

NASA Supersonic Transport Emissions Update

**Presented to the
AEC Roadmap Community
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Recap of Prior AEC Discussions Regarding NASA Perspectives on Supersonic Transport Emissions

- **2017 “NASA Emissions Research for Future Commercial Supersonic Transport Aircraft”**
 - Initial discussion of Lean Direct Injection (LDI) research
 - Differences between subsonic and supersonic engine/aircraft systems
- **2018 “Supersonic Transport Perspectives by Industry, Government, and Academia”**
 - Update of LDI & emergent research in applying alternative fuels
 - Initial city pair studies identifying two potential markets: <2500, >4000 nmi
 - Comparison of subsonic vs supersonic LTO Times-in-Mode and required thrust levels using NASA models of 737-800 and 55t STCA
- **2019 “NASA Combustion & Emissions Research for Supersonic Transports”**
 - Combustion & materials targeting retrofit adaptations for existing rich-burn components, with stepping stones to adv. rich-burn & future lean-burn
 - Discussed need for additional SST study vehicles for addressing passenger size, cruise Mach, technology EIS.

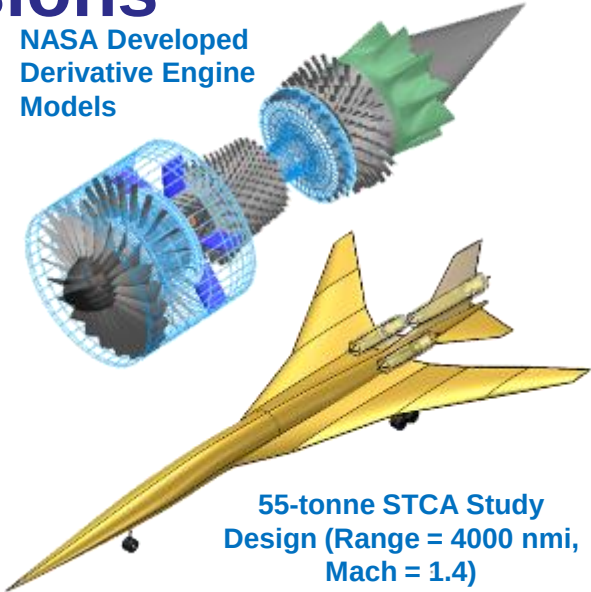


55t Supersonic Technology Concept Aeroplane

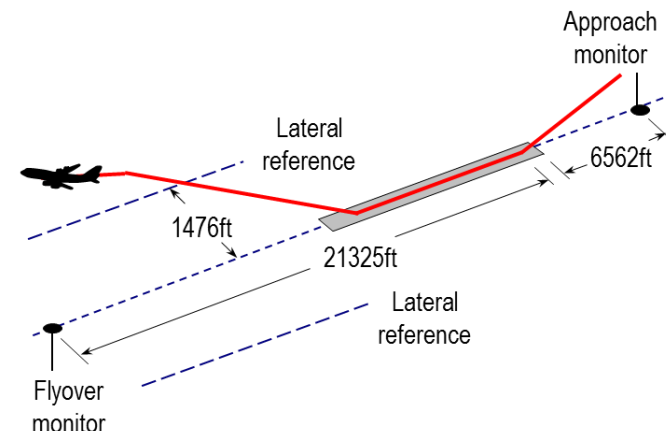
Predictions for LTO Noise & Emissions

- NASA efforts include targeted testing and analysis to reduce uncertainty in LTO noise & emissions
- 2020 AIAA SciTech Special Session included the public release of **NASA's 55tonne STCA design study***
 - LTO noise results show the tech challenges & potential range penalties for near-term certification to subsonic standards
 - LTO emissions results similarly show the tech challenges of meeting even the CAEP/6 NO_x and CO standards, as well as the new Particulate Matter standards impacting subsonics aircraft

NASA Developed
Derivative Engine
Models



55-tonne STCA Study
Design (Range = 4000 nmi,
Mach = 1.4)

