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Analysis of Greenhouse Gas Emissions Impact of Proposed Expansion of Hangar Capacity at Hanscom Field

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1. Summary

North Airfield Ventures, LLC and Runway Realty Ventures, LLC (collectively, the project proponent) have proposed a significant expansion of hangar capacity at Hanscom Field in Bedford, Massachusetts. The expansion plan calls for up to 17 new hangars with a total floor area of 395,700 square feet serving privately owned based aircraft,[1] as opposed to aircraft providing air taxi or commercial aviation service. This additional hangar capacity would support a significant number of new aircraft with their associated flight operations and greenhouse gas (GHG) emissions. The Massachusetts Port Authority (Massport) and the project proponent have claimed that the project would not expand flight operations or GHG emissions, instead contending that the project would serve aircraft that relocate to Hanscom from other airports and that this shift in aircraft to Hanscom would reduce operations and GHG emissions by eliminating so-called "ferry flights" (i.e., flights with no passengers). The analysis presented in this report tests this claim based on flight data for aircraft that have flown into and out of Hanscom over a recent 12-month period.

As detailed further below, we find that there are three jet aircraft that exhibit the characteristics of "ferry flights" and that would realize a reduction in their operations and GHG emissions if they were to relocate to Hanscom from their current base. Cumulatively, the relocation of these aircraft would reduce ferry flights into and out of Hanscom by 132 flights per year, reducing GHG emissions by 41.9 to 140.8 metric tons of CO2e per year. However, these three aircraft generate 57 non-ferry flights from their current bases, and these flights would migrate to Hanscom, adding to Hanscom operations. Net operations at Hanscom, without considering any new aircraft enabled by the project, would be reduced by 75 landings/takeoffs per year out of 38,100, or 0.2%. In addition to the three relocated aircraft, the remaining new hangar capacity could eventually hold 63-76 new aircraft, increasing operations by an estimated 5,487 to 6,568 flights per year and generating approximately 133,784 to 161,390 metric tons of CO2e per year of GHG emissions. These new emissions are approximately 950 to 3,900 times greater than those saved by elimination of ferry flights. Netting out emissions reductions from eliminated ferry flights, these additional aircraft at Hanscom are estimated to generate approximately 133,643 to 161,348 metric tons of CO2e per year.

The estimate of 132 ferry flights used in our analysis stands in stark contrast to the project proponent's estimate of 3,543 ferry flights eliminated per year. This overestimation of ferry flight activity by the project proponent stems in large part from its overly broad definition of what constitutes a ferry flight. Excluding flights for aircraft already based at Hanscom, the project proponent designates a flight as a ferry flight if (1) the destination/origin airport is within a 350-mile radius of Hanscom, (2) the flight has an airport ground time of up to 18 hours, and (3) the aircraft is a business aircraft type. The proponent, however, did not analyze flight itinerary data to determine whether the aircraft making the 3,543 flights follow a ferry pattern (i.e., origin to Hanscom, Hanscom to ultimate destination, destination back to Hanscom, and Hanscom back to origin). Therefore, many of the flights that the proponent counts as ferry flights are not ferry flights but instead are travelers making day trips to the Boston area. In addition, although the hangar expansion is intended for based aircraft, the proponent includes transient aircraft in its ferry flight estimate; these aircraft would not relocate to Hanscom as a result of the project. The proponent also failed to examine the full flight itinerary data for the aircraft it identified in its ferry flight analysis to

[1] The project is 522,380 square feet gross, made up of 395,700 square feet of open hangar and 126,680 of ancillary and support space.

determine if an aircraft owner would likely find it advantageous to relocate its aircraft to Hanscom. If an aircraft ferries to Hanscom for just a small fraction of its flights, relocating the aircraft to Hanscom would likely increase its operating costs, making relocation to Hanscom unlikely. Therefore, to the extent that a given aircraft reflected in the proponent's ferry flight estimate ferries to/from Hanscom for a small fraction of its operations, it is unlikely to relocate to Hanscom, and its ferry flights would not be eliminated as a result of the project.

The project proponent also includes ferry flights from Boston's Logan International Airport in this estimate. However, the data show that no aircraft based at Logan airport exhibit ferry flight activity through Hanscom Field. Therefore, this project would not relieve Logan from private jet ferry flight activity. Instead, additional aircraft based at Hanscom Field as a result of this project could lead to *increased* ferry flights to other hangar-limited airports such as Logan.

In addition to overestimating ferry flights to/from Hanscom, the project proponent incorrectly assumes that the addition of hangar capacity at Hanscom would not affect the annual number of flights, stating that growth in operations simply reflect national and local economic trends. This assumption does not comport with text in the FAA's Fiscal Years 2018-2038 forecast, which states that growth in flight operations is dependent on infrastructure development within the aviation system.[2] Similarly, the proponent's decoupling of flight operations from hangar capacity is inconsistent with the FAA's Advisory Circular on the development of airport master plans, which states that airports should consider how increased hangar capacity is likely to predict the demand for flights. [3]

Based on our analysis, the proposed project will greatly increase the number of operations at Hanscom Field and the GHG emissions associated with the facility's flight operations. Due to the very small number of aircraft likely to relocate to Hanscom from other airports, the beneficial effect of avoided ferry flights would be insignificant when compared with the substantial increases in operations and GHG emissions expected from new aircraft based at Hanscom Field.

2. Background

GHG emissions associated with aircraft are becoming of increasing societal concern as aviation emissions are projected to grow significantly, in contravention of plans to decrease emissions across other sectors of the economy. According to carbonbrief.org, under a business-as-usual scenario where the aviation industry grows by 5 percent each year and no substantial improvements to technology or infrastructure are made, aviation is estimated to consume 27% of the remaining 1.5 degree C carbon budget between 2015 and 2050.[4] For this reason, it is of special interest to examine portions of the industry that have the highest emission rates per passenger mile. The proposed private jet hangar

[2] Federal Aviation Administration, FAA Aerospace Forecast Fiscal Years 2018-2038.

[3] Federal Aviation Administration, *Airport Master Plans*, as modified January 27, 2015.

[4] Carbon Brief, "Analysis: Aviation could consume a quarter of the 1.5C carbon budget by 2050" , 2016.

project is one of the largest in the U.S. to create infrastructure enabling the further growth of private jet operations and has aroused significant public and governmental concerns.[5]

Hanscom Field General Aviation Airport is owned and operated by Massport, a quasi-state agency in the Commonwealth of Massachusetts. Formerly operated under lease as Hanscom Air Force Base, military flight operations ceased in 1974, and the airport operates under a 1978 Master Plan specifying the types of use the airport provides, which includes general aviation and small commuter aircraft.[6] The airport has two runways of 7,000 and 5,100 feet and is capable of handling all aircraft sizes up to Air Force 1 and other large charter aircraft.

Hanscom Field has the highest volume of general aviation use among airports in New England, with 125,000 operations in 2022, of which jet operations made up 38,400.[7] There is a continuing trend at Hanscom and similar airports where flights by small piston-engine aircraft are declining and flights by private jets are increasing. According to Massport data, from 2019 to 2022 propeller flight operations fell by 15% while private jet operations rose by 16%.[8]

The result of these trends at Hanscom and other airports nationwide is that new hangars are being built for jets, and older small "T" hangars for single engine piston aircraft are being replaced with larger hangars.[9] In the last decade, Massport data show the gross jet hangar space at Hanscom Field has increased from 283,000 sq feet to 478,614 sq ft, representing a 70% increase.[10] The proposed project, at 522,380 gross square feet, represents more than doubling of the airport jet hangar capacity. This single project would add the same level of jet hangar capacity that was built at Hanscom incrementally over the prior 60 years.

