NASA SBIR 2018 Phase I Solicitation

A1.04 Supersonic Technology - Reduce Take-off and Landing Noise

Lead Center: GRC

Technology Area: TA15 Aeronautics

This solicitation is aimed at further exploring technologies that reduce landing and take-off noise while maintaining range and sonic boom within acceptable levels. This may include innovations in propulsion design, propulsion-airframe integration, vehicle operations, and high-lift airframe elements.Â A concept vehicle with low-boom configurations such as those identified in the above references is desired; however, other operational concepts, for example those not involving overland supersonic flight may be considered if there is an overlap in technology benefits.Â

The following list summarizes the topics for which proposals are sought in this solicitation. Details for each topic area are provided in the following section:Â

- Topic 2.1 - Innovative High Lift Concepts for Highly Swept Supersonic Wings.
- Topic 2.2 - Alternative Variable Propulsion Architectures.
- Topic 2.3 - Efficient Optimization of Supersonic Nozzles to Minimize Jet Noise.Â

Topic 2.1 - Innovative High Lift Concepts for Highly Swept Supersonic Wings.Â

Objective

This topic seeks innovative high lift concept proposals that would enable takeoff and landing noise levels that meet certification requirements (consistent with those of the subsonic fleet), have minimal to no impact on supersonic performance, and are compatible with low-boom vehicle designs. Each concept should include a preliminary assessment of its performance at takeoff/landing speeds, its component noise, and an assessment of its impact on likely laminar flow requirements.Â

Approach

The high-lift system is an integral part of the take-off, landing, stall recovery, and low-altitude maneuvering segments of a supersonic aircraftâ€™s mission. Low-aspect ratio, thin, highly swept wings typical of supersonic aircraft generally do not perform well at low speed and present challenges to designing a high lift system. For modern supersonic aircraft, high lift systems not only need to enable good takeoff and landing performance, but also need to be quiet and stow so as to not interfere with natural laminar flow leading-edge design approaches that may be under consideration. Any high-lift system should also delay or reduce undesirable pitch characteristics.Â

Modern supersonic aircraft may have to meet the same low-noise requirements near an airport that subsonic aircraft do. Therefore, high-lift systems must have good performance to get the aircraft as high as possible over the â€œcutbackâ€ measurement point, and be low-noise for the approach-to-landing measurement point. An estimate of component noise will be required for all proposed high lift concepts and the basis of that estimate provided. As an example, continuous mold-line flaps have been investigated for subsonic aircraft and may be also be applicable on supersonic aircraft. Therefore, the subsonic studies would serve as a basis for the estimate of the component noise in a supersonic application. If there are no relevant studies for a particular concept, a proposal for such a study should be included.Â

Wing leading-edge laminar flow design technology may include a sufficiently small wing leading-edge radius (to manage supersonic attachment-line flow transition associated with leading-edge boundary-layer contamination/stability) as well as certain leading-edge treatments (to manage insect/debris contamination and cross-flow transition). Technology enabling wing leading-edge radius variations ranging from a large radius for use at low-speed conditions to a small radius for use at supersonic conditions may be considered. The leading-edge high-lift system shall minimize any steps/gaps/sealing issues when stowed for the supersonic cruise configuration. The trailing-edge high-lift system is not a concern for the laminar flow wing design, but still needs to address steps/gaps/sealing issues to minimize drag for supersonic cruise efficiency requirements. Although a subtle distinction, the laminar-flow requirement only applies to the supersonic cruise conditions; for low-speed conditions, a turbulent high-lift wing configuration may be more robust and preferable to meet these challenging high-lift requirements.Â

Ideas considered in previous supersonic research efforts (which had L/D requirements, but not low-noise or laminar-friendly requirements) included simply-hinged leading- and trailing-edge flaps. Questions remain regarding the adequacy of the performance of these concepts, given the more stringent criteria stated above.Â

Under a prior NRA contract, a baseline commercial passenger concept was developed for the Commercial Supersonic Technology Project.Â Â This representative mid-term configuration can be used to evaluate the proposed high lift concepts.Â

