Supersonic aircraft in a net-zero world

By Dan Rutherford (International Council on Clean Transportation – ICCT)

Introduction

The aviation industry is under pressure from consumers and governments to slash emissions. At the International Air Transport Association 2021 General Assembly last October in Boston, global airlines committed to net-zero aviation by 2050 and have issued a series of technology roadmaps detailing how they will get there. In parallel, more than 200 ICAO experts have collaborated within the Committee on Aviation Environmental Protection (CAEP) on a comprehensive report to assess the feasibility of a Long-Term Aspirational Goal (LTAG) for international aviation. In February, CAEP met to finalize the LTAG report, and also to debate a parallel, related issue: attempts to revive supersonic transport aircraft, or SSTs.

These two goals are challenging to rectify. Flying faster than the speed of sound is inherently energy-intensive, in part because supersonics use powerful, narrow engines to produce the high thrust needed to break the sound barrier. This means high fuel burn—up to 10x more fuel per seat kilometer compared to subsonics according to a Massachusetts Institute of Technology (MIT) report to the National Aeronautics and Space Administration (NASA) — disproportionate climate impact, and the spectre of increased airport noise.

SAFs and supersonics: hand in glove, or oil in water?

Proponents of supersonics argue that low-carbon sustainable aviation fuels (SAFs) can throttle back supersonic emissions. SAFs can be used in today's engines and aircraft at up to 50% blends and are energy-dense enough to power long-haul and high-speed flights. But SAFs remain expensive – two to five times that of fossil jet fuel – and rare, accounting for only 0.05% of global jet fuel supply in 2020. They are also controversial when generated from edible crops, which are linked to accelerated deforestation in the tropics.

Can the twin goals of zero emission aviation and supersonic aircraft be rectified? To date, no government or industry net zero roadmap has been able to do so. Waypoint 2050, the global roadmap released by the International Air Transport Association (IATA) didn't model supersonic aircraft, calling them "niche" and waving away their excess emissions with strict standards that don't yet exist. ICAO's LTAG report also didn't model their impacts, positing a small market size and industry claims that they will be operated on 100% SAFs "from day one". But how likely is that, given the energy intensity of SSTs and their challenging economics?

To answer this question, ICCT joined forces with MIT's Laboratory for Aviation and the Environment (LAE) in a joint study on the compatibility of supersonics and SAFs. Together, they modelled the economics, operations, and emissions of two potential supersonics designs – a "Small SST" seating 15 and operating at 1.4 times the speed of sound (MN 1.4) and a "Large SST" seating 75 designed for MN 1.7. Operations and emissions were estimated on both conventional "Jet A" fossil fuel and a synthetic "e-kerosene" generated from renewable electricity.

What did they find? In a nutshell, that supersonics are a poor use of scarce SAF supplies. Due to their underlying fuel intensity – 7 to 9x that of subsonics per seat-km – even an excellent SAF providing a 90% reduction in life cycle CO_2 would only modestly (-6% to -24%) reduce CO_2 relative to subsonic aircraft operated on fossil jet fuel (Figure 1).