Private jet hangars generally fall into two categories: those serving private jet based aircraft, and those serving taxi services, shared, or itinerant aircraft. The latter category is primarily served by "Fixed Base Operators" (FBOs), which provide additional services such as cleaning, conference/meeting space, fueling, and pilot accommodations. Massport has stated at public meetings that the intent is to serve based jet aircraft.[11]

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[5] Epstein, C, "As the Private Aircraft Fleet Grows, Hangar Availability Dwindles", Business Jet Traveler, March 2023. Quoting industry sources that for hangars greater than 30,000 sq "there are probably only 10-15 being built at the moment." Of the projects identified, no project was greater than 300,000 sq ft. The proposed project at Hanscom Field is 522,380 sq ft.

[6] Massachusetts Port Authority, Hanscom Field Master Plan and Economic Impact Statement. June 15, 1978.

[7] Massport, Hanscom Field Annual Noise Report, June 2023, pp.12,18. The sum of 36,808 daytime and 1,617 nighttime jet operations.

[8] Massport, Hanscom Field Annual Noise Report, June 2023, pp12,18. Jets increased from 33,370 to 38,400, while propeller aircraft fell from 87,135 to 74,308. 2019 nighttime data from 2019 Noise Report.

[9] A T-hangar is a type of hangar shaped similarly to a T, consistent with the shape of single engine piston aircraft.

[10] Massport, 2017 Hanscom Field Environmental Status and Planning Report. P 2.7 to 2.11, In 2013, Hangars 1,2,3,10,13,16, and 21 totaled 283,000 sq ft. By the end of 2023 hangars 24, 17, and the recent F4 (Atlantic Aviation) added 196,000 sq ft.

[11] Mike Rosenberg, "According to Massport, New North Airfield Development Will Not Include Fueling, " *The Bedford* Citizen, June 23, 2022 and presentation on North Airfield Project by Sharon Williams, Director of Airport Administration, May 12, 2023, Hanscom Civil Air Terminal, Bedford, MA.

The benefits of jet ownership depend on how conveniently owners may use these aircraft. The location of the airport where a private jet is stored in relation to the owner is therefore critically important, particularly in comparison to alternative travel options. Prospective jet owners local to Hanscom Field who are considering the acquisition of an aircraft need a hangar where they can store it. Massport reports that there is currently a waiting list for private jet hangar space, and that it would like to provide hangar capacity to meet future anticipated demand. While the proposed project at Hanscom is claimed to be a response to this demand, the FAA advises that providing convenient hangar capacity itself can drive demand (i.e., demand is conditional on the availability of convenient hangar capacity).

The Draft Environmental Impact Report as well as project plans and descriptions released by the project proponent and Massport to date assert that no new greenhouse gas emissions will be created by the additional private jet aircraft enabled by the proposed hangar capacity. They further claim that the project will reduce GHG emissions from jets. In a recent letter from the proponent to the community they represent that: "…the Project would result in environmental benefits associated with reduced air emissions by reducing overall aircraft trips. Currently, aircraft fly in and out empty to pick up and drop off aircraft operators who cannot secure aircraft storage space at Hanscom, as well as employees of Massachusetts-based companies located in close proximity to the Airport. This practice results in extra flights (referred to as "ferry flights") that would otherwise not be required with aircraft stored at Hanscom."[12] Massport and the proponent claim that there are many current jet owners who would like to base their aircraft at Hanscom Field but cannot due to the lack of hangar capacity at Hanscom. These jet owners purportedly base their aircraft at other nearby airports and summon their aircraft to pick them up at Hanscom Field. When these travelers return from their destination, their aircraft drop them off at Hanscom and return to the nearby base for storage. These "short hop" flights without passengers are a type of "ferry flight."

If additional Hangar capacity were to become available at Hanscom Field, Massport and the project proponent have represented that certain aircraft that regularly make ferry flights to Hanscom Field would relocate to Hanscom, thereby eliminating their ferry flights and the associated GHG emissions.

According to industry trade press, typical private jets require approximately 5,000-6,000 sq ft of hangar space.[13] Based on this figure and the proposed 395,700 sq ft of hangar space that would be added at Hanscom Field under the proposal, the proposed project could serve 66-79 jet aircraft.[14] If all the new hangar capacity created by this project were to serve aircraft exhibiting ferry flights for the majority of their operations, the proposal would result in a net decrease in GHG emissions and aircraft operations. If none of the new capacity were to serve such aircraft, the total jet emissions that are enabled by the 66-79 new aircraft housed by this project would represent a large increase of Hanscom-enabled emissions and operations. Determining the expected magnitude of these effects requires estimation of the number of aircraft currently exhibiting ferry flight operational behavior, along with their operations and emissions.

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[12] Michael Argiros of North Airfield Ventures, letter addressed to citizen group Mothers Out Front, Jan 8, 2024.

[13] Epstein, C, "As the Private Aircraft Fleet Grows, Hangar Availability Dwindles", Business Jet Traveler, March 2023. Quoting industry sources, noting some new very large international private jet aircraft require up to 11,000 sq ft.

[14] In the DEIR (p. 2-6), the proponent assumes 40 to 55 aircraft would be accommodated in the proposed hangars but does not provide a basis for this assumption.

This study estimates these effects based on historical flight data and the GHG emissions profile of these aircraft.

The proponent has suggested in the Draft Environmental Impact Report that future aircraft emissions may be reduced via electrification of some aircraft or the use of Sustainable Aviation Fuels (SAF). The US National 2021 Aviation Climate Plan does not expect electric aircraft to replace jets by 2050.[15] Electrification faces the fundamental technical barrier that all known battery technologies are 20 times heavier per unit energy than jet fuel.[16] SAF is today produced in very small quantities and has a high cost; therefore, it is not a near-term option for achieving significant GHG reductions from the aviation sector.[17] For these reasons, and due to no specific proposals in the project related to these hypothetical technologies, the use of conventional jet fuel for the aircraft enabled by this project is assumed for the foreseeable future.

For the purposes of this analysis, we assume that any hangar capacity built at Hanscom will be fully utilized.

3. Defining Ferry Flights

As described above, the expansion of hangar capacity at Hanscom is expected to result in the relocation of certain aircraft that regularly make ferry flights there from their current home base. This section explains what a ferry flight is, what types of aircraft are considered in this analysis of ferry flights, and what the impact of moving an aircraft from its home base to a ferry airport would be. In addition, this section identifies the specific types of ferry flights that would potentially influence the decisions of aircraft owners to relocate their aircraft to Hanscom Field if the proposed hangar capacity were developed.

3.1 Definition of a Ferry Flight

A flight pattern that is considered a "ferry flight" is defined as follows:

1. A flight departs a "home base" airport, where the aircraft is hangared/parked, to an intermediate "Ferry" airport. This flight is generally without revenue-generating passengers or cargo and is known as the FERRY TO flight.
2. The flight lands at the intermediate Ferry airport, takes on passengers/cargo, and flies to a destination airport.
3. The flight may pause at the destination airport or go on to make other flights (including returning to the home-base airport).
4. The flight departs the destination airport with passengers/cargo and returns to the intermediate Ferry airport where the passengers/cargo are deplaned.
5. The flight departs the intermediate Ferry airport for the home-base airport. This flight segment is known as the FERRY FROM flight.