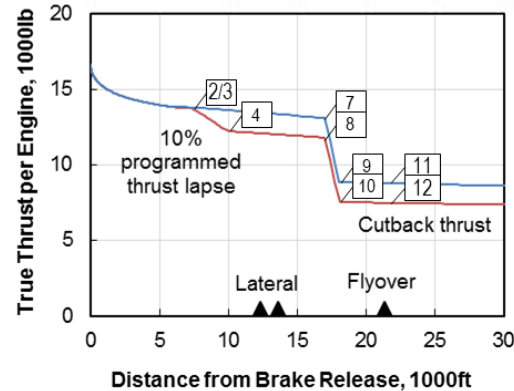
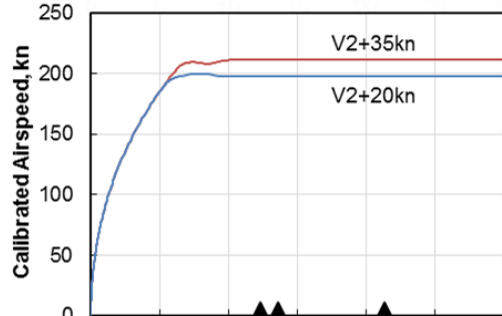
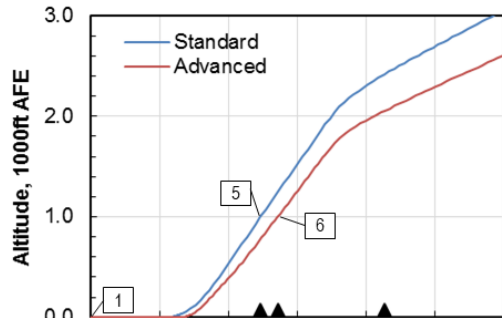


* AIAA 2020-0263 "Supersonic Technology Concept Aeroplanes for Environmental Studies"; Berton, Huff, Seidel, Geiselhart



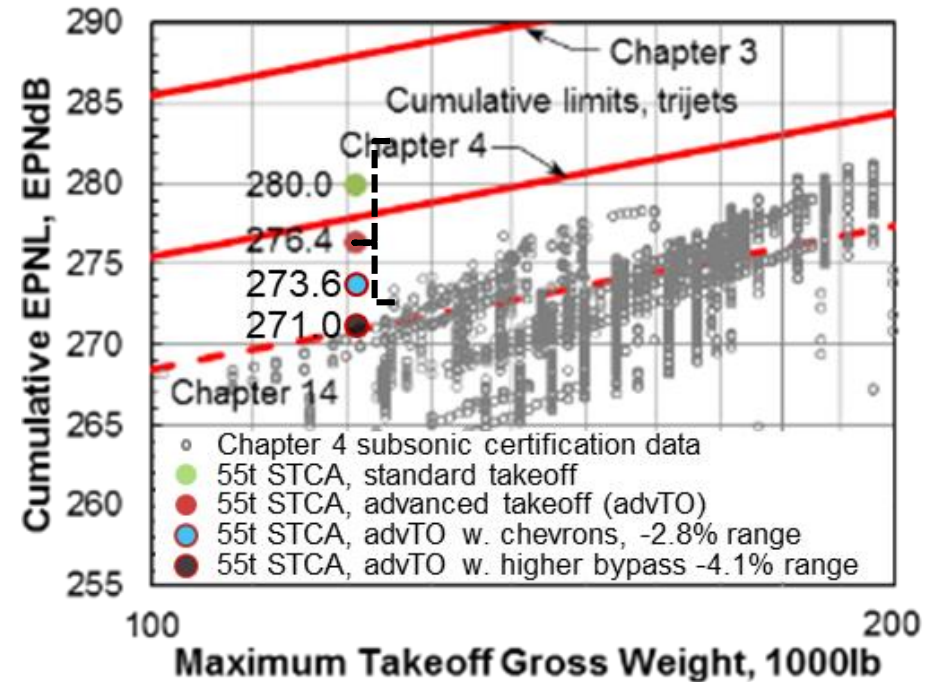
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Profiles for Noise Certification with Variations & Sample Uncertainties



Point	DFBR, ft	Altitude, ft	Speed, kcas	Thrust, lb
1	0	0	0	16,617
2	6560	35	199	13,811
3	7375	35	210	13,720
4	10,062	400	212	12,207
5	12,325	1000	199	13,437
6	13,550	1000	212	12,001
7	17,000	1916	199	13,090
8	17,000	1616	212	11,791
9	18,037	2093	199	8844
10	18,104	1785	212	7531
11	21,325	2418	199	8762
12	21,325	2054	212	7474
13*	-7518	394	165	5328

*Approach point (glide slope is 3 degrees)

