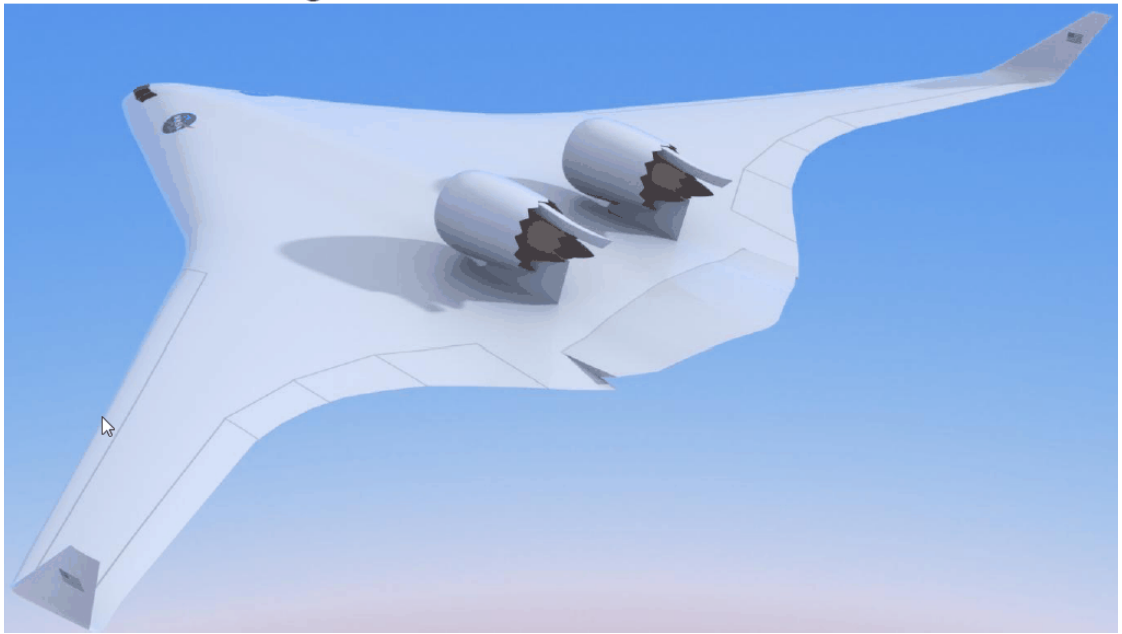
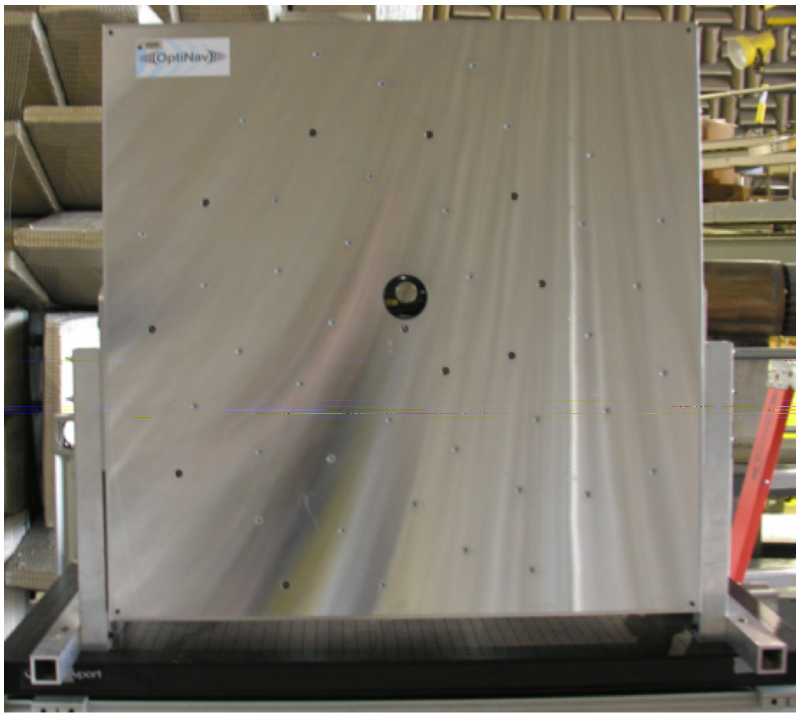
Jet-Surface Interaction Test: Phased Array Noise Source Localization Results

Gary Podboy
NASA Glenn Research Center
Cleveland, Ohio, USA

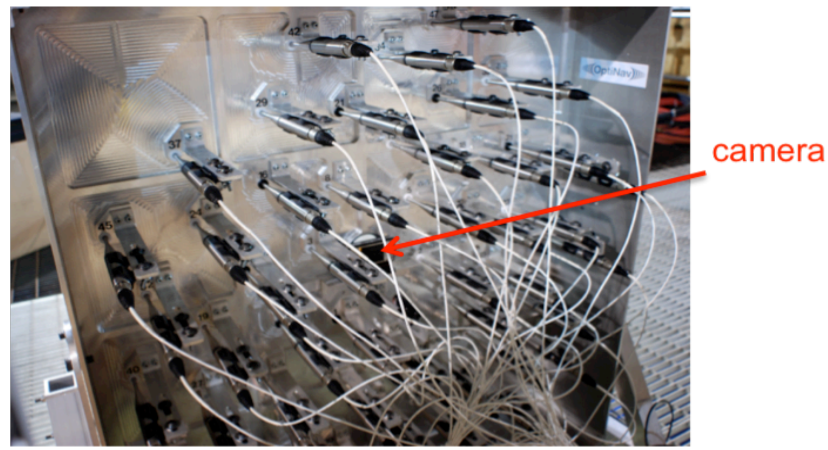
Support Provided by NASA Subsonic Fixed Wing Project



