Potentialities of Noise Reduction Using Low Noise Takeoff Thrust Management for Advanced Supersonic Civil Aeroplanes

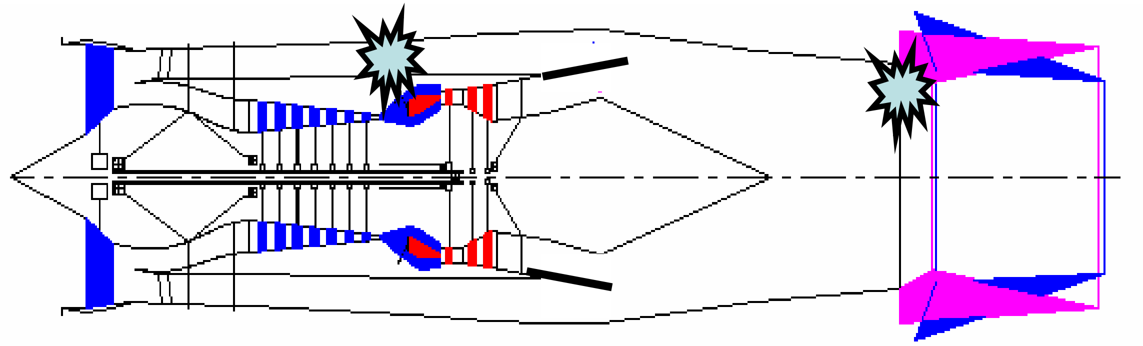
Artur Mirzoyan, Iurii Khaletskii (CIAM)

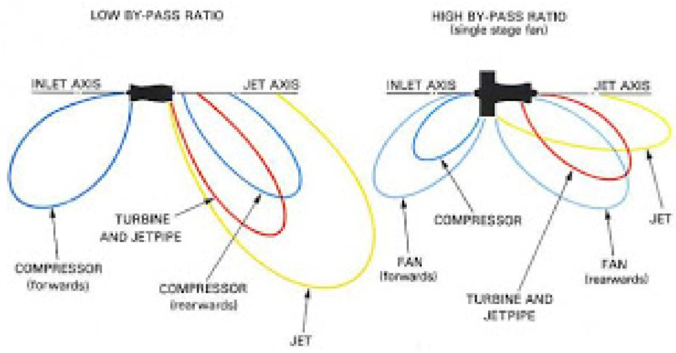
Current status of investigations on SCA noise

- more stringent requirements to subsonic aeroplanes (Chapter 14) (=>BPR 3.5-4 instead of 2-2.5 in HISAC project)
- high thrust loading of SCA, wide capabilities for engine thrust throttling (0.4-0.6 vs. 0.25-0.35 for subsonic civil aeroplanes)
- capability to use of nozzle variation for increase of noise reduction (provision of the same level of thrust at different combinations of fuel consumption and nozzle throat area)

Essence of CIAM approach to SCA takeoff noise management for Supersonic Civil Aeroplanes (SCA)

- ❑ Optimal (“low noise”) takeoff thrust management should provide maximal reduction of cumulative (Lateral and Flyover) noise at takeoff and initial climb
- ❑ Low noise takeoff thrust management includes optimal control by 3 thrust management factors:
  - ✓ method of thrust throttling (by nozzle and fuel flow variations)
  - ✓ initial altitude of thrust throttling
  - ✓ rate of thrust throttling
- ❑ Main noise sources (fan, jet, airframe, etc.) should be taken into account
- ❑ Actual airworthiness requirements (climb gradients, etc.) should be taking into account

