Federal Aviation Administration

Memorandum

Date: FEB 2 9 2016

To: Dr. Lourdes Maurice, Executive Director, Office of Environment and Energy, AEE-1

From: Lorelei Peter, Assistant Chief Counsel for Regulations, AGC-200

Prepared by: Karen L. Petronis, Senior Attorney for Regulations

Subject: Supersonic Aircraft Operations in the United States

With interest in supersonic aircraft operations increasing, you have requested that my office consider certain forward-looking aspects of supersonic aircraft operations over land in the United States. You requested an interpretation of 14 CFR §91.817, and in followup conversations, have revised your request to focus on an operator's ability to use the concept known as "Mach cutoff" to comply with the regulation. Our discussion needs to start with a brief history of the regulation of sonic boom from civil aircraft.

The FAA's authority to measure and regulate aircraft noise is rooted in Section 611 of the Federal Aviation Act of 1958, which gave the FAA the authority to "prescribe and amend such regulations as the FAA may find necessary to provide for the control and abatement of aircraft noise and sonic boom." (P.L. 90-411, July 21, 1968). That authority is now codified in 49 USC 44715.

In 1970, the FAA proposed the addition of §91.817, Civil aircraft sonic boom, in order to "[A]fford the public protection from civil aircraft sonic boom" in accordance with its statutory authority (35 FR 6189, April 16, 1970). The preamble for the proposed rule indicates that because there were no conclusive results that showed the effect of sonic boom on either the population or the environment, creation of a sonic boom by civil aircraft would be prohibited over land in the United States. Notably, the preamble states that neither technology nor psychology had been able to establish "a ceiling below which sonic booms caused by civil aircraft in commercial air transportation would be considered "tolerable" or "acceptable.""

The final rule was published in 1973, and contained considerable discussion of comments that had been submitted to the NPRM. Interestingly, there was less discussion of the actual prohibition than about the envelope of possible permitted operations under Appendix B. The tone that was set regarding future development of supersonic aircraft and their operation over land in the United States is best represented by our statement:

> [F]irst, the burden of the environmental acceptability of new and potentially harmful actions rests on the proponent of such actions rather than on the potentially affected public, but, second, that where consistent with this objective, reasonable opportunity for demonstrating or developing environmental acceptability should be available to the proponent of the action who is willing and able to control his demonstration of acceptability in the public interest.

The final rule resulted in what we know now as §91.817(a) and Appendix B.[1] The regulation accomplishes the goal of no sonic boom by prohibiting speed in excess of Mach 1. Paragraph (a) states simply that no person may operate in excess of Mach 1 in the United States except when authorized under an Appendix B special flight authorization. We often refer to this as "no sonic booms over land" but we need to remember that it encompasses all of the United States and is a barrier to exceeding Mach 1, considered the precursor to the creation of a sonic boom.

The original rule did not include §91.817(b) about which you ask "what is possible?" To this end, we understand that there are entities in the industry that read the language of (b) to allow the possibility of operating using Mach cutoff to remain in compliance with the regulation. Section 91.817(b) states:

(b) In addition, no person may operate a civil aircraft for which the maximum operating speed limit M_{MO} exceeds a Mach number of 1, to or from an airport in the United States, unless--

(1) Information available to the flight crew includes flight limitations that ensure that flights entering or leaving the United States will not cause a sonic boom to reach the surface within the United States; and
(2) The operator complies with the flight limitations prescribed in paragraph (b)(1) of this section or complies with conditions and limitations in an authorization to exceed Mach 1 issues under appendix B of this part.

Paragraph (b) was proposed in October 1977, and was a small part of a much larger rule whose focus was to give the Concorde, the only supersonic aircraft then operating, an operational exemption.[2] However, the stated purpose of the new paragraph (b) was clear:

> The proposed changes ... are intended to protect the coastal areas of the United States from sonic boom. The current rule [referring to §91.817(a)] prohibits the creation of sonic boom by civil airplanes that are in the United States by prohibiting flight in excess of Mach 1 while the airplane is within U.S. territorial limits. However, in relation to airplanes approved for operation to U.S. airports from outside the United States, the current rule does not specifically address the problem of a sonic boom created by an airplane which is outside the United States but reaching the surface within the United States.