Optinav Array48 Phased Array



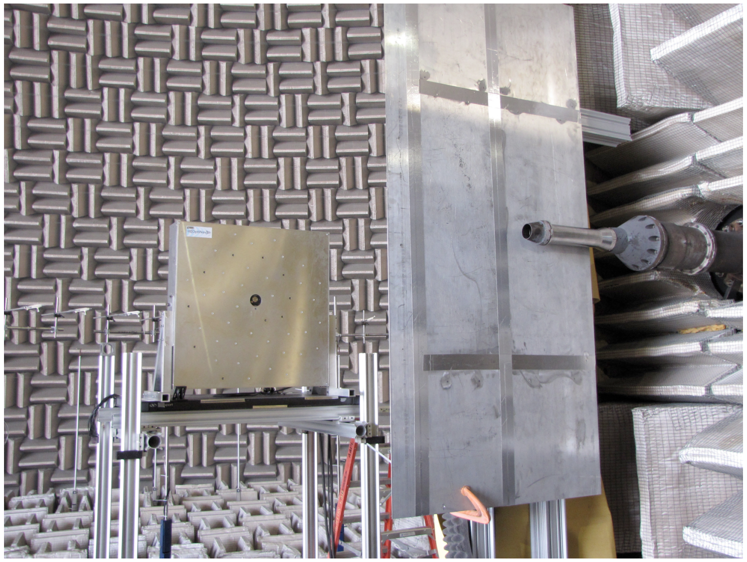
Front



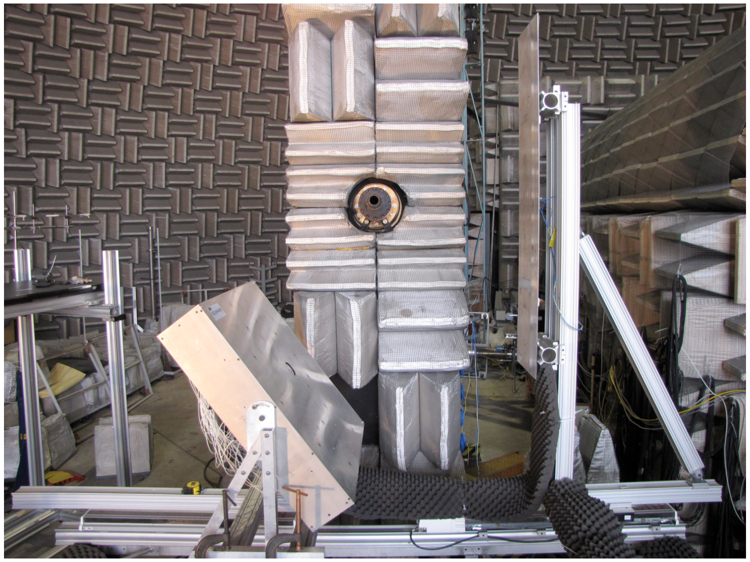
Back

Reason for Acquiring the Phased Array Data

To help explain conventional, single-microphone results



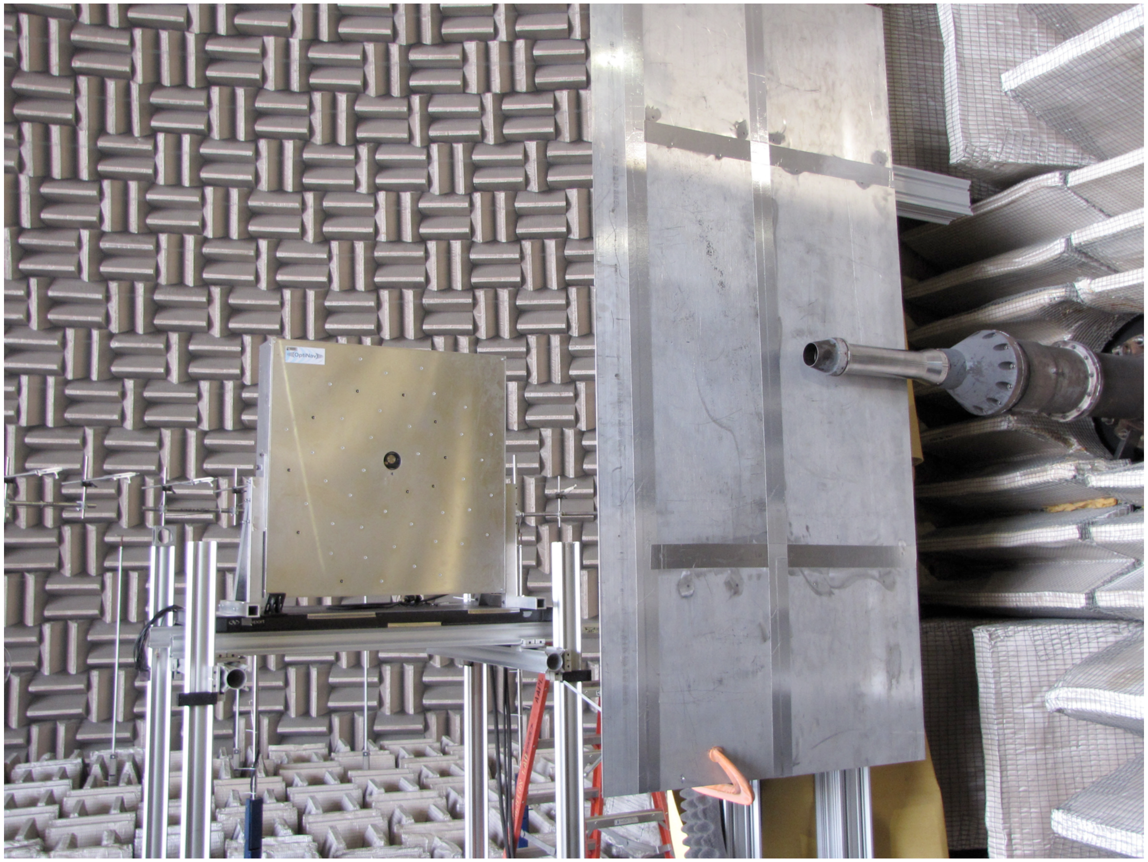
Array location for
shielding surface tests



Array location for
reflecting surface tests

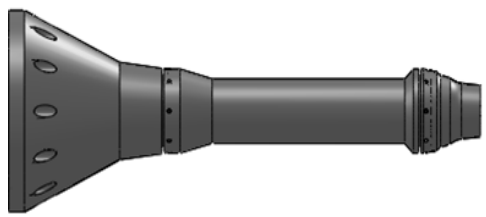
Distribution of Noise Sources in the Bare Jet are Important