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[15] Federal Aviation Administration, *2021 Aviation Climate Action Plan*, p 14

[16] Crownhart, C "This is what's keeping electric planes from taking off" *Technology Review*, August 2022.

[17] Pavlenko, et al, "Assessing sustainability implications of sustainable aviation fuels," International Council on Clean Transportation, March 2021. Noting on p14 that "simply displacing petroleum jet fuel with any alternative jet fuel will be insufficient to drive deep decarbonization in aviation."

An example flight pattern that includes FERRY TO and FERRY FROM flight segments is shown below. The home-base airport is KASH (Boire Field in Nashua, New Hampshire). The intermediate ferry airport is KBED (Hanscom Field, Massachusetts). The destination airport is KXXX. Other destination airports that do not involve the ferry airport are KYYY.

- KASH→KBED (FERRY TO)
- KBED → KXXX
- KXXX→ KYYY → ….. → KASH → KYYY → KXXX
- KXXX→ KBED
- KBED → KASH (FERRY FROM)

It should be noted that a given aircraft may not perform a symmetrical ferry flight. For example, for air taxi, charter, or owners with more than one aircraft, a specific aircraft may perform the FERRY TO flight segment, while another aircraft owned by the same operator, performs the FERRY FROM flight segment.

Not all aircraft that exhibit the ferry flight behavior described above would be candidates for re-basing at Hanscom if the proposed hangar project were to be developed. In particular, itinerant aircraft that engage in a ferry flight pattern of travel would not re-base at Hanscom because the proposed expansion of hangar capacity is intended to serve based aircraft only. Similarly, piston-engine aircraft that ferry to and from Hanscom would not be candidates for re-basing into the proposed facility since the hangar capacity proposed is a high-end facility designed for *jet* aircraft, and other smaller hangars exist for propeller aircraft. Aircraft may also exhibit ferry behavior for reasons unrelated to the choice of home base, such as ferry flights for routine maintenance or training. Aircraft with a ferry flight pattern for these reasons would not be candidates for re-basing at Hanscom. Finally, owners of aircraft that make a relatively small number of ferry flights to Hanscom are unlikely to have a strong economic incentive to re-base their aircraft at Hanscom, as re-basing would increase the need for ferry flights to the airport where they are currently based.

3.2 Ferry Flights Considered in Analysis

Based on the considerations outlined above, this analysis focuses narrowly on ferry flights for aircraft that would be legitimate candidates for re-basing at Hanscom based on aircraft type and individual aircraft's pattern of travel. Specifically, aircraft were considered as candidates for re-basing to Hanscom if they met all of the following criteria:

1. **Jet aircraft:** While ferry flights can be performed by many different types of aircraft, this analysis considers only **jet** aircraft as candidates for relocating their home base at Hanscom. The hangars proposed in this project are specifically designed to accommodate jet aircraft, and the airport recently added additional smaller hangars for propeller aircraft. Of Hanscom Field's total operations, jet aircraft comprise approximately 30 percent.[18] The remaining 70 percent of operations are attributable to non-jet aircraft, which may exhibit significant ferry flight behavior but are not included in this analysis. Nevertheless, the proponent did identify a particular

[18] Massport, Hanscom Field Annual Noise Report, June 2023, pp.12,18. The sum of 36,808 daytime and 1,617 nighttime jet operations.

propeller aircraft as a major contributor to ferry flights, and a special analysis of this type of aircraft was added to this study.

2. **Based (jet) aircraft:** In addition to being jets, the aircraft potentially re-locating to Hanscom must be **based aircraft** as opposed to itinerant aircraft that provide air taxi or related services. Based on representations made by Massport and the project proponent, the proposed hangar capacity at Hanscom is not designed to serve itinerant aircraft. [19]

3. **Ferry flights to/from Hanscom make up a large portion of the aircraft's operations:** For a given aircraft, ferry flights to/from Hanscom Field may make up a large or small part of its operations. The owner of an aircraft is unlikely to benefit by re-locating that aircraft at Hanscom if most of the aircraft's operations are NOT ferry flights to/from Hanscom Field, but rather other flights to/from the aircraft's current base. To determine which jet aircraft exhibit enough ferry behavior to qualify for relocation to Hanscom Field, a threshold must be established. For this analysis, we assume that more than 50 percent of an aircraft's flights to/from its current base must exhibit ferry behavior for it to qualify. Otherwise, there is likely no net benefit to relocation to Hanscom, and such relocation would actually increase an aircraft's flight operations at Hanscom, contrary to the reduction benefit claimed by the proponent.

3.3 Impact of Moving Home-Base Hangar to Ferry Flight Airport

If the home base for an aircraft were relocated from its current base to Hanscom, this would have two impacts on operations at Hanscom. First, the ferry flights that the aircraft currently takes to/from Hanscom would be eliminated. For instance, if the aircraft from the example in Section 3.1 above were moved from its current home base (e.g., KASH) to Hanscom (e.g., KBED), the following flights would be *eliminated* from Hanscom (i.e., the current intermediate FERRY airport):

- FERRY TO flights (e.g., KASH → KBED)
- FERRY FROM flight (e.g., KBED → KASH)

The second effect of base relocation to Hanscom would be the *addition* of non-ferry flights that the aircraft in question currently takes to/from its current base airport:

- NON-FERRY flights that currently depart from/arrive at KASH (e.g., KASH → KYYY, KZZZ → KASH)

For aircraft that re-locate their base to Hanscom, these non-ferry flight operations would contribute to increased operations at Hanscom. The GHG emissions associated with these non-ferry flights, however, are excluded from the analysis of GHG impacts presented below since these emissions are generated in the baseline (i.e., absent the expansion of hangar capacity at Hanscom).

It is important to note, however, that flight patterns may change over time as a result of changes in aircraft ownership or aircraft hangar leasing arrangements.

[19] Mike Rosenberg, "According to Massport, New North Airfield Development Will Not Include Fueling, " *The Bedford* Citizen, June 23, 2022 and presentation on North Airfield Project by Sharon Williams, Director of Airport Administration, May 12, 2023, Hanscom Civil Air Terminal, Bedford, MA.

4. Collection and Processing of Flight Data

This analysis uses Automatic Dependent Surveillance – Broadcast (ADS-B) flight track data from a third-party provider for the October 2022 to October 2023 period to assess the number of ferry flights to and from Hanscom Field. ADS-B is an aviation surveillance technology in which an aircraft determines its position via satellite navigation or other sensors and periodically broadcasts its identifying information, position, and other related data. These broadcasts are picked up by ADS-B Receivers, which are used to detect and track aircraft equipped with ADS-B transponders. The flight track data used in this analysis were provided by a third-party volunteer network of ADS-B Receivers and processed into a flight origin/destination format. The data were also cross-checked and validated with other volunteer ADS-B networks and publicly available Federal Aviation Administration (FAA) data.

Based on the criteria outlined in Section 3.2 above for identifying aircraft as candidates for relocation to Hanscom Field based on aircraft type and ferry flight travel patterns, we processed the ADS-B data according to the following procedure to identify aircraft that may potentially re-locate to Hanscom:

1. ***Identify aircraft flying into or out of Hanscom:*** Aircraft tail number has KBED listed as the origin and/or destination.

2. ***Limit aircraft to jets:*** Limit data from previous step to aircraft/tail numbers for which Turbo-Fan or Turbo-Jet is listed as the engine type.