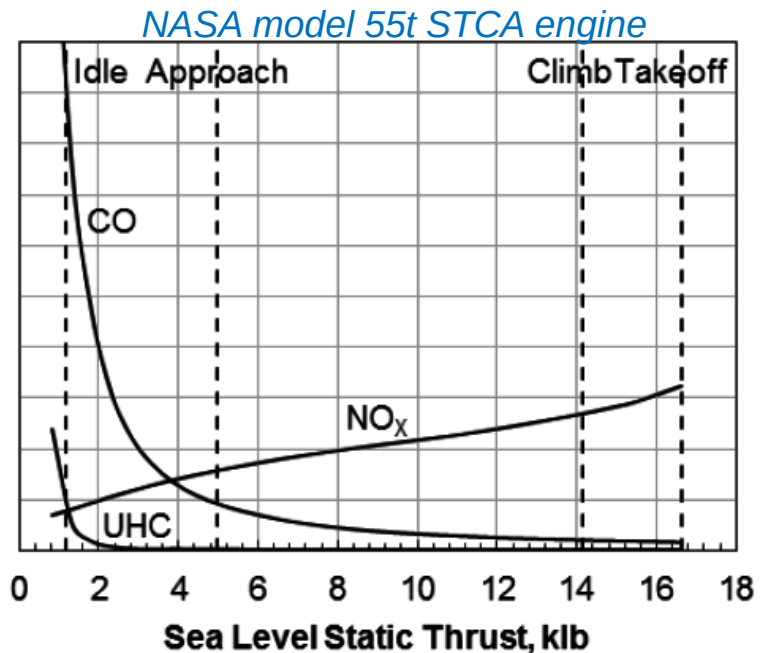
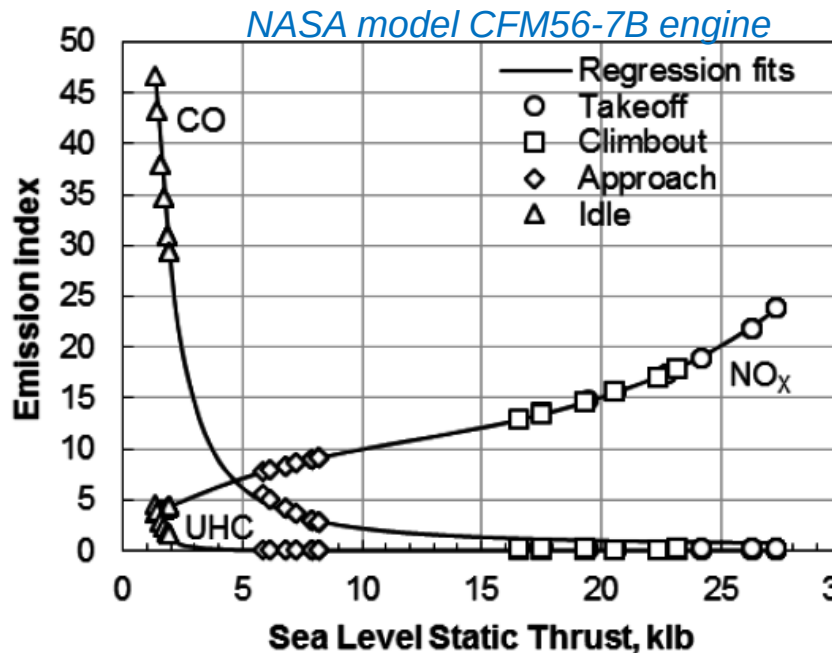


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Noise & Vehicle Performance Dictate Thrust & Times-in-Mode, Impacting Emissions

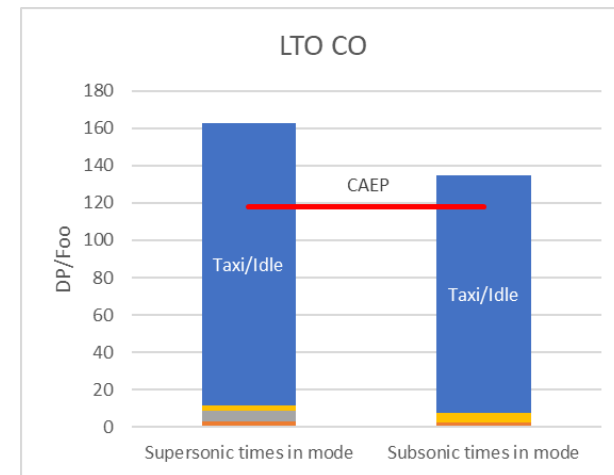
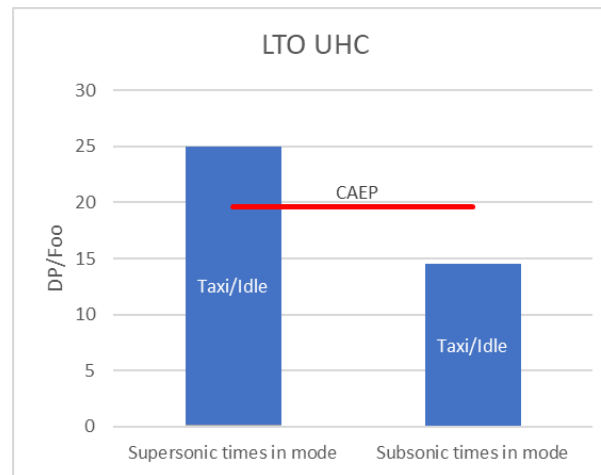
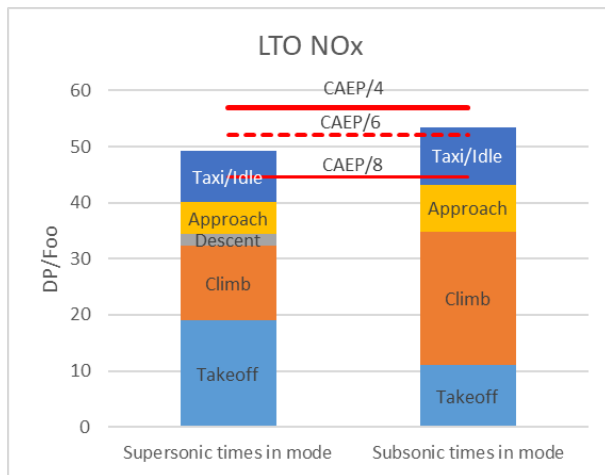
- **Landing-takeoff gaseous emission index**