Array Location for Bare Jet Tests

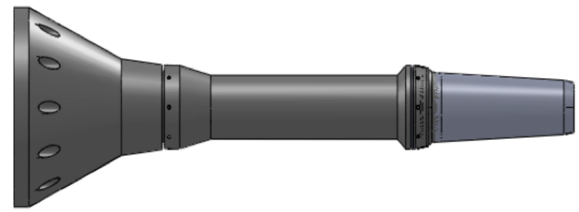


Array on a stationary stand
55 jet diameters away
broadside to the jet

Jet Operating Conditions



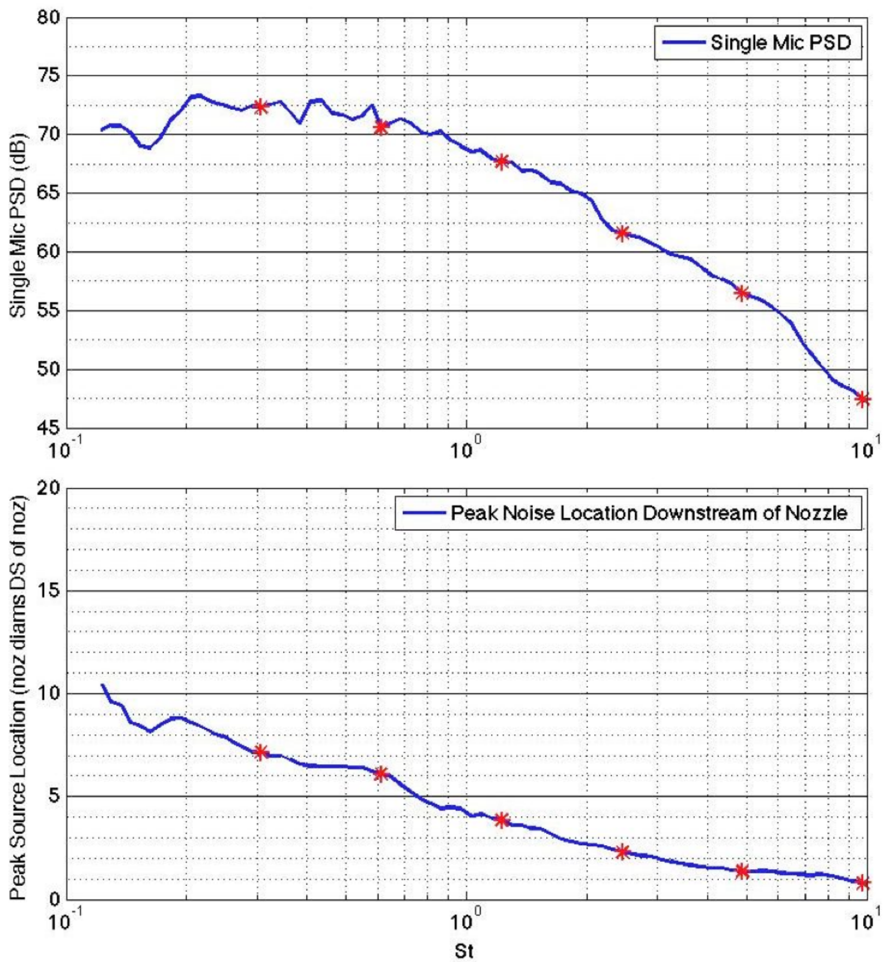
SMC000 Nozzle
convergent

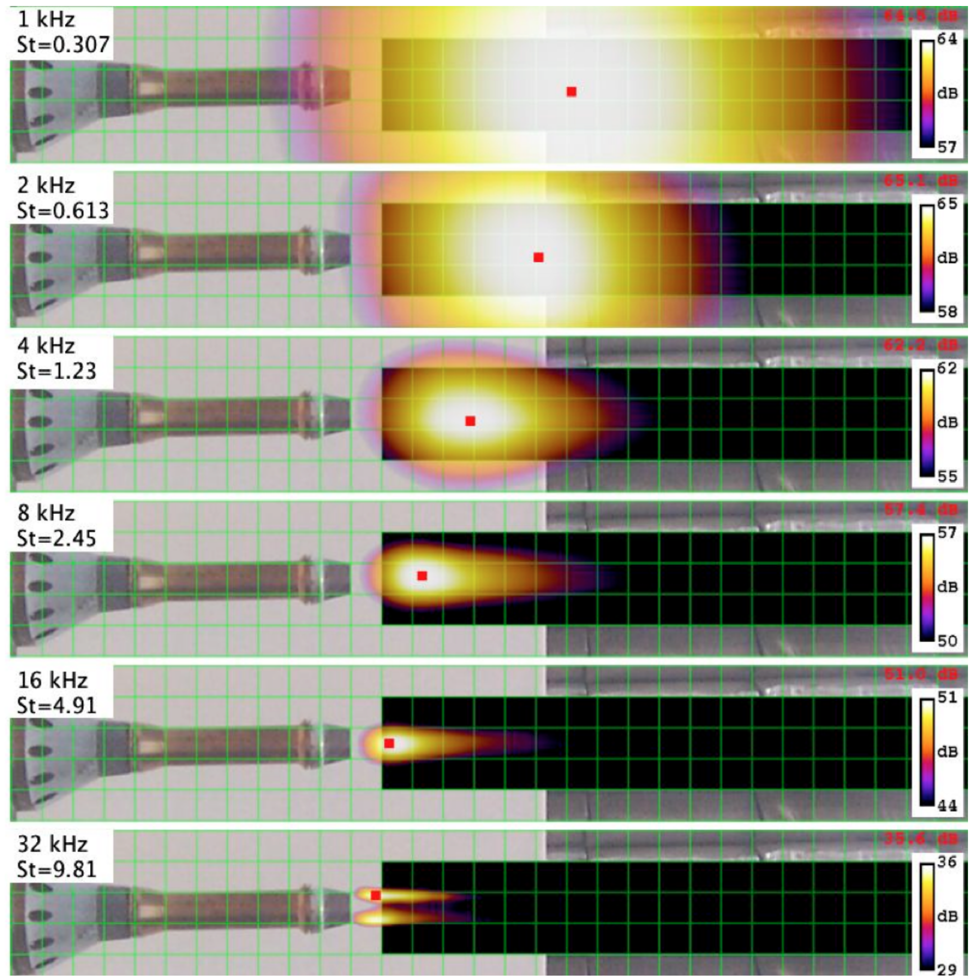


SMC016 Nozzle
convergent-divergent
M_d=1.5