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[1] The rule was adopted as §91.55 but Part 91 was later revised and the noise regulations redesignated in Subpart I, beginning with §91.801.

[2] The Concorde has considerable restrictions on its operation in the United States. The Concorde was not exempted from §91.817(a) and was never allowed to fly in excess of Mach 1 in the United States.

(42 FR 55181, October 13, 1977)

The preamble goes on to briefly describe the noise monitoring operations that had been set up following the debut of the Concorde, and the recordation of a sonic boom at Shark River, NJ, from an airplane that was 19 miles off the coast (outside territorial waters). The operator voluntarily changed its procedures to "ensure that supersonic speed is not attained or maintained closer than 25 miles from the coast." The proposed rule stated that the new paragraph (b) would "[condition] approval to operate to or from U.S. airports upon compliance with limitations like those voluntarily adopted by the aircraft operator following the Shark River sonic boom." The preamble then restated the text of the rule regarding information available to the flight crew to ensure no sonic booms impacted "the surface in U.S. territory … from flights entering and leaving the United States."

It is clear from the preamble that §91.817(b) is meant to expand the protection against sonic boom, not suggest a means of skirting it. The drafters understood that they could not place the prohibition on Mach 1 into some nebulous expanse of international airspace, but the recorded 19-mile boom and the operator's voluntary limitation served as a basis for a reasonable operational restriction, which at the time meant permission to land in or take off from the United States. Thus, paragraph (b) was created, and it was placed in the operating rules of Part 91 as a means of "conditioning approval to operate to or from U.S. airports upon compliance with limitations" that would ensure no sonic booms reached the coastline. At the time, the limitations anticipated were those in an AFM requiring a drop below supersonic speed at some distance from the U.S. shoreline before the aircraft would be given operational permission to enter the United States. The agency did not adopt this first voluntary operational speed limitation as the only means of compliance, but left it open to other limitations on aircraft entering the country that might be developed that proved acceptable in protecting the U.S. population along the shoreline.

Notably, nothing about paragraph (b) ever sought to change the positive prohibition in paragraph (a) regarding speed in excess of Mach 1. The stated history of paragraph (b), including the fact that it was adopted concurrent with the operational restrictions on the Concorde, indicates that it was not adopted to hedge the prohibition on speeds in excess of Mach 1. To suggest that now is to deny the existence of the prohibition in (a) and fail to understand the era in which paragraph (b) was created, as well as its stated reasons for existence. The regulators at the time knew they were not prescient, and did not presume that there would be some aircraft system that would predict the generation of a sonic boom by an aircraft. The regulation was merely an expansion of the paragraph (a) prohibition to the edges of the country's territorial authority. If an operator did not have some sort of expressed operational limitation, it could be denied authority to enter. While the provision may have been inarticulate in its content, the intent in the preamble is clear, and the language merely illustrates the agency's struggle with the protection of the U.S. population from a new source of considerable noise and annoyance, including when such was generated beyond its borders. Simply, §91.817(b) stated that an operator was not going to be given operational approval to come to the United States unless it had limitations in place to ensure that no sonic boom reached our shores upon approach.

With that in mind, we turn to your request that questions the use of "Mach cutoff" as an operational alternative allowing speeds in excess of Mach 1. We understand Mach cutoff to be

an atmospheric refraction phenomenon that suggests that at flight above a certain level, any sonic boom created by an aircraft is refracted, or dissipated into something less than the known shock wave(s) generated by an aircraft that reaching the ground as an overpressure which creates the signature boom. The concept is that at speeds of Mach 1.1 to 1.3, the shock wave produced by an aircraft can be buffered by altitude and weather, resulting in an "evanescent wave" reaching the ground that "would sound much like distant thunder."[3] Many questions about the concept remain. There is certainly not enough research or empirical data to support the idea that it is accepted, predictable science that is ready to be used in support of commercial operation of supersonic aircraft.