The proposed approach should involve multiple stages of activity if more than one concept is being investigated. During initial studies open trade spaces are encouraged. Through quarterly technical interchanges with the NASA team, it is anticipated that a down-select or prioritization of the most viable concepts will occur and will be more fully developed through CFD or experimental studies.Â

Outcome:

This effort will result in:Â

- A suite of high-lift concepts, evaluated for low-speed performance (L/D), component noise, and â€œlaminar-friendliness.â€ The most promising of these concepts will subsequently be used for experimental or high-fidelity computational proof-of-concept investigations on a relevant supersonic transport wing geometry.
- Complete documentation of findings and relevant comparisons.
- Recommendations for follow-on studies.*Â*

*References:*Â

1. H. R. Welge, J. Bonet, T. Magee, D. Chen, S. Hollowell, A. Kutzman, A. Mortlock, J. Stengle, C. Nelson, E. Adamson, S. Baughcum, R. Britt, G. Miller, and J. Tai, â€œN+2 supersonic concept development and systems integrationâ€, CR-2010-216842, NASA, 2010. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100030607.pdf**â€ƒ**

Topic 2.2: Alternative Variable Propulsion ArchitecturesÂ

Objective

The objective of this subtopic is to explore one or more alternative variable propulsion concepts capable of a two-fold variability in effective bypass ratio with minimal compromise of supersonic cruise performance. The work will consider three-dimensional inlet and nozzle geometries and perform analysis of key propulsion efficiency trades, flight envelope operability, and propulsion noise at the Landing Take-Off phases of flight.Â

Background

To satisfy the increasing stringency of commercial Landing/Take-Off (LTO) noise, efficient supersonic cruise propulsion systems would ideally operate at high mass flow for take-off (low jet velocity) and safely transition to high specific thrust (high jet velocity) for supersonic operation. In recent decades, variable cycle technologies have afforded a measure of success in this pursuit, with some compromise in propulsion system weight and complexity [1]. Most recently, tip-fan versions of a variable cycle engine have been explored as a way to invoke higher fan mass flows at take-off with higher installed specific thrust for cruise3. Additional alternative concepts have also been expressed (e.g., mixer-ejector nozzles, supplemental mechanical/electric fans, or other concepts) to reconcile the dichotomy of high flow acoustic take-off with efficient supersonic cruise.Â Historically, however, all such variable propulsion systems have suffered size, weight, and realizability issues adversely affecting vehicle integration and cruise range performance. Furthermore, development of a propulsion system with such unique operating characteristics has challenged the economics of limited production supersonic vehicles.

While a number of such variable propulsion concepts have been contemplated for commercial supersonics to date, many have yet to be explored with modern analysis tools/methods or at a sufficiently credible level of detail or with an eye toward reducing uncertainty.Â Lack of realistic geometry including inlet, nozzle, and vehicle integration have oversimplified or obviated issues with such concepts as flow valves and moving surfaces that transition throughout the flight envelope.Â In addition to new concepts, use of modern design methods may allow reconsideration of some alternative propulsion architectures but with greater design realism in overcoming prior associated technical roadblocks.Â Vehicle integration for low sonic boom and supersonic drag has also been a major issue impacting the utility of high flow propulsion concepts as these considerations value minimizing nacelle cross-sectional area or fineness ratio.Â Correspondingly, engine/accessories packaging, inlet and nozzle interfaces, and integration with endemic features of supersonic vehicles must be considered (e.g., highly swept thin wings, propulsion in-board or aft-fuselage mounting and boundary-layer diversion).Â

Approaches

A set of metrics, including mass flow variability, cruise efficiency, range, and airport noise should be developed to evaluate alternative variable propulsion architectures.Â Promising alternative variable propulsion architectures should be evaluated using low-fidelity system analysis on a representative supersonic aircraft mission.Â Low-boom aircraft concepts, such as those referenced in published system studies4-10 may be used as a point of departure.Â Furthermore, propulsion approaches that modify existing or more â€œconventionalâ€ propulsion architectures are of key interest for achieving large changes in effective bypass ratio or specific thrust in an economical approach.Â

In their search for innovative concepts, proposers are encouraged to seek partnerships with non-traditional industries, large and small engine manufacturers, and universities with capabilities to explore credible levels of detail and reduced uncertainty.Â