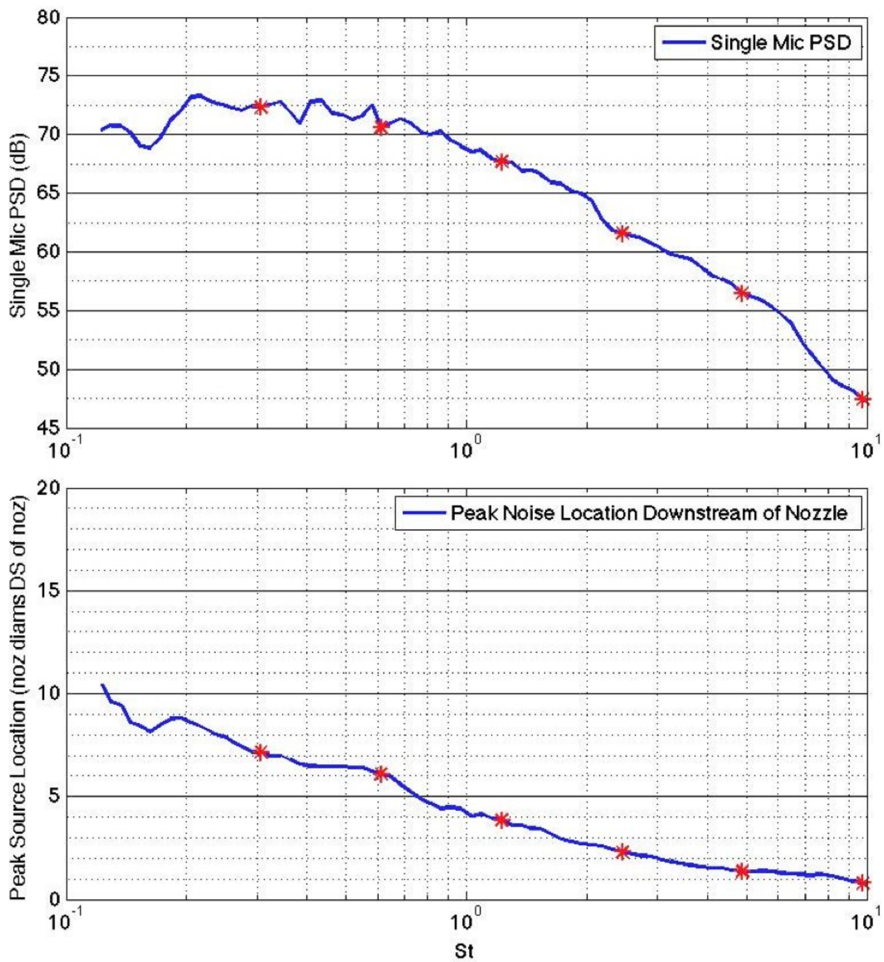
Nozzle	Setpoint	NPR P_t/P_{amb}	TSR T_s/T_{amb}	M_a V/c_{amb}	M_j V/c_{local}
SMC000	3	1.20	0.95	0.50	0.51
SMC000	7	1.86	0.835	0.90	0.98
SMC000	27	1.36	1.76	0.90	0.68
SMC000	46	1.24	2.70	0.90	0.55
SMC000	9010	3.18	0.74	1.18	1.40
SMC016	11606	2.75	0.76	1.13	1.29
SMC016	11610	3.67	0.72	1.31	1.50
SMC016	11617	4.32	0.76	1.41	1.61