3. ***Focus on aircraft with minimum threshold of operations:*** Aircraft with minimum flight operations activity are unlikely to be re-based at Hanscom, as the cost savings associated with doing so are likely to be minimal. We therefore limit our analysis to jet aircraft that operated more than 20 times during the one-year period examined.

4. ***Set distance threshold for potential ferry flights:*** To exclude flights that are not likely to be ferry flights from the data generated from the previous steps, the analysis was limited to flights meeting the following criteria:
    a. To KBED from an origin within 120 nautical miles of KBED; or
    b. From KBED to a destination within 120 nautical miles of KBED.

5. ***Limit analysis to aircraft that are likely to be based aircraft:*** The steps outlined above may identify both based aircraft and itinerant aircraft that exhibit ferry flight behavior. To limit the analysis to based aircraft (i.e., exclude itinerant aircraft), we specified two criteria for filtering the data:
    a. Aircraft destination from KBED or origin prior to arrival at KBED is one of the four most frequented destinations or origins for the aircraft.
    b. The aircraft has overnighted at that destination or origin (above) more than any other airport (i.e., the aircraft is based at that airport).

    This consistency of pattern in terms of origin/destination better aligns with the travel behavior of a based aircraft than an aircraft that frequently moves between locations to maximize operator revenue (e.g., fractional jet itinerant operations).

4.1 Estimated Number of Aircraft Relocating to Hanscom

The criteria outlined above identified jet aircraft that are candidates for relocating their home base to Hanscom Field. With additional hangar capacity available at Hanscom, re-locating an aircraft's home base would be at the discretion of the aircraft's owner. For the purposes of this analysis, we assume that

an aircraft owner would change an aircraft's home base to Hanscom if 50 percent of the aircraft's current flights to/from its current home base are ferry flights from/to Hanscom Field.[20] The rationale behind this assumption is that relocation of the aircraft's home base to Hanscom would provide an added level of convenience and/or cost savings for the aircraft owner if the owner ferries the aircraft to/from Hanscom for the majority of its flights to/from its current home base. If less than 50 percent of the flights to/from the aircraft's current home base do not exhibit a ferry travel pattern to/from Hanscom, this would imply that the added convenience of re-locating the aircraft's home base to Hanscom would be less than the level of convenience afforded by the current home base. Furthermore, the current aircraft operations that did not ferry through Hanscom would now occur at Hanscom, which would more than offset any savings in ferry flights. The relocation would result in a net increase in Hanscom operations, which is directly contrary to the proponent's representation that eliminating ferry flights leads to a decrease in operations.

Based on this rationale, we compared the number of departures from and returns to each candidate aircraft's home base to the number of ferry flights to and from KBED. Three aircraft meeting the criteria outlined above were identified as having more than 50 percent of their base flights exhibiting ferry behavior. The flight track data for these three aircraft identified a total of **132 ferry flights in and out of Hanscom Field** during the one-year data collection period. Two of these aircraft are currently based at Boire Field in Nashua, New Hampshire; the other is currently based in Portsmouth, New Hampshire. There are five jet aircraft that meet the five criteria outlined above but for which ferry flights to/from Hanscom make up between 5 and 50 percent of their base flights, which are based in Lawrence (KLWM), Waterbury-Oxford (KOXC), Plymouth (KPYM), and Marshfield (KGHG); those aircraft would be poor candidates for relocation to Hanscom.

In reviewing the ferry flight data, we also identified no ferry flights between Boston's Logan International Airport and Hanscom. Instead, additional aircraft based at Hanscom Field as a result of this project could lead to increased ferry flights to other hangar-limited airports such as Logan.

4.2 Project Proponent Ferry Flight Estimate

In its assessment of the potential environmental effects of the proposed hangar expansion at Hanscom, the project proponent produced its own estimate of the annual number of ferry flights that would be avoided as a result of the project.[21] The proponent's estimate of 3,543 ferry flights per year stands in stark contrast to the estimate of 132 ferry flights per year presented in this analysis. For the various reasons described below, we conclude that the proponent's estimate is a gross overestimation of the number of ferry flights that would be avoided due to the project.

[20] This 50 percent threshold is relative to flights to/from the aircraft's home base. Flights not involving an aircraft's home base are excluded from the calculation, as such flights are assumed not to influence decisions about re-locating the aircraft to Hanscom.

[21] VHB, L.G. Hanscom Field North Airfield Development Bedford, Massachusetts - Draft Environmental Impact Report. EEA No. 16654, March 2024.

To understand why the proponent's analysis overestimates ferry flights for aircraft likely to relocate to Hanscom, it is instructive to state the four criteria used by the proponent to identify ferry flights. These include:[22]

- Business aircraft type and commercial aircraft operations;
- "Short Turn" flights with airport ground time of up to 18 hours;
- Not Hanscom Field tenant aircraft; and
- The destination/origin airport is within a 350-mile radius of Hanscom.

The proponent's reliance on these criteria yields an inaccurate estimate of ferry flight activity at Hanscom, due to both the incompleteness of these criteria and the bias associated with certain individual criteria. More specifically, these shortcomings are as follows:

The proponent failed to determine whether the flight itineraries for aircraft making so-called ferry flights exhibit a ferry flight pattern of activity. By definition, an aircraft making ferry flights to Hanscom travels there with no passengers onboard, picks up passengers, continues from Hanscom to another destination, brings the passengers back to Hanscom from that destination, and finally returns to its base. If an aircraft were to fly to Hanscom and subsequently return to its location of origin on its next flight, the flight to Hanscom would not be a ferry flight. Thus, an essential criterion for correctly identifying a flight as a ferry flight is that the aircraft in question follows a ferry pattern consistent with that outlined above. Because the proponent's analysis does not apply this criterion, its ferry flight estimate likely includes many flights that are not ferry flights (e.g., flights for aircraft that transported passengers to Hanscom and subsequently returned them to their location of origin). Making such a determination requires detailed analysis of aircraft-specific flight itinerary data (i.e., landings and takeoffs by date, time, and location). The project proponent's aviation consultant specifically stated during the February 20 presentation of its analysis prior to the DEIR release that it did not attempt to conduct such an analysis of itinerary data.[23]

The proponent's analysis includes both based aircraft and transient aircraft. The project proponent has represented that the additional hangar capacity proposed at Hanscom would serve based aircraft rather than transient aircraft.[24] However, the proponent's ferry flight analysis does not distinguish between based aircraft and transient aircraft and therefore includes transient aircraft, such as NetJets, that would not be candidates for relocation to Hanscom. Due to its inclusion of transient aircraft, the project proponent systematically overestimates the number of ferry flights by aircraft that might relocate to Hanscom as a result of the project.

The proponent incorrectly assumes that all ferry flights to Hanscom would be eliminated as a result of the hangar expansion. Using the criteria outlined above, the project proponent estimates the annual number of ferry flights to and from Hanscom and assumes that all of these ferry flights would be

[22] These criteria are as listed in section 2.3.2 of VHB, L.G. Hanscom Field North Airfield Development Bedford, Massachusetts - Draft Environmental Impact Report. EEA No. 16654, March 2024.

[23] Presentation delivered by Kate Larson of HMMH, February 20, 2024.