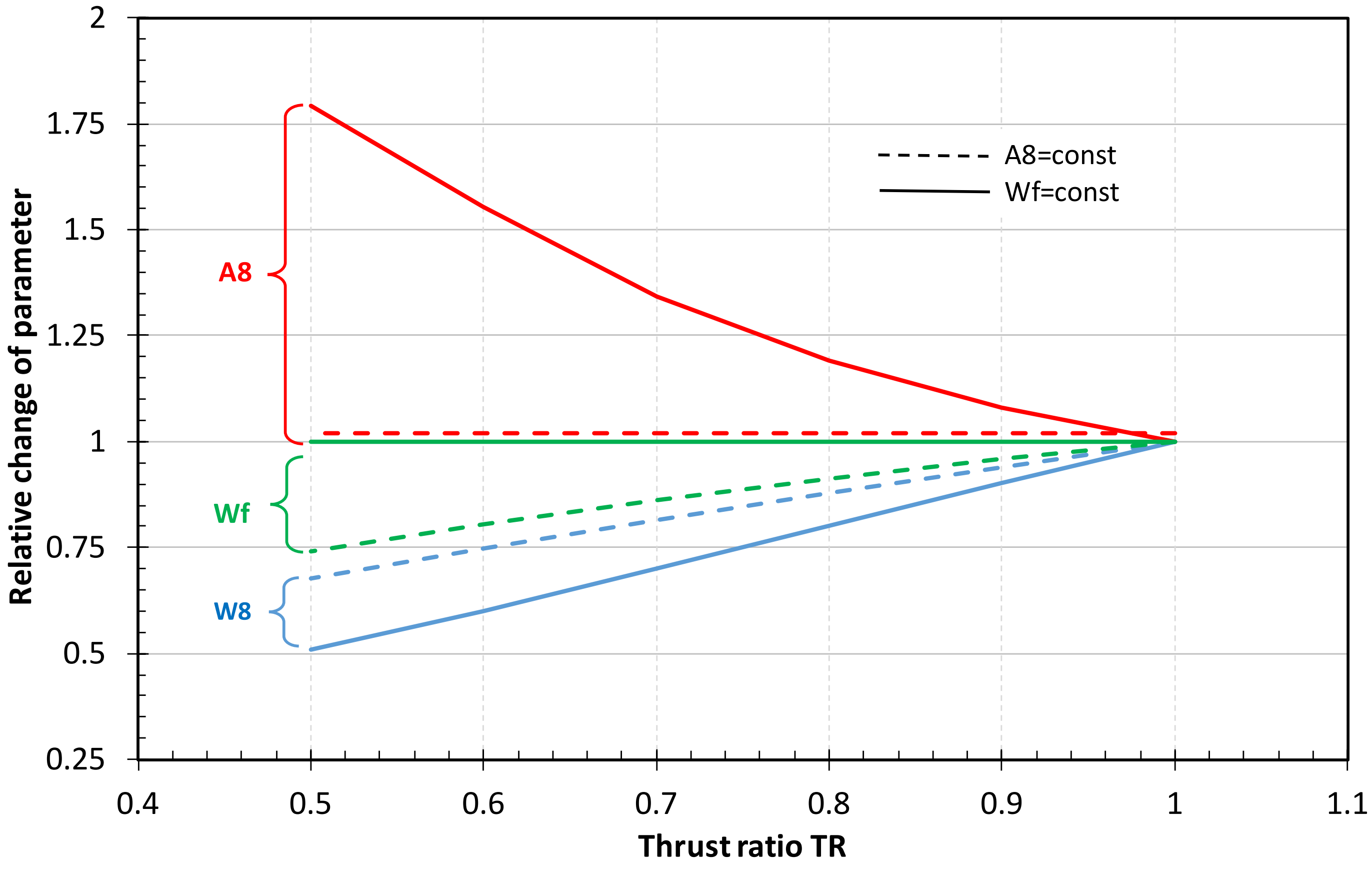




Different method of thrust throttling

- $A8$=const, W_{fan}=var – conventional method (with descreasing of air flow and RPM)
- W_{fan}=max=const – optimal method to maximal reduction of jet velocity (and accordingly jet noise) + decrease of engine acceleration time!
- W_{fan}=var=opt and $A8$=var=opt – optimal way to maximal noise reduction at takeoff (currently is under investigations)