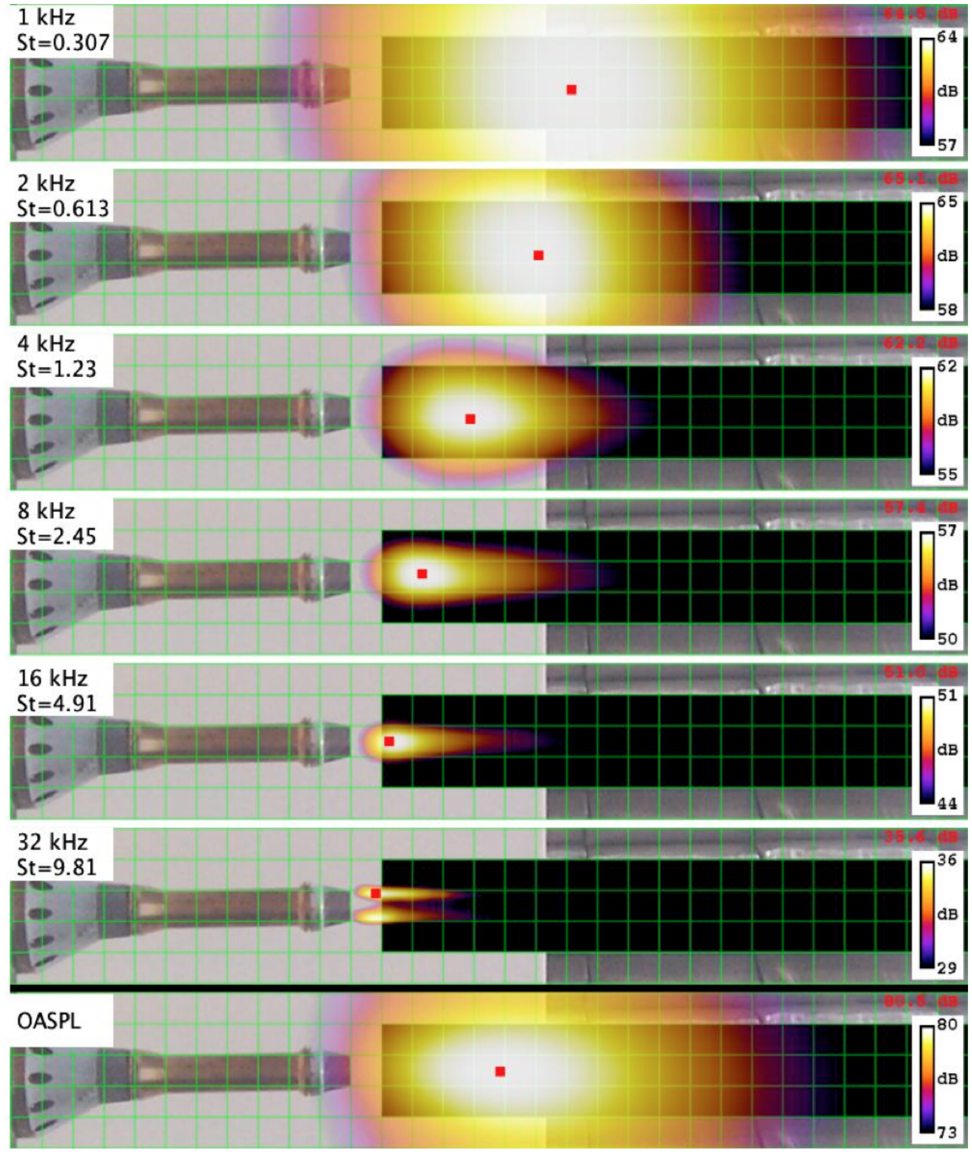
SMC000 Nozzle M_a=0.50 TSR=0.95



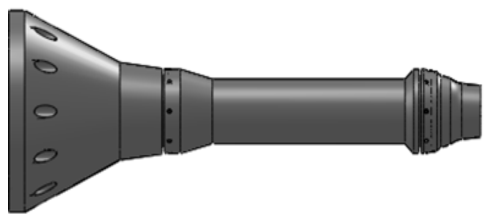


SMC000 Nozzle M_a=0.50 TSR=0.95

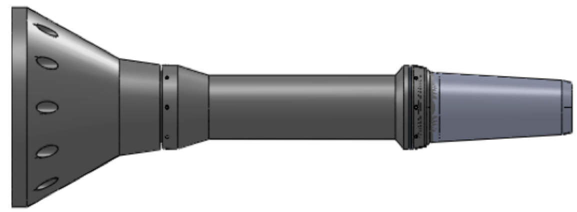




Jet Operating Conditions



SMC000 Nozzle
convergent



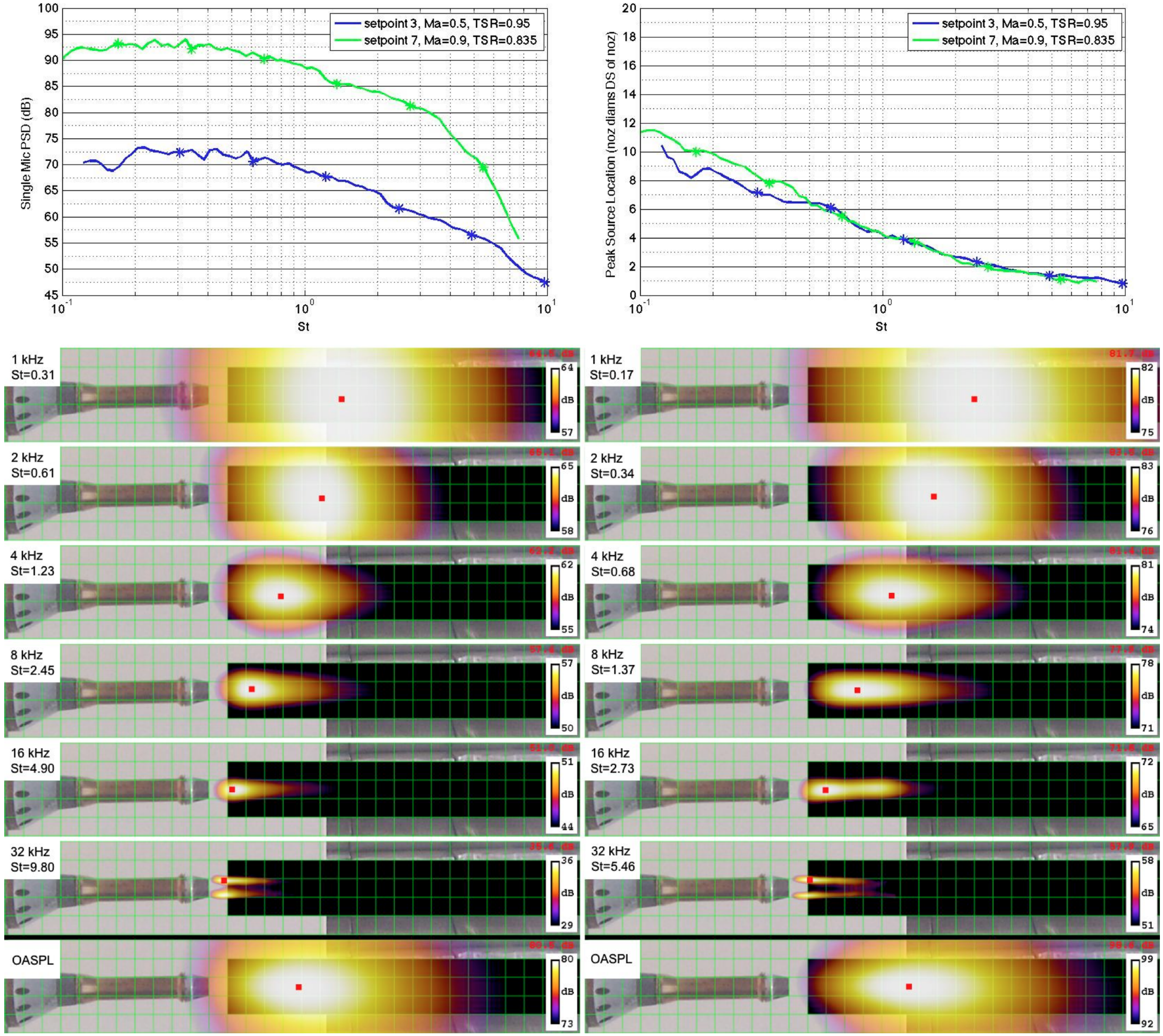
SMC016 Nozzle
convergent-divergent
M_d=1.5