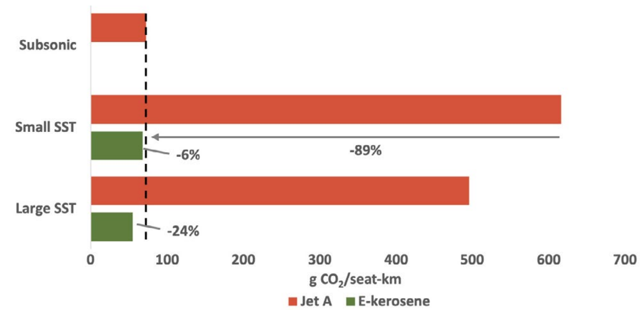

FIGURE 1: CO_2 intensity by aircraft type and fuel

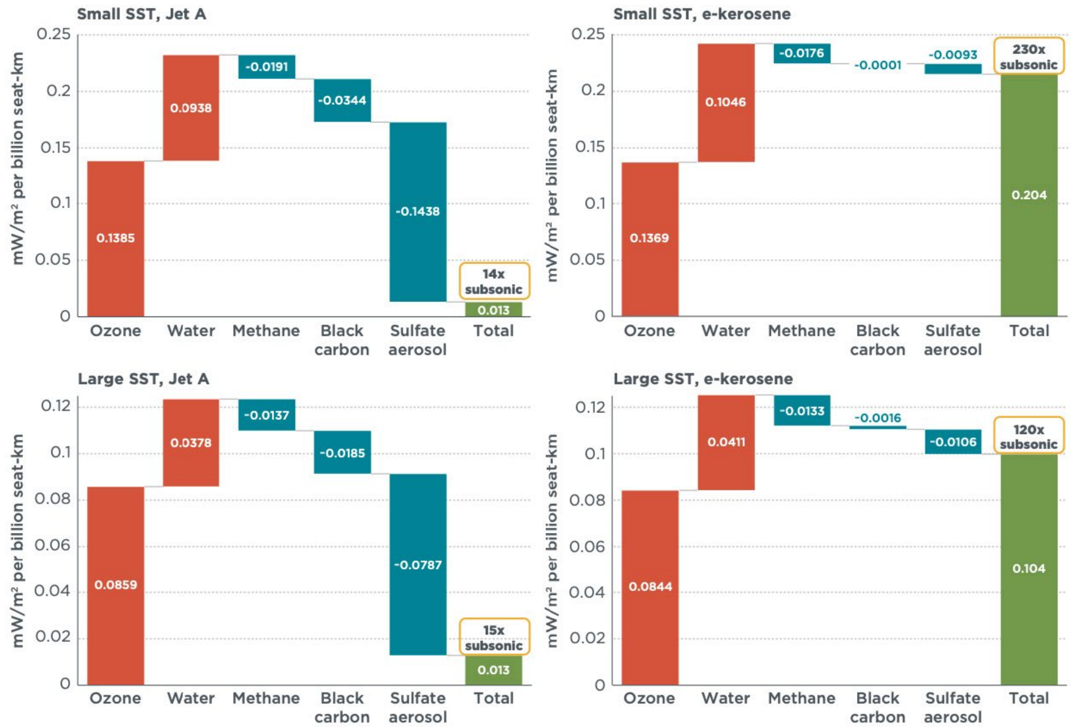

FIGURE 2: Medium-term radiative forcing by SST and fuel

More surprising, even if SAFs were widely available, their use in supersonic flight could actually backfire after accounting for the full atmospheric impacts of SSTs. Prior LAE research for NASA concluded that medium term (non-CO_2, non-contrail) climate impact from fast supersonics can be up to 20 times that of subsonics[1]. That's because the high cruise altitude of supersonics increases the residence time of emissions significantly. Moreover, aircraft exhaust contains a variety of pollutants with either warming or cooling impacts depending upon the elevation at which they are emitted.

SAFs are uniformly low sulfur and low aromatic content. Burning those fuels in the stratosphere could actually increase the net warming of supersonics by unmasking the warming effects of ozone destruction and water vapor (Figure 2, two right panels, compared to baseline impacts on Jet A in the two left panels). That diagram shows the cumulative radiative forcing impact, in mW/m² per billion seat-km, for warming species (red), cooling species (blue), along with the total, by SST and fuel type.

So operating supersonic on a low-sulfur, low aromatic jet fuel could actually exacerbate the medium-term climate impacts of supersonics, from about 15 times that of supersonics up to 120 to 230 times the subsonic baseline. The fleetwide result would be stark. Even a limited number of operations (less than 1% of seat kilometers in 2035) could potentially increase the medium-term climate impacts of commercial aviation by two-thirds. (Figure 3, top and bottom bars).

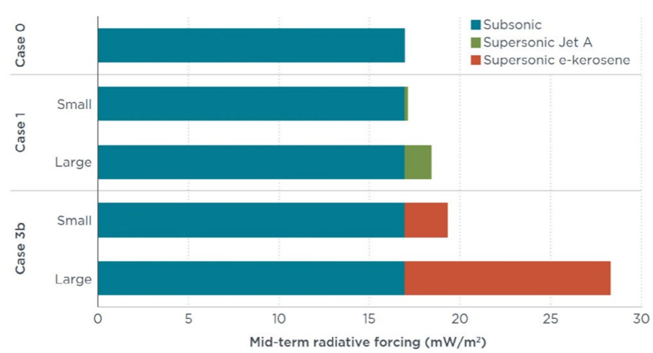

FIGURE 3: Fleetwide medium-term radiative forcing by case and SST

1 https://ntrs.nasa.gov/citations/20205009400

They conclude that assuming that SAFs can address the climate impacts of supersonics is premature. Moreover, economic modeling concludes that the high cost of SAFs will make them cost prohibitive for supersonics for the foreseeable future. The combination of SAFs higher cost and SSTs greater fuel intensity could increase fuel costs to 25 times that of subsonic aircraft burning Jet A, threatening the already questionable finances of supersonics. Their analysis suggests that any SSTs produced are likely to operate on fossil jet fuel, not SAFs, after being delivered as airlines search for profitability. That may turn out to be a blessing– given limited supplies, it would be preferable for scarce SAFs are earmarked for the most fuel-efficient subsonic planes – but any new, unabated emissions from SSTs will make net-zero aviation that much harder to achieve.

Conclusions

This work highlights that emissions from supersonic aircraft should be regulated on their own basis, without assuming that low carbon fuels will be sufficient. As the only accredited organization representing civil society at ICAO, ICSA members believe that SSTs should meet the same noise, air pollution, and CO_2 standards as subsonic aircraft. This approach will help ensure no net increase in noise or emissions due to the reintroduction of supersonic aircraft and is consistent with industry's goal of net-zero emissions in 2050. In tandem, governments should focus on promoting the highest-quality SAFs and targeting them to the best use, notably long-haul flights that require the most energy dense liquid fuels.