[24] Mike Rosenberg, "According to Massport, New North Airfield Development Will Not Include Fueling, " *The Bedford* Citizen, June 23, 2022 and presentation on North Airfield Project by Sharon Williams, Director of Airport Administration, May 12, 2023, Hanscom Civil Air Terminal, Bedford, MA.

eliminated by the project. This assumption fails to account for the decision-making process of aircraft owners, who make decisions on where to hangar their aircraft based on all of the expected operations for that aircraft rather than just a subset. For example, an aircraft based in Nashua may make 2 ferry flights per year to Hanscom but makes 48 (non-ferry) flights from Nashua to other destinations. Because ferry flights to Hanscom make up such a small portion of the aircraft's annual flights, the aircraft operator in this case is unlikely to relocate the aircraft to Hanscom. Otherwise, the operator would likely need to ferry the aircraft from Hanscom to Nashua for several of its other flights. By not accounting for this decision-making process, the proponent overestimates the number of ferry flights that would be avoided due to the project.

The 18-hour ground time is unrealistically long for a ferry flight: The proponent's analysis assumes that flights to Hanscom with airport ground time of up to 18 hours may be ferry flights. This cutoff is unrealistically high, and the proponent did not attempt to validate this assumption with data for known ferry flights. Because the purpose of a ferry flight is to pick up passengers at Hanscom and take them to another destination or to return an aircraft to its base after dropping passengers off at Hanscom, the ground time for such flights is unlikely to be more than a few hours. Flights with 18 hours of ground time are more likely to be flights bringing business travelers to Hanscom for a day of business meetings in the Boston area. The facilities at Hanscom include conference room space for this purpose.

The 350-mile radius for identifying ferry flights is excessively far for a ferry flight: The proponent's analysis also assumes that flights arriving to Hanscom from within a 350-mile radius of the facility are ferry flights if they meet the proponent's other criteria. For based aircraft that may be relocated to Hanscom, this distance is unrealistically far for ferry flight activity, as it implies that aircraft owners located near Hanscom hangar their aircraft up to 350 miles away and incur the additional time and fuel costs of ferrying them to Hanscom when much closer options are available.

Taken together, the limitations of the proponent's approach for identifying ferry flights are likely to mischaracterize a large number of flights as ferry flights. Potential examples include the following:

- If a business traveler from Philadelphia (within the proponent's 350-mile radius) were to fly to Hanscom at 9:00 a.m., attend meetings near Hanscom during the day, and fly back to Philadelphia at 9:00 p.m., the proponent would count this as a ferry flight. When asked about this example during a February 20 presentation of its analysis, the project proponent confirmed that this would be counted as a ferry flight.
- If an individual based on Martha's Vineyard flew his/her jet to Hanscom on a Saturday afternoon to attend a Red Sox game and subsequently flew back to Martha's Vineyard that night, this would also be counted as ferry flight under the proponent's approach. During its February 20 presentation of its analysis, the proponent confirmed that this would also be counted as ferry flight.
- NetJets and air taxi services rely extensively on repositioning flights so that they can meet demand at individual airports. Any repositioning flights that meet the proponent's criteria would be counted as a ferry flight, as confirmed by the project proponent at the February 13 meeting of the Massport Community Advisory Committee. However, none of these flights are ferry flights, and none of these flights would be eliminated as a result of the proposed hangar expansion.

4.3 Ferry Flights from Logan Airport

In addition to the major shortcomings in the proponent's approach described above, the proponent's analysis indicates that many of the ferry flights to Hanscom originated from the Boston Logan Airport. More specifically, during the February 13 meeting of the Massport Community Advisory Committee, the proponent's consultant indicated that 300 ferry flights originate from Logan.[25] However, during that same February 13 meeting, a Massport representative indicated that there are no based private jets at Logan Airport. Therefore, the proposed hangar expansion at Hanscom would not eliminate any ferry flights from Logan. On the contrary, if there are no based private jets at Logan, the development of hangar capacity at Hanscom may provide an additional source of ferry flights to Logan, increasing operations there.

4.4 Project Proponent Inclusion of PC-12 Aircraft in Ferry Flight Analysis

The project proponent's analysis of ferry flights potentially avoided as a result of the project found that flight operations for turboprop Pilatus PC-12 aircraft represent 28 percent of all ferry flights to/from Hanscom.[26] Based on the proponent's estimate of 3,543 ferry flights, this would imply 992 avoided ferry flights by PC-12 aircraft.

The Pilatus PC-12 is configured like a jet and commonly used as a jet alternative for short trips. There is a fleet of 60 of these aircraft at a time share operator based in Portsmouth, said to be the "the world's largest fleet of Pilatus Aircraft." This fleet of PC-12 aircraft is dispatched to many sites to pick up passengers including at Hanscom Field. Such a service can be considered an itinerant aircraft and would not be a candidate for relocation at Hanscom. Nevertheless, since the proponent represented this aircraft to be the principal type of aircraft generating ferry flights, its detailed operations were studied as part of this report.

We analyzed the flight operations data for all PC-12s flying into or out of Hanscom between August 2023 and March 2024. Using the same data and methods as outlined above for jet aircraft (i.e., the methods applied in this analysis rather than the methods applied by the project proponent), we identified just 49 PC-12 aircraft making 284 ferry flights to or from Hanscom during this period. Extrapolating to a full year, we estimate 426 ferry flights by these aircraft. As described above, Hanscom ferry flights for a given aircraft will be avoided only if more than 50 percent of its flights to/from its current base are ferry flights to/from Hanscom. Based on the data for the PC-12 aircraft that exhibit this ferry flight pattern, none of these aircraft meet the 50 percent threshold that would indicate a benefit from relocating to Hanscom. On average, Hanscom ferry flights represent approximately 9 percent of the flights to/from the current base for these aircraft. This level and type of activity is expected since the large PC-12 fleet services the northeast region and Hanscom is the largest jetport in New England. On this basis, none of the PC-12 flights identified as ferry flights in the proponent's analysis are likely to be avoided as a result of the proposed expansion of Hangar capacity at Hanscom.

[25] Presentation delivered by Kate Larson of HMMH, Meeting of the Massport Community Advisory Committee, February 13, 2024.

[26] VHB, L.G. Hanscom Field North Airfield Development Bedford, Massachusetts - Draft Environmental Impact Report. EEA No. 16654, March 2024, p.2-8.

5. Scope of GHG Emissions Captured

This analysis captures the full breadth of GHG emissions associated with jet aircraft. To capture all GHGs emitted through the operation of jet aircraft, this analysis first calculates emissions of carbon dioxide (CO_2). Rather than calculating emissions of other GHGs individually, this analysis calculates emissions of carbon dioxide equivalents (CO2e) based on estimated emissions of CO_2. CO2e is a unit that standardizes and compares the emissions and warming effects of different GHGs based on their global warming potential. The CO2e emissions presented in this report reflect CO_2, ozone (O_3), methane (CH_4), and water vapor (H_2O). To calculate CO2e emissions based on estimates of CO_2, this analysis uses a multiplier of 2 based on existing literature. As indicated by the IPCC, the overall radiative forcing by CO2e from aircraft is 2-4 times larger than the forcing by CO_2 alone.[27] Based on this range, the multiplier of 2 applied in this analysis results in a conservative estimate of GHG impacts.

6. Analysis and CO2e Effects

The analysis of GHG emissions impacts presented in this report includes four main components:

1. ***Ferry Flight Emissions Analysis:*** estimates the annual emissions reductions resulting from the elimination of existing ferry flights to and from Hanscom Field due to aircraft relocation.
2. ***Additional Based Aircraft Analysis:*** estimates the annual GHG emissions produced from a single based aircraft at Hanscom Field.
3. ***Breakeven Analysis:*** explores how many based aircraft would need to be added at Hanscom Field to completely offset the emissions reductions from eliminated ferry flights.
4. ***Full Capacity Analysis:*** estimates the annual GHG emissions associated with the Hanscom Field expansion project if all new hangar space is fully utilized, net of GHG savings from avoided ferry flights.