Nozzle	Setpoint	NPR P_t/P_{amb}	TSR T_s/T_{amb}	M_a V/c_{amb}	M_j V/c_{local}
SMC000	3	1.20	0.95	0.50	0.51
SMC000	7	1.86	0.835	0.90	0.98
SMC000	27	1.36	1.76	0.90	0.68
SMC000	46	1.24	2.70	0.90	0.55
SMC000	9010	3.18	0.74	1.18	1.40
SMC016	11606	2.75	0.76	1.13	1.29
SMC016	11610	3.67	0.72	1.31	1.50
SMC016	11617	4.32	0.76	1.41	1.61

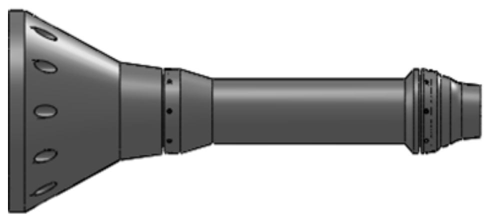
SMC000 Nozzle Two Cold Subsonic Jets

M_a=0.5 cold

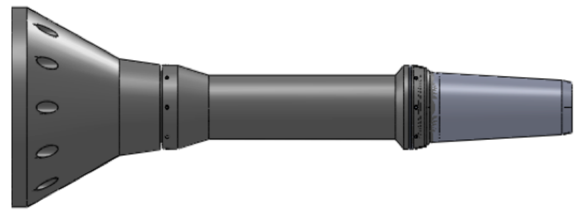
M_a=0.9 cold



Jet Operating Conditions



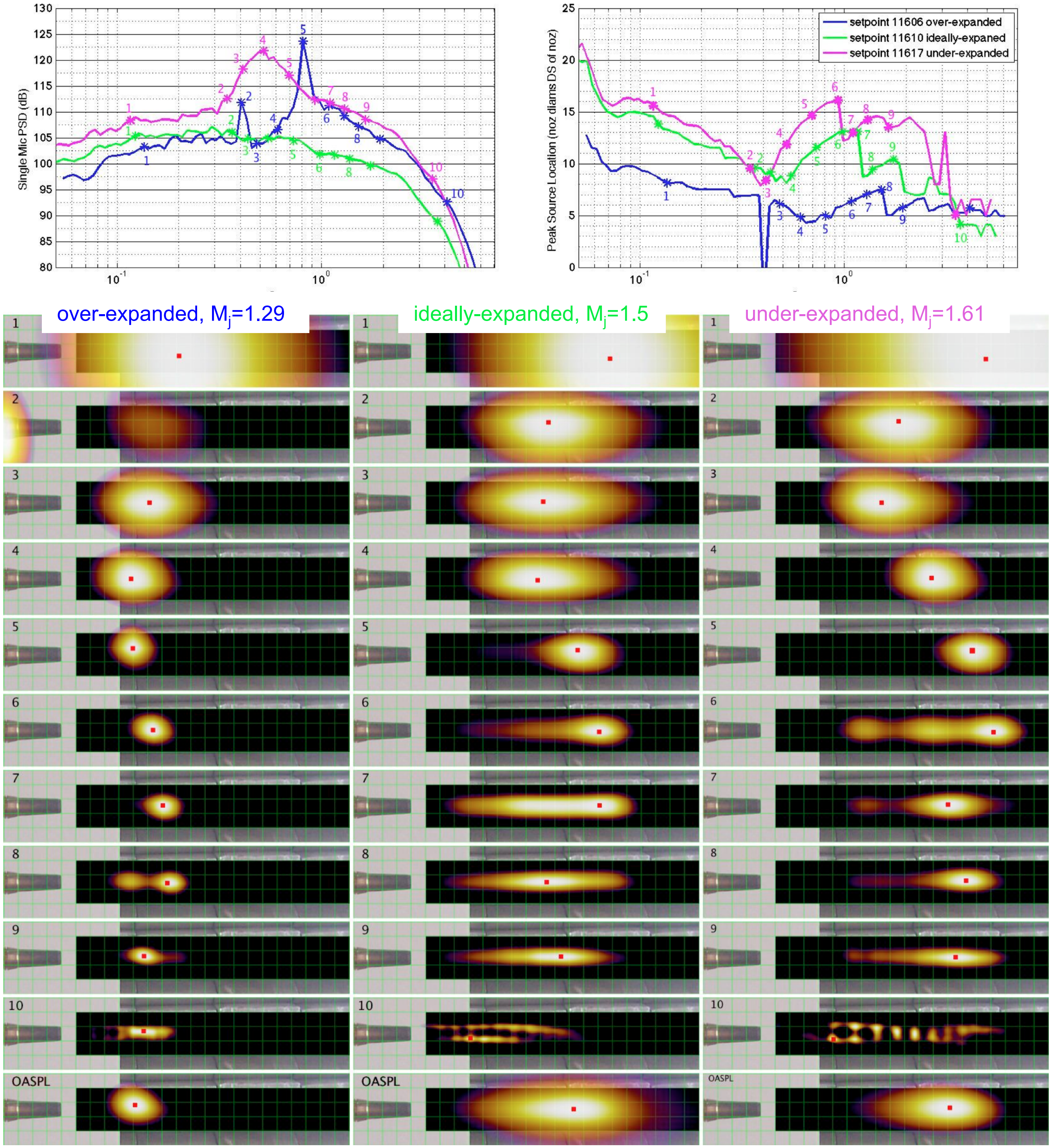
SMC000 Nozzle
convergent



SMC016 Nozzle
convergent-divergent
M_d=1.5

Nozzle	Setpoint	NPR P_t/P_{amb}	TSR T_s/T_{amb}	M_a V/c_{amb}	M_j V/c_{local}
SMC000	3	1.20	0.95	0.50	0.51
SMC000	7	1.86	0.835	0.90	0.98
SMC000	27	1.36	1.76	0.90	0.68
SMC000	46	1.24	2.70	0.90	0.55
SMC000	9010	3.18	0.74	1.18	1.40
SMC016	11606	2.75	0.76	1.13	1.29
SMC016	11610	3.67	0.72	1.31	1.50
SMC016	11617	4.32	0.76	1.41	1.61