Impact of method of thrust throttling on change of engine parameters

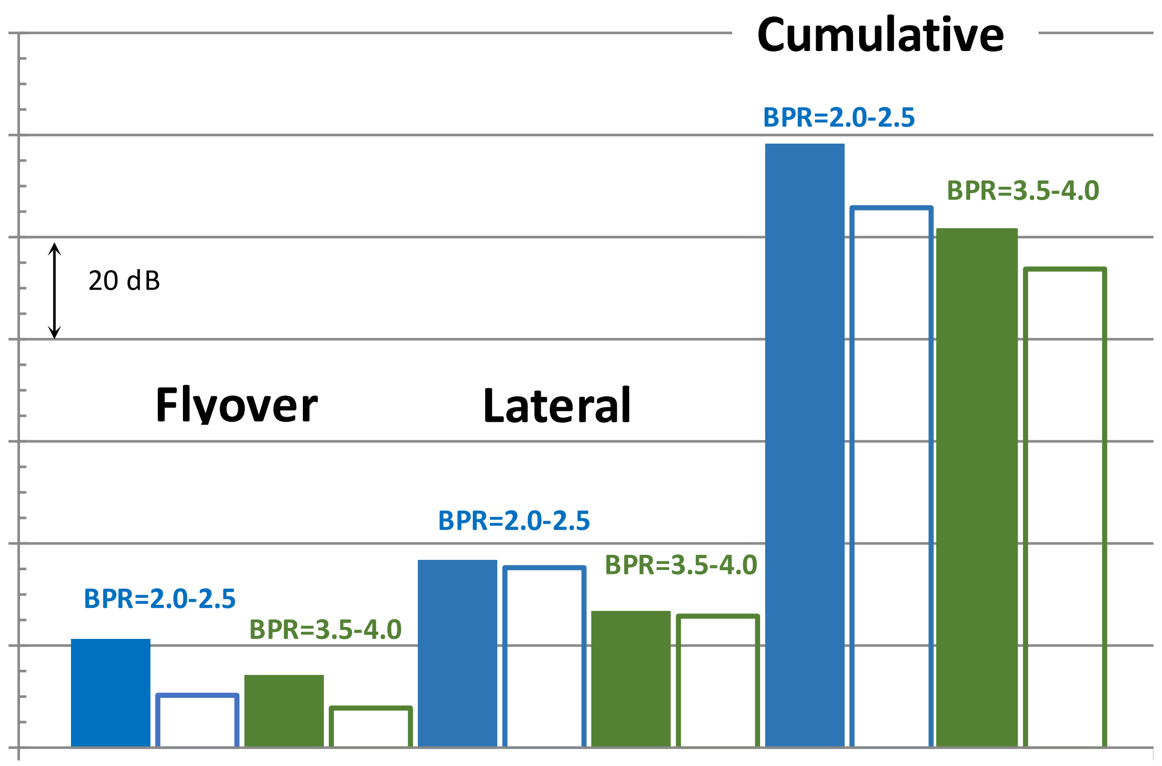


➢ **W_{fan}=const is more efficient than $A8$=const on jet noise reduction due to additional decreasing of jet velocity W8**

Jet noise efficiency of takeoff thrust management for different BPR engines

Impact on jet noise at takeoff for different BPR engines

- Efficiency of jet noise reduction at W_{fan}=const is worsen with increase of BPR (8 dB instead of 12 dB for cumulative takeoff noise) due to decrease of absolute level of jet velocity
- Method of throttling (W_{fan}=const or A8=const) don't practically impact on Lateral jet noise level due to at high values of TR way of throttling has low influence on the jet velocity reduction
- Further fan noise predictions showed that to maximize takeoff noise reduction optimal combination of variation of W_{fan} and A8 are needed at thrust throttling



Impact of initial altitude and rate of thrust throttling on SSBJ takeoff noise

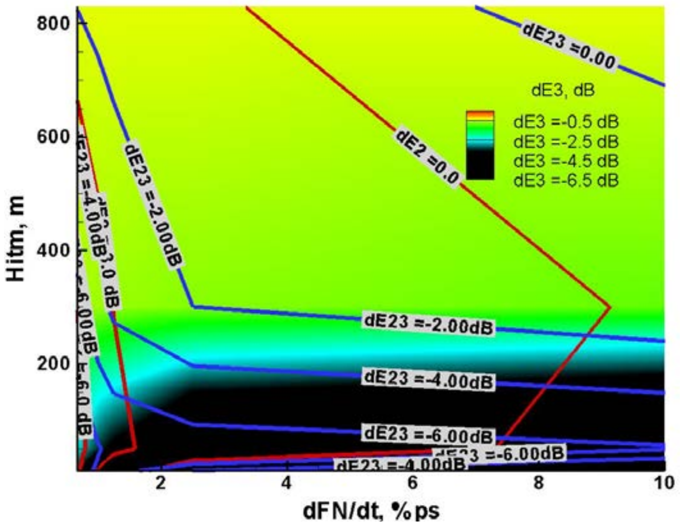
- **Initial altitude of thrust throttling H_{iTM}**

