigation measures necessary to ensure no public or critical asset exposure to hazards, such as control of public access or wind placards. To obtain a license, an applicant must demonstrate in its application that the launch vehicle does not have sufficient energy for any hazard to reach outside the flight hazard area and must describe the methods used to ensure the flight hazard areas are cleared of the public and critical assets in accordance with § 450.110(c)(1) and (2). Hazards may include inert debris, effects from an explosive event, effects from toxic propellants, etc.

1.4 **Level of Imperatives**.

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. In addition, an operator may tailor the provisions of this AC to meet its unique needs, provided the changes are accepted as a means of compliance by the FAA during review of the application for a license. Throughout this document, the word “must” characterizes statements that directly follow from regulatory text and therefore reflect regulatory mandates. The word “should” describes an option that, if used, would constitute a means to comply with the regulation; variation from the provisions of this AC is possible but must satisfy the regulation to constitute a means of compliance. The word “may” describes variations or alternatives allowed within the accepted means of compliance set forth in this AC.

2 APPLICABILITY.

2.1 The guidance in this AC is for launch and reentry vehicle applicants and operators required to comply with 14 CFR part 450. The guidance in this AC is for those seeking a launch or reentry vehicle operator license, and a licensed operator seeking to renew or modify an existing vehicle operator license. This AC provides an acceptable means to demonstrate compliance with § 450.101(a), (b), and (c) by using physical containment as a hazard control strategy in accordance with the requirements in § 450.110.

2.2 The material in this AC is advisory in nature and does not constitute a regulation. This guidance is not legally binding in its own right and the FAA will not rely upon this guidance as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with this guidance document (as distinct from existing statutes and regulations) is voluntary only, and nonconformity will not affect rights and obligations under existing statutes and regulations. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other means of compliance that an applicant may elect to present.

2.3 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes to, or deviations from, existing regulatory requirements.

3 APPLICABLE REGULATIONS AND RELATED GUIDANCE DOCUMENTS.

3.1 Related Statute.

- 51 United States Code (U.S.C.) Subtitle V, Chapter 509.

3.2 Related FAA Commercial Space Transportation Regulations.

The following 14 CFR regulations must be accounted for when showing compliance with 14 CFR 450.110 Physical Containment. The full text of these regulations can be downloaded from the U.S. Government Printing Office e-CFR. A paper copy can be ordered from the Government Printing Office, Superintendent of Documents, Attn: New Orders, PO Box 371954, Pittsburgh, PA, 15250-7954.

- Part 440, *Financial responsibility*.
- Section 401.7*, Definitions.*
- Section 450.101, *Safety criteria.*
- Section 450.107, *Hazard control strategies.*
- Section 450.110*, Physical containment.*
- Section 450.113, *Flight safety analysis requirements—scope.*
- Section 450.115, *Flight safety analysis methods.*
- Section 450.117, *Trajectory analysis.*
- Section 450.123, *Population exposure analysis.*
- Section 450.133, *Flight hazard area analysis.*
- Section 450.161, *Control of hazard areas.*

3.3 Related FAA Advisory Circulars.

FAA Advisory Circulars (are available through the FAA website, http://www.faa.gov).

- AC 450.101-1A, *High Consequence Event Protection*, dated May 20, 2021.
- AC 450.107-1, *Hazard Control Strategies Determination*, dated July 27, 2021.
- AC 450.115-1A, *High Fidelity Flight Safety Analysis*, dated June 24, 2021.
- AC 450.117-1, *Trajectory Analysis for Normal Flight,* dated August 19, 2021.
- AC 450.123-1, *Population Exposure Assessment,* when published.
- AC 450.161-1, *Control of Hazard Areas*, when published.