This section presents the methods and results (in CO2e) for each of these analysis components.

6.1 Ferry Flights Analysis

This section estimates the annual GHG emissions reductions resulting from the elimination of ferry flights to and from Hanscom Field for those jet aircraft identified as likely to re-locate. The analysis presents two different estimates of these impacts: one derived from the Federal Aviation Administration's (FAA's) Aviation Environmental Design Tool (AEDT) and another based on fuel consumption rates for representative aircraft, as obtained from JetAdvisors.

AEDT Estimate

This emissions reductions estimate is calculated using the results of an AEDT run focused on the three aircraft identified as likely to re-locate to Hanscom. Based on the aircraft identifying information included in the flight track data used to identify ferry flights, the aircraft likely to relocate to Hanscom include a Cessna 700 Citation Longitude, a Gulfstream IV, and a Hawker 900XP. The following equation outlines

[27] Intergovernmental Panel on Climate Change (IPCC). 1999. "IPCC Special Report: Aviation and the Global Atmosphere," page 8-9. Available at: https://www.ipcc.ch/site/assets/uploads/2018/03/av-en-1.pdf.

the calculation of the ferry flight GHG emissions avoided if these aircraft were to relocate to Hanscom Field:

$$EmissionsAvoided = LTO \times GHG_{LTO}$$

Where:

- *EmissionsAvoided* is the annual GHG emissions avoided
- *LTO* is the number of ferry flights (landings and takeoffs) to and from Hanscom Field per year.
- GHG_{LTO} is the amount of CO2e produced per ferry flight.

As presented above, this analysis estimates a total of 132 ferry flights in and out of Hanscom Field per year for the aircraft likely to relocate to Hanscom if hangar capacity is developed. To estimate the CO_2 emitted per ferry flight, the AEDT run calculated emissions down from 10,000 feet (for landings) and up to 10,000 feet (for takeoffs). The average emissions for a single LTO across the three aircraft types was approximately 158.8 kg (0.16 metric tons) of CO_2. Applying the factor described above to calculate CO2e emissions, we estimate CO2e emissions of 317.6 kg (0.32 metric tons). For 132 avoided ferry flights, this yields a total estimate of 41.9 metric tons of CO2e avoided per year by the elimination of ferry flights at Hanscom Field.

Fuel Consumption-Based Estimate

As an alternative to estimating GHG emissions savings based on AEDT, we calculated these impacts based on the average fuel consumption per ferry flight. The following equation outlines this approach for calculating emissions reductions:

$$EmissionsAvoided = LTO \times Fuel_{LTO} \times GHG_{gal}$$

Where:

- *LTO* is the number of ferry flights (landings and takeoffs) to and from Hanscom Field per year.
- $Fuel_{LTO}$ is the average fuel consumption in gallons per ferry flight.
- GHG_{gal} is the amount of CO2e produced per gallon of jet fuel consumed.

For the number of ferry flights per year (*LTO*), the analysis applies the same estimate of 132 ferry flights in and out of Hanscom Field per year as applied in the AEDT analysis.

To estimate the average fuel consumption per ferry flight, we assume a one-way distance of 33 miles per ferry flight. This value represents the weighted average distance of ferry flights to Hanscom among the three aircraft likely to relocate to Hanscom if hangar capacity is developed there, using the number of ferry flights per aircraft as weights. Average fuel consumption per ferry flight was calculated by scaling the estimated fuel consumption for a 300-mile flight down to a 33-mile flight. This estimate is based on aircraft specifications from JetAdvisors for the three aircraft types described above and is scaled down by 1/5th to account for the difference in flight distance and to reflect the fact that ferry flights are likely to

be more fuel intensive per mile traveled (due to limited cruising) than the typical flight.[28,29] This produces an average estimate of 54.7 gallons of fuel consumed per ferry flight across the three aircraft types.

The amount of CO2 emitted per gallon of jet fuel consumed (GHG_{gal} in the above equation) is estimated to be 9.75 kg.[30] Applying the factor of 2 described above, this translates to 19.5 kg of CO2e per gallon (0.0195 metric tons).

Applying these values to the equation presented above, we estimate annual ferry flight emissions of approximately 140.8 metric tons of CO2e for aircraft that would be likely to relocate to Hanscom if hangar capacity were to become available (132 ferry flights × 54.7 gallons of fuel per flight × 0.0195 metric tons of CO2e per gallon = 140.8 metric tons).

Comparison of Ferry Flight Emissions Estimates

The estimates of avoided ferry flight emissions based on the two approaches outlined above differ significantly, with the AEDT-based approach at 41.9 metric tons of CO2e per year and the fuel consumption-based approach at 140.8 metric tons per year (see Table 1). This is likely due to the latter approach applying a conservative assumption that fuel consumption per 33-mile ferry flight would be one-fifth the fuel consumption of a 300-mile flight. Due to the lower speeds for landing and takeoff and the energy required for takeoff, the relationship between flight distance and flight time is unlikely to be linear. However, it is likely that fuel consumption for a 33-mile flight is less than one-fifth the fuel consumption for a 300-mile flight. Thus, the fuel consumption-based value may overestimate CO2e savings from eliminated ferry flights.

Table 1. Ferry Flight Analysis Inputs and Results

Assumptions/Estimates		Assumed or Estimated Value
Key Inputs	Number of ferry flights[1]	132
	Distance per ferry flight[1]	33 miles
CO2e Estimates	AEDT-based estimate of CO2e emissions	41.9 metric tons CO2e per year
	Fuel consumption-based estimate of CO2e emissions	140.8 metric tons CO2e per year

Notes:

1. Number of ferry flights and distance per ferry flight derived from Automatic Dependent Surveillance – Broadcast (ADS-B) flight track data.

[28] JetAdvisors, LLC. Performance Statistics for Cessna Citation Longitude, Gulfstream G-IV, and Hawker 900XP; accessed at https://jetadvisors.com/; December 12, 2023. Based on the JetAdvisors data, we estimate an average fuel consumption of 363 gallons per hour for these aircraft.

[29] The relationship between miles traveled and flight time is not direct since landing and takeoff involve lower speeds than cruising. This 1/5th scaling factor is considered to be conservative, which may result in overestimation of emissions.

[30] US EPA, Emission Factors for Greenhouse Gas Inventories, 2014.

6.2 Analysis of Annual Emissions per Additional Based Aircraft

This section estimates the annual emissions produced per additional based aircraft hangared at Hanscom Field. The following equation outlines the calculation of these emissions:

$$EmissionsAdded_{ac} = Fuel_{gal} \times Hours \times GHG_{gal}$$

Where:

- $Emissionsadded_{ac}$ is the annual GHG emissions added per based aircraft.
- $Fuel_{gal}$ is the average fuel consumption in gallons per hour per aircraft.
- *Hours* is the annual number of operating hours for one jet aircraft.
- GHG_{gal} is the amount of CO2e emitted per gallon of jet fuel consumed.

For the average fuel consumption per hour ($Fuel_{gal}$), we assumed the same value (363 gallons per hour) as used for the fuel consumption-based estimate of avoided ferry flight emissions presented above. This value reflects fuel consumption data published by JetAdvisors for the three specific jet models included in the ferry flight analysis. By using the same aircraft mix as in the ferry flight analysis, we ensure that any differences between our estimates of avoided ferry flight emissions and increased emissions for additional aircraft based at Hanscom reflect changes in flight activity rather than differences in the assumed GHG intensity of ferry aircraft versus new aircraft based at Hanscom.