  - **Rate of thrust throttling dFN/dt**

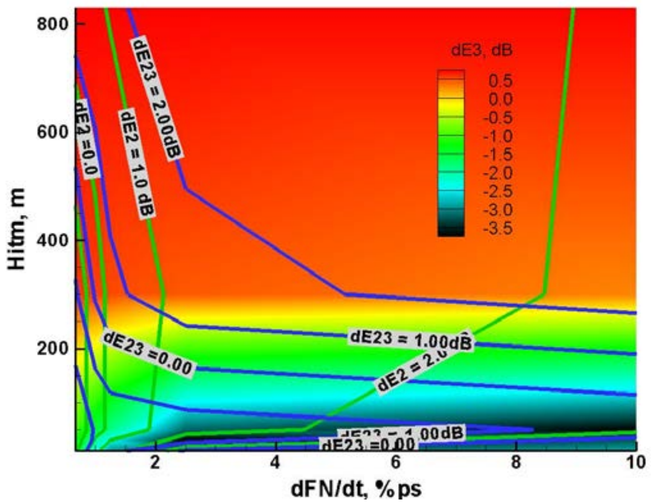
- impact on the rate and duration of sound of upper 10 PNdB in Lateral point
- defines flight altitude, at which minimal thrust will be reached (it is important from flight safety point of view)

Impact of HiTM and dFN/dt on takeoff jet noise at different ways of throttling

A8=const



Wfam=const



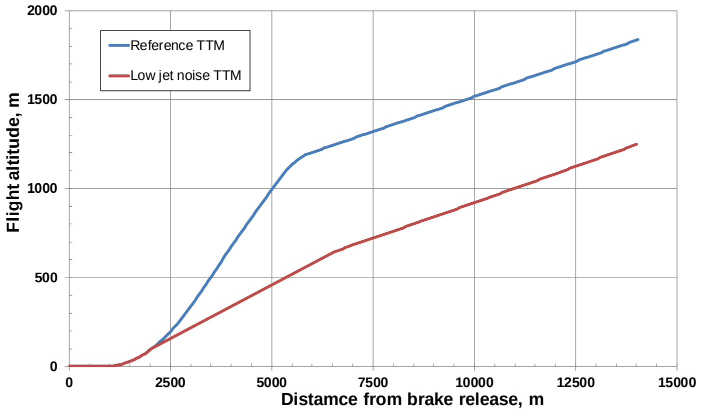
- Lateral and Flyover jet noise is ~ const at dFN/dt > 2-3%/s and $H_{i\,TM}$ > 200-250m
- if ↓$H_{i\,TM}$ < 20-30m and dFN/dt <1-2%ps → EPNLFlyover ~ const , aand $EPNL_{Lat}$ limited ↓

- at the same $H_{i\,TM}$ (up to 20-30m and dFN/dt < 1-2%) significantly decrease EPNL Lateral (by 2-3dB) and EPNLFlyover (by 1-1.5dБ)$_3$ cum.jet noise at takeoff by 3-4.5 dB)

- **Lowering of HiTM up to 20-30m and dFN/dt up to 1-2%/s together with using method of throttling Wfan=const allow to reduce cumulative takeoff jet noise by 4-4.5dB**
- **Using low HiTM and dFN/dt =-1-2%/c could allow reach minimal thrust level after 300m, and increase of flight safety**