3.4 **Related Documents.**

- Air Force Space Command Instruction (AFSPCI) 13-610, *Launch and Range Operations*, dated May 14, 2018.
- AFSPCI 10-1215, *Support to FAA-Licensed Space Launch Activities*, June 15, 2007.
- National Aeronautics and Space Administration (NASA) *Procedure Requirements*, NPR 8715.5B, *NASA Range Flight Safety Program*, dated February 2, 2018. https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8715&s=5B
- Risk Committee, Range Safety Group, Range Commanders Council, *Common Risk Criteria for National Test Ranges*, RCC 321-20, White Sands, NM, 2010. https://www.hsdl.org/c/

Note: The industry documents referenced in this section refer to the current revisions or regulatory authorities' accepted revisions.

4 DEFINITION OF TERMS.

For this AC, the terms from § 401.7 and the following definitions apply:

4.1 Debris Risk Analysis

An evaluation of the risk to unsheltered people, people in buildings, people on ships, and people in aircraft due to debris to ensure compliance with § 450.101.

4.2 Failure Mode

A failure mode is a category of potentially hazardous events that share significant similarity in system response, prior to consideration of mitigations or hazard control strategies.

4.3 Flight Safety Analysis (FSA)

A quantitative evaluation of the risks to people and critical assets addressing both normal flight and malfunctions of the launch vehicle and safety-critical systems.

4.4 Hazard

Any real or potential condition that could cause death or serious injury or loss of functionality of a critical asset.

5 ACRONYMS.

AC – Advisory Circular

AST – Office of Commercial Space

CFR – Code of Federal Regulations

E_C – Expected Casualty

FAA – Federal Aviation Administration

FSA – Flight Safety Analysis

GIS – geographic information systems

NOTAM – Notices to Air Missions

NOTMAR – Notices to Mariners

OMB – Office of Management and Budget

P_C – Probability of casualty

U.S.C. – United States Code

6 INTRODUCTION TO PHYSICAL CONTAINMENT.

Physical containment as a hazard control strategy is most appropriate for low energy test flights, when a launch vehicle does not have sufficient energy for any hazards associated with its flight to reach the public or critical assets. Orbital launches and reentries are not conducive for physical containment as a hazard control strategy because those operations have enough energy for the hazards associated with the launch or reentry to reach outside the flight hazard area.

6.1 Hazard Control Strategy Background.

Sections 450.101(a) and (b) identify the requirements for expected casualty and probability of casualty thresholds that must not be exceeded for a launch or reentry mission, respectively. Thresholds exist for collective and individual risks for people on land and on waterborne vessels, as well as probability of impact for aircraft. Section 450.107(a) identifies that flight abort (§ 450.108), flight hazard analysis (§ 450.109), physical containment (§ 450.110), and wind weighting (§ 450.111) may be used as a hazard control strategy to ensure the safety criteria in § 450.101(a), (b), or (c) are met. This AC provides an acceptable means for using physical containment as a hazard control strategy.

6.2 Employing Physical Containment as a Hazard Control Strategy.

This AC provides methods to accomplish a physical containment analysis that complies with § 450.110(b). In accordance with § 450.110(b), to use physical containment as a hazard control strategy, an operator is required to develop the flight hazard area in accordance with § 450.133; ensure that the launch vehicle does not have sufficient energy for any hazards associated with its flight to reach outside the flight hazard area; ensure the hazard area is clear of the public and critical assets; and apply other mitigation measures necessary to ensure no public or critical asset exposure to hazards, such as control of public access or wind placards.

6.3 Conservative Approach to Characterize Physical Containment.

This approach should employ simple means and conservative assumptions to meet physical containment requirements. In general, the thresholds and other physical containment methods presented here should be used to determine if a more sophisticated analysis is warranted, or as an alternative when the quality of the data available to support the analysis is so low that an additional margin of safety is prudent.

6.4 Procedure for Physical Containment Evaluation.

This AC provides guidance for meeting the requirements of § 450.110 when physical containment is appropriate as a hazard control strategy. This includes the assumptions and justifications for the method of analysis, compatibility with foreseeable conditions, and how mitigations are accounted for. The basic steps to evaluate physical containment are:

a. Identifying the phase of flight for physical containment.

b. Defining the flight hazard area of physical containment.

c. Evaluating the feasibility of physical containment.