SMC016 Nozzle
Cold Supersonic Jets



Tam's Model of BBSN

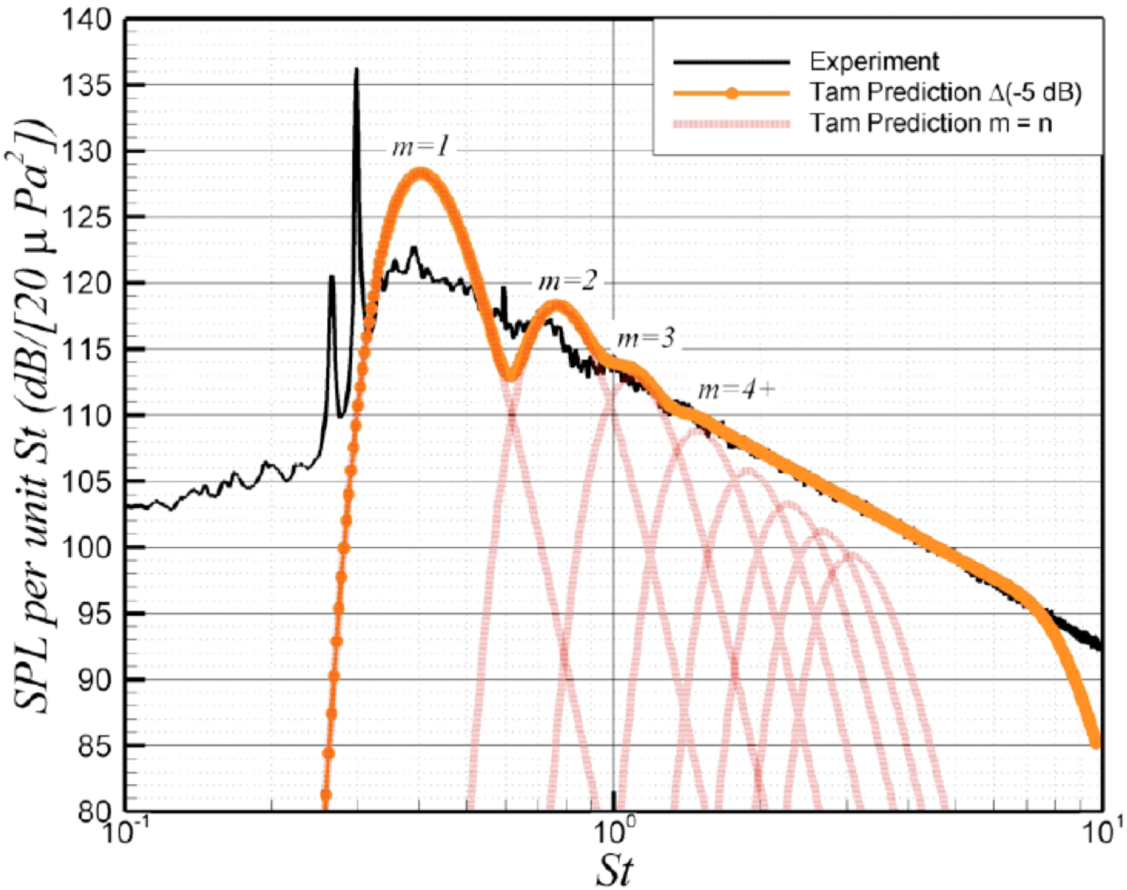
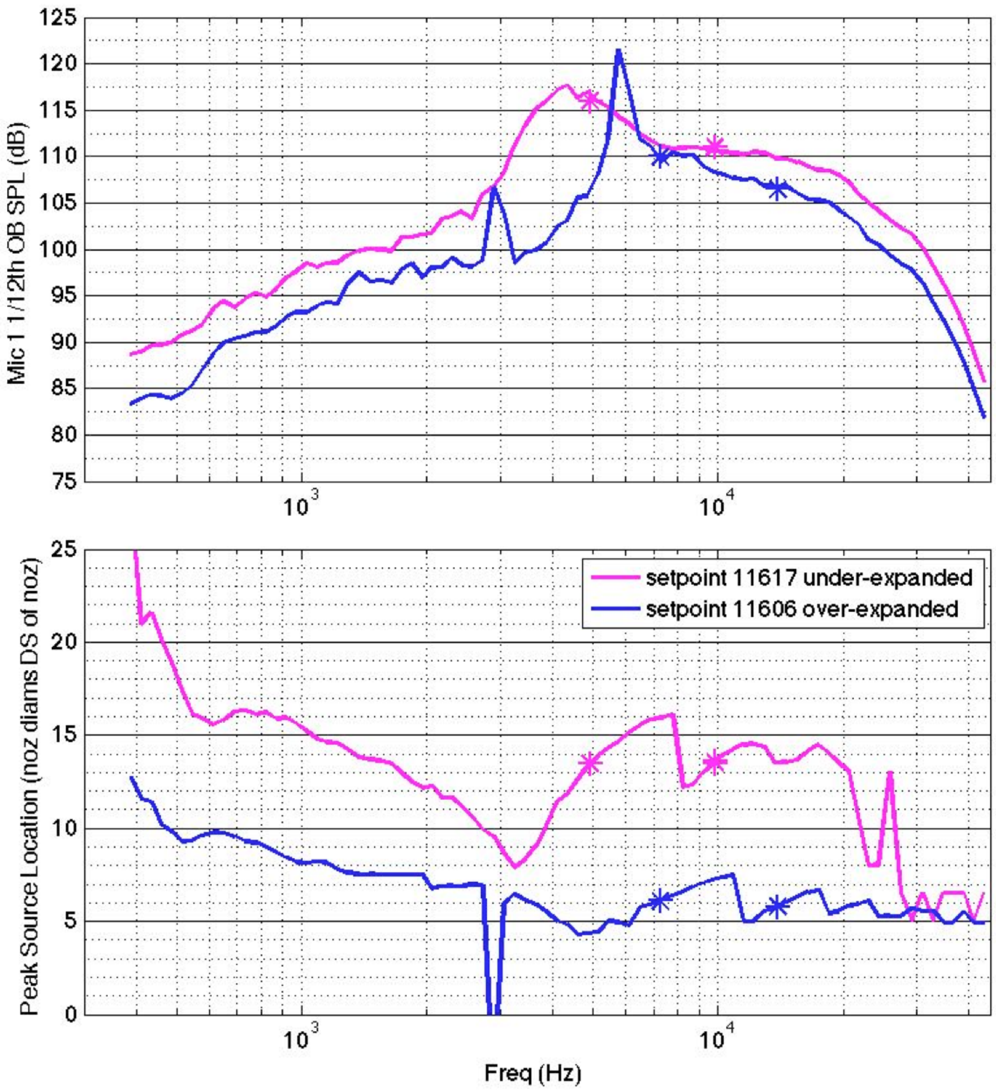
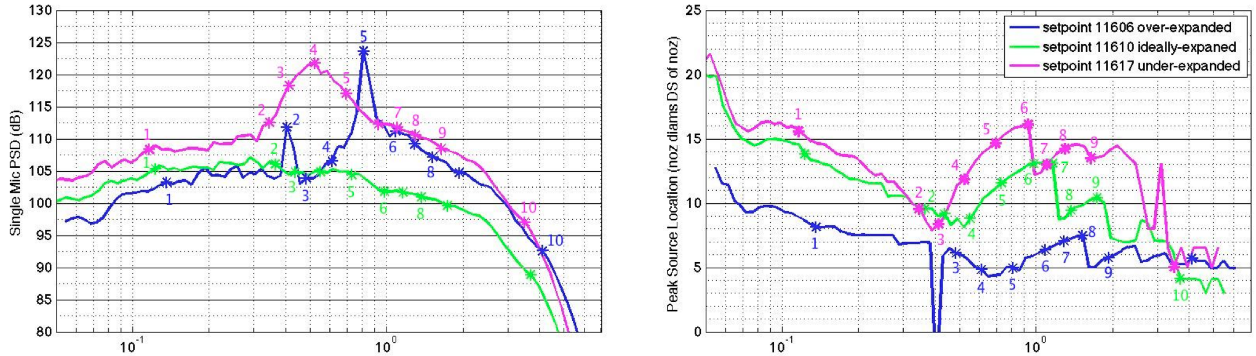