Takeoff thrust management of SSBJ engine for maximal jet noise reduction

Trajectory

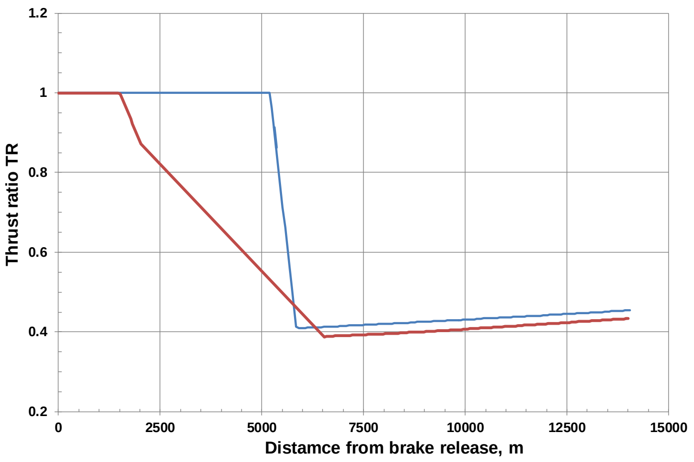


SSBJ-supersonic business jet

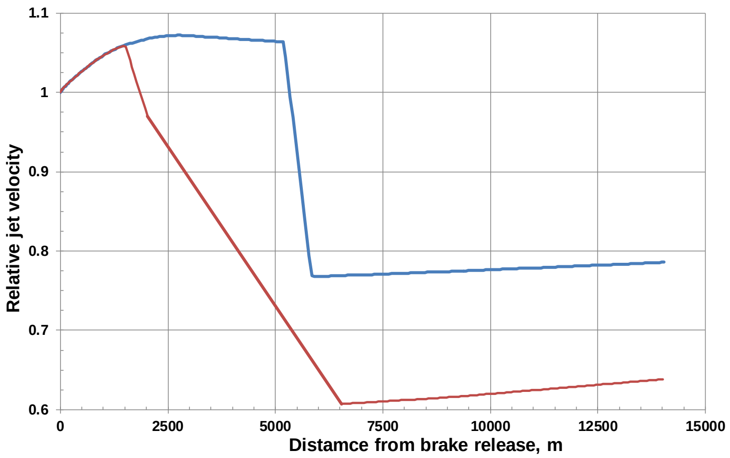
Reference A/C and engine

Max takeoff weight TOGW = 47.2 t
Wing area S = 130 m^2
Max takeoff thrust FN_{TO} = 14.0 t
Cruise Mach number M_{cr} = 1.8
Number of engines = 2
Mixed TF with variable supersonic nozzle
ByPass Ratio BPR = 3.52
Overall Pressure Ratio OPR = 20.0
Temperature Throttle Ratio TTR = 1.13

Thrust



Jet velocity W8



Reference Takeoff Thrust Management

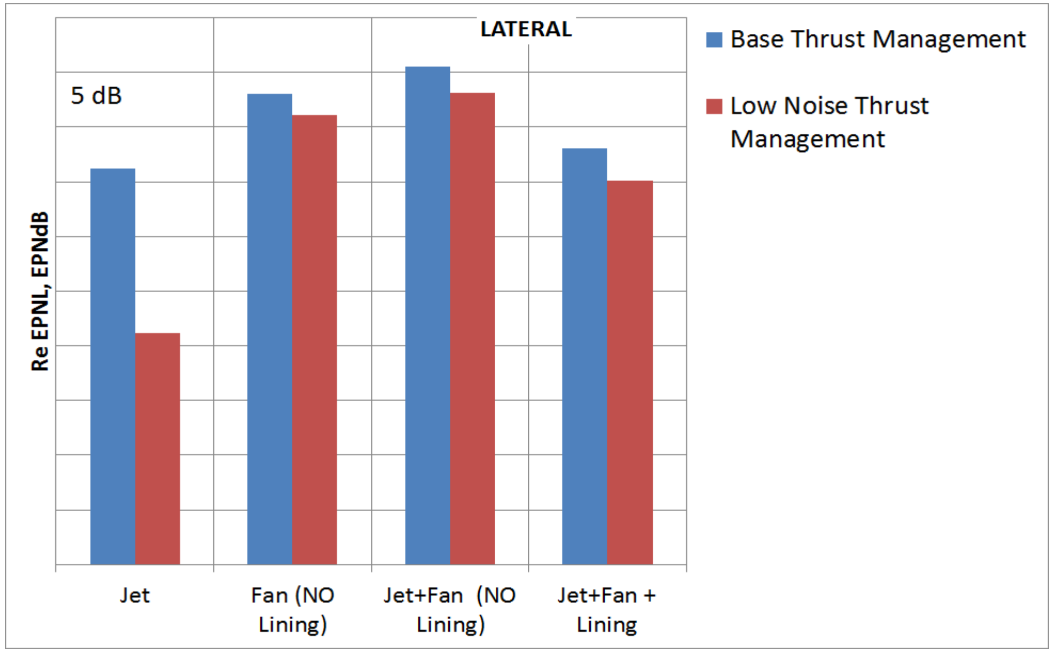
$A8_{ref}$ = const
Initial distance of throttling $L_{iTM\ ref}$ (start of cutback) = 5200m
Rate of throtlling dFN/dt_{ref} = 10% ps