Much of the current online material referencing Mach cutoff appears associated with entities in the industry that promote the phenomenon as an exploitable basis for allowing supersonic flight over land. References to Mach cutoff flight acknowledge that it is an atmospheric phenomenon that is weather dependent and not at present predictable in its stability; this same unpredictability is found in the NASA references. There is no indication that the phenomenon has been documented and studied for its useful parameters, including how it could be predicted and monitored from on board an aircraft operating over a wide area and changing weather at supersonic speeds. It appears to require a prediction of atmospheric conditions well ahead of where an aircraft is at any moment. Nor is there any information publicly available that suggests the phenomenon is under continued study such as to warrant its consideration as a means of effectively mitigating sonic boom for flights conducted over land, no ongoing practical research into the phenomenon, especially over the particular geography and variable weather in the United States. Any actual flight tests (for noise recordation) to document its existence, predictability, and functionality would require an Appendix B authorization to operate if done by a civil entity, and no requests we know of have been received by the FAA.

Moreover, the use of Mach cutoff presumes an operational speed in excess of Mach 1, and that speed remains prohibited over all of the United States by §91.817(a). As we noted earlier, §91.817(b) does not function as some sort of loosening of the paragraph (a) prohibition as long as the flight crew knows what is happening, but was adopted to protect the United States from booms produced outside its borders that propagate and impact the population. It cannot be interpreted as more.

In no case may the exploitation of the Mach cutoff phenomenon be regarded as compliance with §91.817(a), since its use requires a violation of the terms of the regulation. Neither paragraph of the regulation can be read as allowing speed in excess of Mach 1 as long as the flightcrew believes a sonic boom produced by the airplane will not reach the ground. Such a conclusion ignores the express language of §91.817(a) and requires a significant misreading of §91.817(b), the history and purpose of which were discussed here. Mach cutoff may someday be prove itself out to be a viable operational profile, but even then, its use over land in the United States would require an exemption from §91.817 or a change in the rule language itself. Further, any technology associated with its use would likewise need to be certificated for installation on aircraft.

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[3] *Flight Demonstration of Low Overpressure N-Wave Sonic Booms and Evanescent Waves*, Haering, et al.; *Sonic Boom, Six Decades of Research*, Maglieri, et al., National Aeronautics and Space Administration, 2014, *infra*.

Federal Aviation Administration

Memorandum

Date: June 2, 2015

To: Mark Bury, Assistant Chief Counsel, AGC-200

From: Dr. Lourdes Q. Maurice, Executive Director, AEE-001

Prepared by: Rebecca Cointin, Manager, Noise Division, AEE-100

Subject: Clarification of Regulatory Text

Since 1973, FAA regulations prohibit any civil, Mach 1 and greater, flight operations overland in the United States (Captured in Title 14 Code of Federal Regulations Part 91.817 Civil Aircraft Sonic Boom). Since 2004, several U.S. aircraft manufacturers have maintained an interest in development of a supersonic business jet aircraft that could operate overland. Manufacturers believe that there is a business case for a supersonic business jet and are evaluating ways to overcome the challenges presented by part 91.817.

In technical discussions, one potential manufacturer has stated they feel they can demonstrate compliance with part 91.817 by manipulating the operation of the aircraft during phases of flight while overland so as to avoid the sonic boom noise from ever reaching the ground level. This so-called Mach-cutoff procedure is highly dependent on minute to minute operational conditions during each flight as well as the meteorological conditions that influence sonic boom noise transmission from the point of noise origin to any receiver location on the ground for the full duration of the flight. Technically there are many challenges associated with implementing this procedure in day to day operations. As we are not sure how their proposal would legally meet part 91.817, we would appreciate your review of the regulation and its history to see if the proposal would be legally permissible.