Average annual operating hours (*Hours*) are estimated to be 300 hours per aircraft based on publicly available estimates obtained from the literature.[31,32]

Lastly, the emissions factor for CO2e emissions is estimated as 19.5 kg (0.0195 tons) of CO2e per gallon of jet fuel consumed.[33] This is consistent with the value used above for estimating ferry flight emissions.

Applying these inputs to the formula above, we estimate that each additional based aircraft at Hanscom would have annual CO2e emissions of 2,124 metric tons (363 gallons per hour × 300 hours per year × 0.0195 metric tons of CO2e per gallon = 2,124 metric tons).

6.3 Breakeven Analysis

This section presents a breakeven analysis to determine how many based aircraft would need to be added at Hanscom Field for the incremental emissions to completely offset the emissions avoided from the elimination of ferry flights. The breakeven analysis utilizes the results from the Ferry Flights Analysis (section 6.1) and the Additional Based Aircraft Analysis (section 6.2). In this analysis we assume that the three aircraft responsible for the ferry flights relocate to Hanscom, and that the only effect of those aircraft is the elimination of ferry flight GHG emissions. The following equation summarizes the

[31] Gossling, S. and Humpe, A. 2020. "The Global Scale, Distribution, and Growth of Aviation: Implications for Climate Change." *Global Environmental Change, 65*. Available at: https://www.sciencedirect.com/science/article/pii/S0959378020307779.

[32] Gudmundsson, S. 2022. "Chapter 2 – Aircraft Cost Analysis." *General Aviation Aircraft Design (Second Edition).* Available at: https://www.sciencedirect.com/science/article/abs/pii/B9780128184653000033.

[33] Value based on estimate of 9.75 kg of CO2 per gallon, as specified in US EPA, Emission Factors for Greenhouse Gas Inventories, 2014. A multiplier of 2 was applied to this value to convert to CO2e. This factor was obtained from IPCC, 1999, "IPCC Special Report: Aviation and the Global Atmosphere," available at: https://www.ipcc.ch/site/assets/uploads/2018/03/av-en-1.pdf.

calculation of the number of additional based aircraft needed for incremental emissions added to equal emissions avoided:

$$Aircraft_{Based} = \frac{EmissionsAvoided}{EmissionsAdded_{ac}}$$

Where:

- $Aircraft_{Based}$ is the number of new aircraft needed for the incremental GHG emissions to offset the GHG emissions savings from avoided ferry flights.
- *EmissionsAvoided* are the emissions reductions (in tons of CO2e) from the elimination of ferry flights at Hanscom Field by the relocation of the aircraft responsible. This analysis considers two estimates of emissions reductions – one derived from AEDT (41.9 metric tons) and one derived using fuel consumption data (140.8 metric tons per year), as described in detail above.
- $EmissionsAdded_{ac}$ are the new emissions produced (in tons of CO2e) from the addition of each new based aircraft (2,124 metric tons of CO2e per year).

Applying the above equation, we estimate the breakeven number of aircraft as a range based on the two estimates of avoided ferry flight emissions. At the low end and using the AEDT-derived estimate of avoided ferry flight emissions, we estimate a breakeven of 0.02 based aircraft. At the high end and based on the fuel consumption-based estimate of avoided ferry flight emissions, the estimated breakeven is 0.07 aircraft. Both of these estimates are incremental to the three aircraft identified as likely to relocate to Hanscom and represent the additional aircraft needed for the increase in GHG emissions to offset the GHG savings from avoided ferry flights. At both ends of the range, the addition of a single based aircraft at Hanscom in addition to the three projected to relocate (or four aircraft in total) would lead to a net *increase* in GHG emissions. As context, the proposed expansion of hangar capacity at Hanscom includes space for an estimated 66 to 79 jet aircraft. Key inputs and results for the breakeven analysis are summarized in Table 2.

Table 2. Breakeven Analysis Inputs and Results

Inputs/Estimates		Assumed or Estimated Value
Key Inputs[1]	CO2e emissions from eliminated ferry flights	41.9 to 140.8 metric tons CO2e per year
	Jet aircraft relocated to Hanscom (these aircraft emit GHGs absent the hangar expansion project)	3 aircraft
	Annual GHG emissions per based aircraft	2,124 metric tons CO2e per year
Breakeven Estimates[2]	Number of jet relocations to Hanscom, in addition to the ferry flight generators, that offset emissions savings from eliminated ferry flights	0.02 to 0.07 aircraft

Notes:
1. All key inputs derived in sections above.
2. Estimates are incremental to the three aircraft identified as likely to relocate to Hanscom.

6.4 Full Capacity Analysis

This section calculates the annual net emissions associated with the Hanscom Field expansion project if all new hangar space is fully utilized, based on a range of 66 to 79 additional aircraft based at Hanscom. The analysis builds on the results presented above for annual ferry flight emissions avoided and the annual GHG emissions per based aircraft (Sections 6.1 and 6.2). We estimate the net GHG emissions associated with full capacity utilization as a range to reflect (1) uncertainty in the number of based aircraft added at Hanscom and (2) the range of avoided GHG emissions that we estimate above for ferry flights eliminated (41.9 to 140.8 metric tons of CO2e per year).

The following equation describes this calculation of the net emissions for a given number of hangar spaces:

$$NetEmissions_{hs} = [(HS - R_{ac}) \times EmissionsAdded_{ac}] - EmissionsAvoided$$

Where:

- $NetEmissions_{hs}$ is the annual net GHG emissions impact associated with full utilization of the new hangar capacity proposed for Hanscom.
- *HS* is the number of hangar spaces associated with the proposed capacity expansion at Hanscom (66 to 79 spaces).
- R_{ac} is, as defined above, the number aircraft that would likely relocate to Hanscom Field from other airports.
- $EmissionsAdded_{ac}$ is, as defined above, the new emissions produced (in tons of CO2e) from the addition of a single new based aircraft (2,124 metric tons of CO2e per year).
- *EmissionsAvoided* are the emissions reductions (in tons of CO2e) from the elimination of ferry flights at Hanscom Field (irrespective of the number of hangar spaces added). As noted above, this value is estimated as a range: 41.9 to 140.8 metric tons.

In the above equation, the expression ($HS - R_{ac}$) represents the number of based aircraft added at Hanscom, less the three projected to relocate their base to Hanscom from other airports. Because the aircraft that relocate to Hanscom are already operating and emitting GHGs, the analysis does not include these aircraft in the estimate of incremental GHG emissions added.

Based on the approach outlined above, this analysis estimates a net increase in annual GHG emissions of 133,643 to 161,348 metric tons of CO2e, as summarized in Table 3. The low end of this range reflects the addition of 66 based aircraft at Hanscom combined with the high-end estimate of avoided emissions from eliminated ferry flights. The high end of the range reflects the addition of 79 based jet aircraft at Hanscom and is based on the low-end estimate of avoided GHG emissions from eliminated ferry flights.

As a point of comparison for the estimates presented in Table 3, we also estimated GHG emissions associated with the fuel to be delivered to the fuel farm planned for the project. During the February 20 presentation of its analysis prior to the DEIR release, the project proponent stated that two trucks would each deliver 10,000 gallons of jet fuel per day to the fuel farm, or 20,000 gallons per day in total.