Outcome

A final report (non-proprietary and proprietary (if required) versions) is expected at the conclusion of this effort showing at least one conceptual propulsion configuration with a two-fold variability in effective bypass ratio, capable of powering a representative Mach 1.4-1.8 commercial supersonic transport sized for range of at least 4000 nautical miles and 8 - 90 passengers.Â The following items should be included in the final report:Â

- One to a few alternative variable propulsion concepts, investigated to a credible design level and accompanied by supporting trade studies of key design parameters.
- Engine cross-section(s) including outer dimensions and component weights (at a minimum).
- Three-dimensional geometry representations of inlet, nozzle and key components, with appropriate characterization for use in propulsion system model(s).
- Propulsion system model(s) (preferably in NPSS) and assumptions, with recommendations for further development of key technologies or components.
- Installed propulsion performance throughout a representative flight operating envelope.
- Low-fidelity acoustic analysis of the selected concept(s), reflective of the LTO trajectory for the

representative vehicle.Â

*References:*Â

1. Berton, Jeffery J, et al â€œA Comparative Propulsion System Analysis for the High-Speed Civil Transportâ€. NASA/TMâ€”2005-213414. Glenn Research Center, Cleveland, Ohio. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20050123580.pdf.

2. Pratt & Whitney West Palm Beach, Florida & General Electric Aircraft Engines Cincinnati, Ohio.Â â€œCritical Propulsion Components Volume 1: Summary, Introduction, and Propulsion Systems Studiesâ€. NASA/CRâ€”2005-213584/VOL1. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20050185247.pdf.

3. Dennis L. Huff, Brenda S. Henderson, Jeff J. Berton, and Jonathan A. Seidel. "Perceived Noise Analysis for Offset Jets Applied to Commercial Supersonic Aircraft", 54th AIAA Aerospace Sciences Meeting, AIAA SciTech Forum, (AIAA 2016-1635).

4. John Morgenstern, et al, â€œFinal Report for the Advanced Concept Studies for Supersonic Commercial Transports Entering Service in the 2030 to 2035 Period, N+3 Supersonic Programâ€, NASA/CRâ€”2010-216796, NASA, 2010. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100036507.pdf.

5. H. R. Welge, et.al., â€œN+2 Supersonic Concept Development and Systems Integrationâ€, CR-2010-216842, NASA, 2010. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100030607.pdf.

6. H. Robert Welge, et al, â€œN+3 Advanced Concept Studies for Supersonic Commercial Transport Aircraft Entering Service in the 2030-2035 Periodâ€, NASA/CRâ€“2011-217084, NASA, 2011. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110010973.pdf.

7. Todd E. Magee, et al, â€œSystem-Level Experimental Validations for Supersonic Commercial Transport Aircraft Entering Service in the 2018-2020 Time Period Phase I Final Reportâ€, NASA/CRâ€“2013-217797, NASA, 2013. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20130011026.pdf.

8. John Morgenstern, et al, â€œAdvanced Concept Studies for Supersonic Commercial Transports Entering Service in the 2018 to 2020 Period Phase I Final Reportâ€, NASA/CRâ€”2013-217820, NASA, 2013. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20130010174.pdf.

9. John Morgenstern, et al, â€œAdvanced Concept Studies for Supersonic Commercial Transports Entering Service in the 2018-2020 Period Phase IIâ€, NASA/CRâ€”2015-218719, NASA, 2015. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150015837.pdf.

10. Todd E. Magee, et al, â€œSystem-Level Experimental Validations for Supersonic Commercial Transport Aircraft Entering Service in the 2018-2020 Time Periodâ€, NASA/CRâ€“2015-218983, NASA, 2015. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160000771.pdf.