6.5 Applying Other Hazard Control Strategies to Phases of Flight.

The process employing physical containment as a hazard control strategy may be an iterative one. An original plan to use physical containment as a hazard control strategy for the whole mission may not prove feasible. Therefore, it may be necessary to partition the mission and apply physical containment to some phases of flight and apply other hazard control strategies to other phases of flight. The analysis should be reviewed for opportunities to mitigate risk, such as relocation of population, flight track adjustments, and launch point relocations.

7 IDENTIFYING THE PHASE OF FLIGHT FOR PHYSICAL CONTAINMENT.

7.1 Partitioning Physical Containment as a Hazard Control Strategy.

Employing physical containment as a hazard control strategy is applicable for cases where hazards and population are largely separated by geography. The physical containment phase in aggregate with every phase of flight must meet all of the regulatory requirements of § 450.101(a) and (b) and not just the physical containment portion alone. Phases of flight of a mission may be defined, for example, in terms of operating stages, events, or the location of the instantaneous impact point. AC 450.101-1A *High Consequence Event Protection* provides additional guidance in defining phases of flight.

7.2 Candidates for Physical Containment as a Hazard Control Strategy.

The following list gives examples of mission conditions and their suitability for physical containment analysis in accordance with § 450.110(b). AC 450.107-1 *Hazard Control Strategies* provides additional guidance in determining which strategy to employ.

Table 1 – Candidates for Physical Containment as a Hazard Control Strategy

	Likely Candidate for Physical Containment	NOT a Likely Candidate for Physical Containment
Characteristics describing flight or portion of flight	• Phase of flight entirely over open ocean • Limited vehicle kinematic range (downrange/crossrange excursions) • Tightly controlled airspace and access to the flight hazard area • Isolated and unpopulated launch or landing site, i.e., autonomous waterborne vessel or air drop	• Direct overflight or near overflight of population centers or critical assets • Overflight of uncontrolled areas as defined in § 401.7 • Overflight of airspace without sufficient controls and appropriate warnings • Overflight of areas with public or critical assets, such as launch and landing facilities • Gliding reentry with high glide performance or cross range capability

8 DEVELOPING THE FLIGHT HAZARD AREA FOR PHYSICAL CONTAINMENT ANALYSIS.

This section provides an acceptable method to satisfy § 450.110(b)(1), which requires an operator to develop the flight hazard area in accordance with § 450.133. This method will find the maximum kinematic range through conservative means. This section will also provide guidance in determining the bounds of the regions appropriate for physical containment and related flight safety analyses for each region.

8.1 Trajectories for Defining the Flight Hazard Area.

To define the flight hazard area, an operator should start with a set of trajectory dispersions that result from the kinematic constraints of the vehicle, in accordance with §§ 450.110(b)(1) and 450.133. This is a set of feasible trajectories, which may include any potential trajectories that go outside the limits of a useful mission, but are bounded by an area that does not contain any member of the public or critical assets.

8.2 Steps to Defining the Flight Hazard Area.

The flight hazard area should be defined by performing the following steps.

- Find the trajectories that bound the useful mission trajectories. AC 450.117-1, *Trajectory Analysis for Normal Flight* provides additional guidance on trajectory analysis.
- To find the left kinematic limit, take the left-most bounding trajectory and turn the trajectory 90 degrees to the left at a series of 1-second intervals that bound the full mission duration. To extend the range, find the elevation angle that maximizes range. At the end of the trajectory, find the vacuum impact.
- Repeat the analysis for the right kinematic limit.
- For the downrange limits, find the vacuum impact at each sampled time along the trajectories.
- Locate populations and critical assets that are located within the bounds defined by the vehicle's kinematic limit when applying this method to the whole flight. Physical containment can only be used as a hazard control strategy for a phase of flight if the hazard area is clear of the public and critical assets, in accordance with § 450.110(b)(3).