Assuming an emission factor of approximately 9.75 kg of CO_2 per gallon of jet fuel,[34] this would imply 71,186 metric tons of CO_2 emissions per year. Applying the multiplier of 2 referenced above to calculate CO2e emissions from estimates of CO_2 emissions, this suggests annual CO2e impacts of 142,372 metric tons per year, which is within the range of emissions impacts presented in Table 3. Note that these emissions only represent the fuel provided at Hanscom for outgoing legs of trips. Many aircraft will take on additional jet fuel for return trips, which will add significantly to the emissions by the aircraft based at Hanscom.

Table 3. Summary of Net Increase in Annual GHG Emissions

Number of Based Aircraft Added	Emissions Added Per Year (Metric Tons of CO2e)	Emissions Avoided Per Year (Metric Tons of CO2e)	Net Increase in Annual GHG Emissions (Metric Tons of CO2e)
66	133,784	41.9 – 140.8	**133,643 – 133,742**
79	161,390	41.9 – 140.8	**161,249 – 161,348**

6.5 Project Proponent Full Capacity Analysis

The project proponent's analysis of the project's environmental impacts does not explicitly estimate the GHG impacts associated with increased hangar capacity at Hanscom. Instead, the proponent's analysis alleges that aircraft operations at Hanscom (i.e., the number of takeoffs and landings) are driven by national and local economic trends and will be unaffected by the project. Based on this assumption, the proponent claims that the project will result in a net GHG savings, due to avoided ferry flights. As a basis for claiming that overall operations at Hanscom will be the same with or without the project, the proponent points to the Massport 2017 Hanscom Environmental Status & Planning Report (ESPR), which projects that operations at Hanscom will grow at a rate of 0.3% per year through 2035.[35] As validation for its forecast, the ESPR references the FAA's Aerospace Forecast for FY 2018-2038.[36] The FAA forecast, however, acknowledges that airport operations are driven not only by macroeconomic conditions but also by infrastructure development:

> *"As demand continues to grow and workload increases, congestion and delays could become critical limits to growth over the forecast period. FAA's forecasts of both demand and operations are unconstrained in that they assume that there will be sufficient infrastructure to handle the projected levels of activity. Should the infrastructure be inadequate and result in even more*

[34] Energy Information Administration, Carbon Dioxide Emissions Coefficients, September 7, 2023, accessed at https://www.eia.gov/environment/emissions/co2_vol_mass.php.

[35] Massport, 2017 L.G. Hanscom Field Environmental Status & Planning Report, EEA Number: 5484/8696, May 2019.

[36] Federal Aviation Administration, FAA Aerospace Forecast Fiscal Years 2018-2038.

congestion and delays, it is likely that the forecasts of both demand and operations would not be achieved." [37]

An important conclusion from this FAA language is that growth in flight operations is dependent on infrastructure development within the aviation system. The FAA's Advisory Circular on the development of airport master plans more specifically notes that hangar capacity should be considered when projecting flight demand for individual airports:

"If demand levels are likely to be particularly sensitive to one or more factors, the planner should estimate the impact of reasonable changes in the underlying assumptions about those factors. For example, if expected growth in aircraft operations is highly dependent on the continued operation of a fixed base operator (FBO) and there is a reasonable possibility that the FBO will close, the planner should estimate how much that closing would change the predicted demand. The planner should also examine general aviation hangar activity, including the airport hangar waiting list, and estimate how much increased hangar space would change predicted demand."[38]

As confirmed by both of the above-referenced FAA documents, the project proponent is incorrect in claiming that flight operations at Hanscom will be unaffected by the proposed construction of additional hangar capacity. Therefore, the proponent's conclusion that the project will lead to a net GHG savings is incorrect.

7. Changes in Operations

To supplement the emissions analysis presented above, this section estimates the changes in Hanscom Field operations resulting from full utilization of new hangar space at the facility. The following formula describes this calculation of new flights (*ΔOperations*) associated with the addition of 66 to 79 based aircraft:

$$\Delta Operations = HS * \left(\frac{Hours_{Year}}{Hours_{Flight}}\right) * FractionBase$$

Where:

- *ΔOperations* is the annual change in operations (flights per year) associated with full utilization of the new hangar capacity proposed for Hanscom.
- *HS* is the number of hangar spaces associated with the proposed capacity expansion at Hanscom (66 to 79 spaces).
- $Hours_{Year}$ is the annual number of operating hours for one jet aircraft.
- $Hours_{Flight}$ is the number of hours per flight for one jet aircraft.
- *FractionBase* is the portion of an aircraft's total flights that are to/from its home base airport.

[37] Federal Aviation Administration, FAA Aerospace Forecast Fiscal Years 2018-2038, p.48.

[38] Federal Aviation Administration, *Airport Master Plans*, as modified January 27, 2015.

Average annual operating hours are estimated to be 300 hours per aircraft based on publicly available estimates obtained from the literature.[39,40] Average hours per flight are assumed to be 1.67 hours based on flights for based aircraft identified as potential candidates for relocation to Hanscom. This yields an average estimate of 180 flights per aircraft each year. For the *FractionBase* input, this analysis assumes that 46 percent of an aircraft's total flights are to or from its home base airport. Similar to the average flight duration, this value is derived using the data for the subset of aircraft that were considered to be candidates for relocation to Hanscom (before the application of the 50 percent threshold described in Section 4.1).

The calculations described above produce an estimated increase in operations of approximately 5,487 to 6,568 additional flights to and from Hanscom Field per year, if all new hangar space is fully utilized.

8. Conclusion

The results of the analysis presented here strongly suggest that the proposed 395,700 square foot expansion of hangar capacity at Hanscom Field would, on net, lead to a significant increase in aviation-related CO2e emissions. Key results from this analysis that support this conclusion include the following:

- **Few jet aircraft are likely to relocate to Hanscom:** We identified only three based jet aircraft for which relocation to Hanscom Field would likely lead to reduced costs/increased convenience. We reach this conclusion based on analysis of detailed flight data for aircraft flying into and out of Hanscom over a one-year period.
- **Low threshold for net increase in GHG emissions:** Based on the breakeven analysis presented above, just one aircraft in addition to the three likely to relocate to Hanscom would generate GHG emissions that more than offset the emissions avoided from eliminated ferry flights.
- **Emissions associated with full utilization of planned capacity far outweigh any emissions savings:** With 66 to 79 new hangar spaces fully utilized, the increase in GHG emissions from additional based aircraft at Hanscom would be 950 to 3,900 times greater than the GHG emissions avoided from eliminated ferry flights.
- **The DEIR errs in finding that the new hangar capacity will not increase operations or GHG emissions.** FAA guidance states that flight operations are affected by hangar capacity and operations projections be adjusted based on hangar capacity. For this project, the assertion that reductions of ferry flights will offset any operations increases is shown to be incorrect. The hangar capacity will result in between 5,500 and 6,600 additional flight operations and 134,000 to 161,000 additional tons of CO2e, virtually none of which will be offset by reductions in ferry flights.

[39] Gossling, S. and Humpe, A. 2020. "The Global Scale, Distribution, and Growth of Aviation: Implications for Climate Change." *Global Environmental Change, 65*. Available at: https://www.sciencedirect.com/science/article/pii/S0959378020307779.

[40] Gudmundsson, S. 2022. "Chapter 2 – Aircraft Cost Analysis." *General Aviation Aircraft Design (Second Edition).* Available at: https://www.sciencedirect.com/science/article/abs/pii/B9780128184653000033.