Topic 2.3: Efficient Optimization of Supersonic Nozzles to Minimize Jet NoiseÂ

Objective

The objective of this subtopic is to apply optimization methodology to problems in aeroacoustics, specifically to minimize jet noise of future commercial supersonic nozzle designs and installations.Â

Background

Currently, predicting the noise of a non-axisymmetric jet requires either time-accurate computation using Large Eddy Simulation, which is very expensive but potentially very accurate, or Reynolds-Averaged Navier-Stokes (RANS) CFD and acoustic source modeling, which is cheaper but has failed to provide absolute accuracies needed for design. The latter methods have demonstrated the capability to predict trends in noise from variations in nozzle geometry, however, and this capability may be harnessed to do optimization of nozzle geometries to minimize the jet noise. In the time-average methods, the flow solution can be obtained from a RANS-based CFD code, the noise produced from the flow can be computed using an established NASA code, and the transformation of the sound spectra to that of an overhead flight and its EPNL metric is given in FAA documentation.Â

Approach

The vision is that RANS-based methods which predict the noise of an engine nozzle for a given flow condition can be applied in optimization to reduce noise by varying the nozzle shape and/or installation. A successful effort would utilize NASA jet noise prediction knowledge and tools, determine viable optimization strategies and methods that are appropriate for these tools, and demonstrate the system by applying it to a nozzle design problem of interest to NASA.Â

Using a suitable optimization methodology, the proposer would develop a coupled Computational Fluid Dynamics-Computational Aero-acoustics (CFD-CAA) optimization system to find the minimum EPNL metric for a given set of geometric design parameters that describe the nozzle shape. It is expected the process would be suitable for designing three-dimensional, multi-stream, and unconventional nozzle concepts. Given the dependence on high-fidelity RANS computations for jet noise prediction, an efficient optimization process that utilizes gradient information (e.g. a continuous or discrete adjoint approach) is desired. Ideally, the CFD-CAA system will be developed to leverage and/or easily interface with adjoint-capable CFD codes like NASAâ€™s Fully Unstructured Navier-Stokes 3D (FUN3D)3 framework, or similar. Analytical derivatives for the calculations transforming the predicted noise spectra to the EPNL metric have been described in Reference 5.Â

Ultimately, the optimization strategy developed in this task will need to be implemented in an existing design and optimization framework. This framework is not the objective of the task. The success of the method chosen will depend upon ability to manipulate the given prediction codes with an emphasis on computational time, preferably being done on an engineering workstation-class computer, but could include the use of NASA supercomputer resources. The development effort is envisioned to consist of three phases. Phase I would include a survey of optimization methods that might be applied to the current prediction methods and a down-select of approaches to be pursued. Phase II would include development of the optimization method chosen and a simple demonstration of feasibility. Phase III would include demonstration of the system applied to a nozzle relevant to NASA.**Â**

Outcome

This effort will result in:

- A documented exploration of the application of optimization methods to future commercial supersonic nozzles and installations.
- At least one method being demonstrated with enough documentation to be implemented within a NASA design framework.
- An optimized design based on a NASA-originated nozzle suitable for validation in scale-model testing.
- Any codes derived from or integrated with government-furnished codes would be included as deliverables.Â

*References:*Â

1. Khavaran, Abbas; Bridges, James E, and Georgiadis, Nicholas, â€œPrediction of Turbulence-Generated Noise in Unheated Jets (Part 1: JeNo Technical Manual (Version 1)â€, NASA/TM 2005-213827, NASA 2005. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20050207369.pdf.
2. Khavaran, Abbas; Wolter, John D, and Koch Danielle, â€œPrediction of Turbulence-Generated Noise in Unheated Jets (Part 2: JeNo Technical Manual (Version 1)â€, NASA/TM 2009-231827, NASA 2009. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090020362.pdf.
3. Biedron, R., Derlaga, J., Gnoffo, P., Hammond, D., Jones, W., Kleb, B., Lee-Rausch, E., Nielsen, E., Park, M., Rumsey, C., Thomas, J., and Wood, W., â€œFUN3D Manual: 13.0,â€ NASA TM-2016-219330, 2016.Â https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160010563.pdf.
4. Leib, Stewart, J. and Goldstein, Marvin E., â€œHybrid Source Modeling for Predicting High-Speed Jet Noise,â€™ AIAA Journal, Vol. 49, No. 7, pp. 1324-1335, 2011.
5. Lopes, L. V., â€œRobust Acoustic Objective Functions and Sensitivities in Adjoint-Based Design Optimizations and the Propagation of Uncertainty in Noise Computations,â€ AIAA Paper 2017-1673, Jan. 2017.