- Regressions of subsonic CFM56-7B series engines (left); gaseous emission index model of the 55t STCA supersonic variant engine (right).
- Ground level emission models are anticipated to be used to predict emissions produced at altitude in AEDT, different approaches are under investigation for applicability to supersonic en-route emissions (e.g. Boeing Fuel Flow)



NASA 55t STCA engine LTO Gaseous Emissions

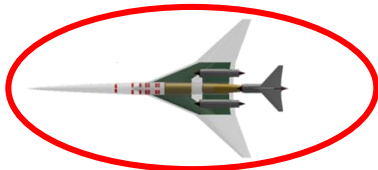
- **CAEP/4 NO_x level appears achievable**
- **CAEP/6 NO_x is a challenge & may require additional certification engines tested with repeatable results**
- **CO is a challenge, especially due to low NO_x designs**
 - Need reduced development margin and/or additional certification engines tested with repeatable results, and/or improved combustor fuel nozzle pilot stage and main stage at low engine power.



NASA Study Vehicles Restated

Supersonic Technology
Concept Aeroplane
(STCA) configurations

Other STCAs
using measures
of proprietary
information



STCA1: M1.4, 8+ PAX, 55 tonne*
(refanned CFM56-7B) Derivative 3-engine

Performance-sized
configurations
(non-Low Boom)

M1.6, 60 PAX



M1.6-1.8, 40 PAX



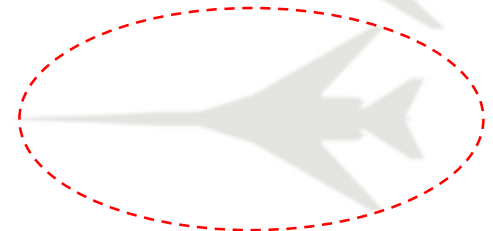
M1.6-1.8, 8-12 PAX (20 PAX)



New 2-engine, current-technology
New 2-engine, advanced-technology

Low Boom configurations

*Acceptable
shaping not possible due
to size*



* Chapter-14 (Stage 5) LTO noise: maximum certificated takeoff weight of 121,254 pounds (55,000 kg) or more on or after December 31, 2017; or that has a maximum certificated takeoff weight of less than 121,254 pounds (55,000 kg) on or after December 31, 2020.

FYI: limit of 45,000 kg takeoff weight for many business jet airports (e.g. Teterboro)



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Summary Comments & Recommendations (1of2)

- **Sufficient premium seat traffic exists at Mach~1.6 to support commercial production rates; also emerging interest in higher speed (possibly hypersonic)**
 - Premium aircraft capacity appears to favor $\ll 100$ passengers (to maintain load factors & reasonable production rates).
 - Most O-D pair routes have substantial overland fractions without diversions from GC, but are added routes enabled by low-boom worth higher fuel burn?
 - **Need broader market-driven understanding of requirements & economic/environmental trades: cruise Mach, size & passengers, tech EIS.**
- **Environmental impacts must be addressed for certification, regardless of cruise mission preferences**
 - LTO noise is more temporal & economically impacting (e.g. property values).
 - LTO & cruise emissions are more lasting; impacting health & the environment (resolution may limit cruise altitudes and speed to achieve acceptable levels).
 - **Need updated study of potentially altitude/Mach limiting chemistries (e.g. ozone neutral).**



Summary Comments & Recommendations (2of2)

- **Studies indicate affordable noise and emissions reductions are ~small for acceptable range penalties (fuel burn) in the near-term**
 - Use of fuel-cooling can improve supersonic durability & cycle efficiency, what are combustion stability & emissions impacts of heated fuels?
 - Can premium high speed vehicles help catalyze alternative fuel production & greener aviation?
- **The interrelationship between LTO noise, operations, and LTO emissions requires integrated understanding of the environmental impacts of future vehicles**
 - Is there a documented process (using AEDT, BADA, etc.?) for incorporating noise and emissions of new vehicles?