8.3 Documenting Physical Containment.

The output of this method is a kinematic limit defining the physically bounded area as a simplification to generating malfunction trajectories. The assumptions, justifications, and other relevant information should be documented in sufficient detail to facilitate an independent verification of the analysis. A graphical and tabular representation of the physical containment phase of flight, trajectories, and malfunctions should be documented.

8.4 Key Assumptions in Defining the Flight Hazard Area:

1. The vehicle should not exceed the performance unconstrained by the potential for breakup due to aerodynamic or inertial loads modeled by turning and maximizing the range of the trajectory.
2. The vehicle is physically contained. There is no risk assessment, so any population in the operating area would violate the mission rules.

9 EVALUATING THE FEASIBILITY OF PHYSICAL CONTAINMENT.

9.1 Flight Hazard Areas.

In accordance with § 401.7, a flight hazard area is any region of land, sea, or air that must be surveyed, publicized, controlled, or evacuated to ensure compliance with the safety criteria in § 450.101. The flight hazard area includes waterborne vessel hazard areas, land hazard areas, and airspace hazard volumes in accordance with § 450.133(b) through (d). An operator must ensure the hazard area is clear of the public, consistent with § 450.110(b)(3). Therefore, the operator should ensure any aircraft routes or shipping lanes that pass through the hazard area are clear of the public during the mission. Meeting this objective is bound by the limitations of acceptable surveillance procedures to include accounting for latency and level of confidence to satisfy the requirements specified in § 450.161. This is because physical containment requires total exclusion of the public, including those in waterborne vessels or in aircraft in accordance with § 450.110(b)(3). The latency of surveillance should be such that no waterborne vessels or aircraft may have transitioned into the surveilled area in the time between surveillance and launch. The FAA recommends that the surveillance assets account for a buffer between the recommended clearance area and an area encompassing the distance a vessel could travel in this time. The FAA acknowledges that the level of confidence of surveillance is bounded by what is reasonable for any surveillance asset to detect. Further guidance for adequacy of surveillance for this approach is provided in AC 450.161-1, *Control of Hazard Areas*.

9.2 Assessing Population Areas and Critical Assets.

An analysis of possible populations in the flight hazard area should be made. For the public, this may be accomplished using LandScan or other population maps, which are further described in AC 450.123-1, *Population Exposure Assessment*. If there is specific knowledge of population centers, population that cannot be controlled, or critical assets in the operating area, those phases of flight should use an alternative hazard control strategy. Seek guidance from the FAA to be sure that all population is properly accounted for. If all population is outside of the flight hazard area, the collective risk (E_c) and probability of casualty (P_c) are zero. A figure showing that there is no population within the bounds of the flight hazard area should be produced.

9.3 **Surveillance and Publication of Hazard Areas.**

Section 450.161 requires that an operator must publicize, survey, control or evacuate each flight hazard area identified in accordance with § 450.133 prior to initiating flight of a launch vehicle or the reentry of a reentry vehicle to the extent necessary to ensure compliance with § 450.101. In accordance with § 450.161(c), an operator must publicize warnings for each flight hazard area, except for regions of land, sea, or air under the control of the vehicle operator, site operator, or other controlling authority with which the operator has an agreement. The operator should develop Notices to Mariners (NOTMARs), Notices to Air Missions (NOTAMs), and ground hazard areas. These areas should be defined by the flight hazard area needed to accomplish physical containment. The hazard areas should be controlled and surveilled for any population; only total evacuation is appropriate for physical containment as a hazard control strategy in accordance with § 450.110(b)(3). In the case of a ground area, this may include fencing, road closures, and observation flights. AC 450.161-1, *Surveillance and Publication of Hazard Areas* provides additional guidance to meet this requirement.

OMB Control Number: 2120-0746
(Expiration Date: 08/31/2023)

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Subject: (insert AC title/number here) Date: Click here to enter text.

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