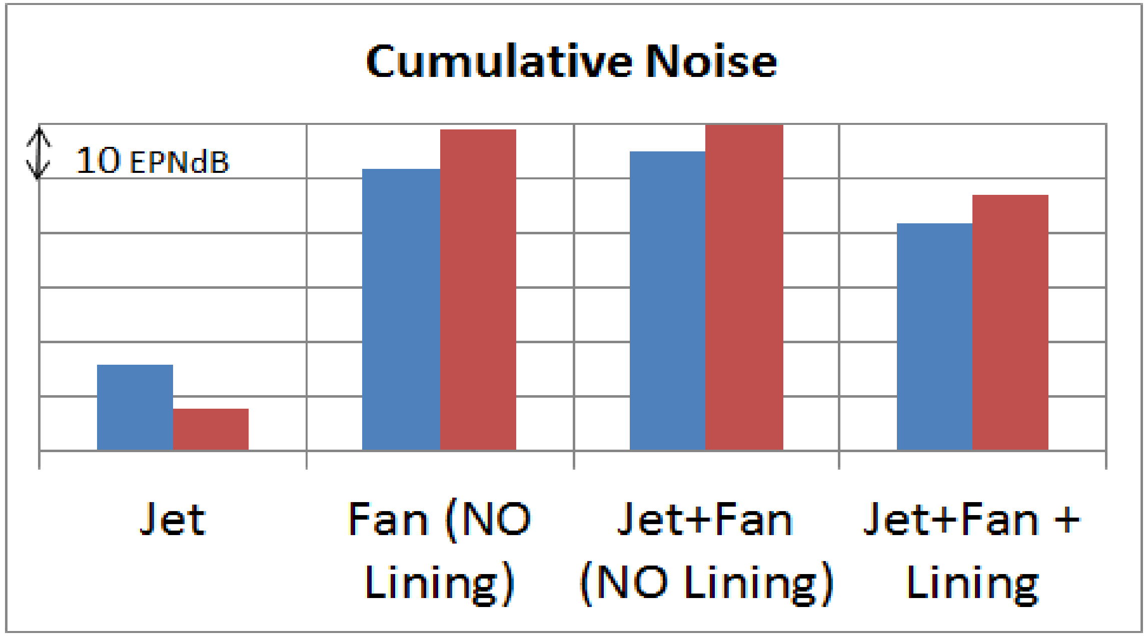
Low jet noise Takeoff Thrust Management

A8 = var
W_{fan} = max
H_{iTM} = opt
dFN/dt_{ref} = opt

- significant lowering of trajectory above the flyover point due to thrust reduction
- Engine power setting (thrust ratio TR) is decreased by 50-60 % above certification points.

SSBJ noise level prediction when jet and lined fan are taken into account





- ❑ Use of Low Jet takeoff thrust management lateral jet noise is reduced by 15 EPNdB in comparison with use of Reference TTM
- ❑ Cumulative takeoff jet noise is reduced by 11 EPNdB

- ❑ Prediction of total aircraft noise (taking into account jet and fan noise and use of acoustic liners) showed that Low Jet noise Takeoff Thrust Management vs Reference TTM is higher by 5 EPNdB.

Optimal takeoff thrust management should taken into account all main aircraft noise sources (fan, turbine, combustor, airframe)

Main conclusions and further investigations

- Studying by CIAM **”low noise” takeoff thrust management** (LNTTM) should provide maximal reduction of SSBJ total takeoff noise
- LNTTM is based on the using of optimal management of 3 thrust throttling factors (method, initial altitude and rate)
- LNTTM should taken into account all main aircraft noise sources (fan, turbine, combustor, airframe)
- To deliver final recommendations on LNTTM following further activities are required:
  - application low noise takeoff thrust management approach for reference SCA, considered in CAEP
  - study of impact of main noise sources on LNTTM depending on aircraft and engine size and parameters

Thank you for your attention!

111116, Russia, Moscow,
Aviamotornaya Str., 2
www.ciam.ru

Tel.: +7 (499) 763-61-67
E-mail: info@ciam.ru