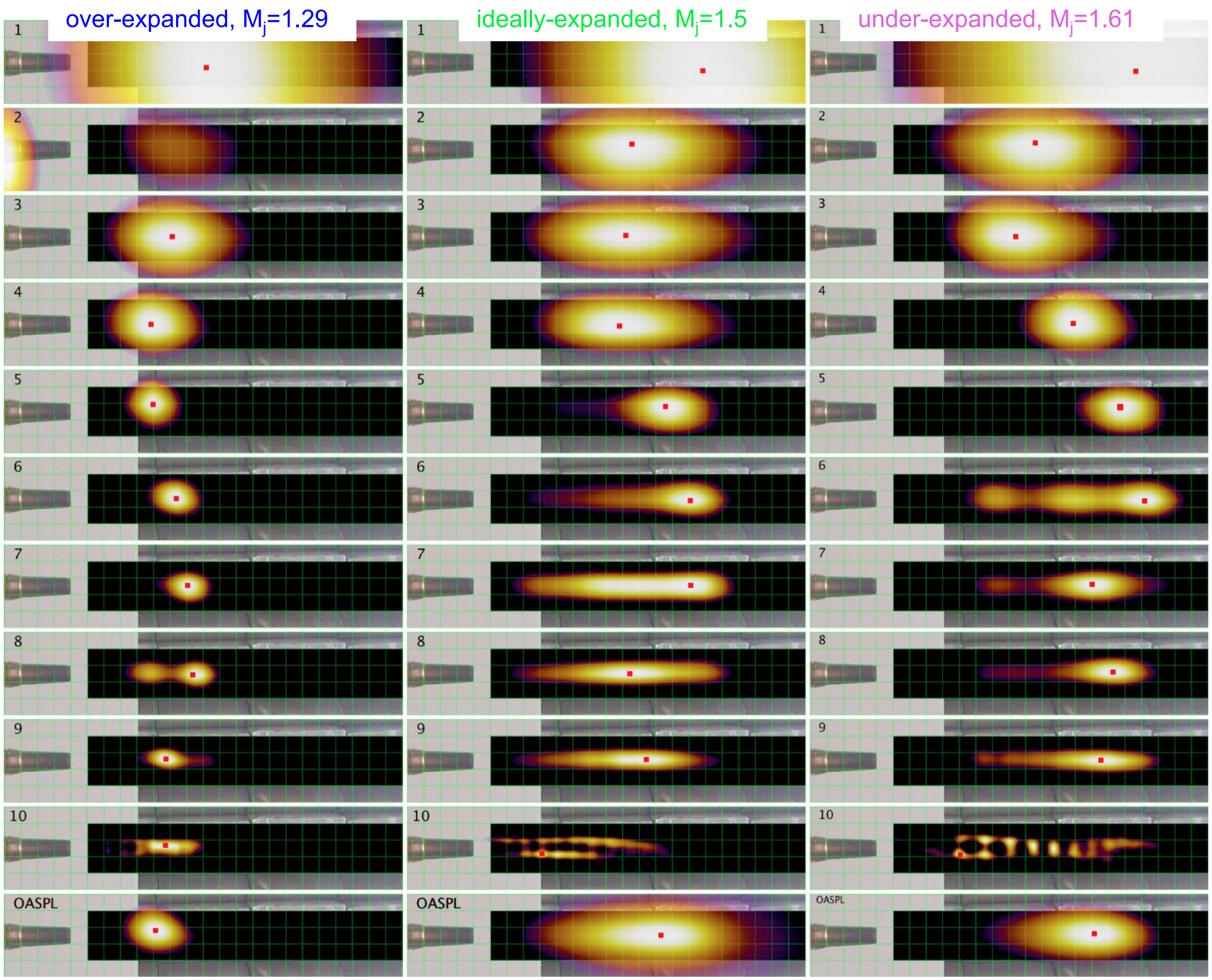
figure taken from Miller, S.A.E., "The Prediction of Broadband Shock-Associated Noise Using Reynolds-Averaged Navier-Stokes Solutions," Ph. D. dissertation, Pennsylvania State University, December 2009

Peak Frequencies from Tam's Model Overlaid on Data

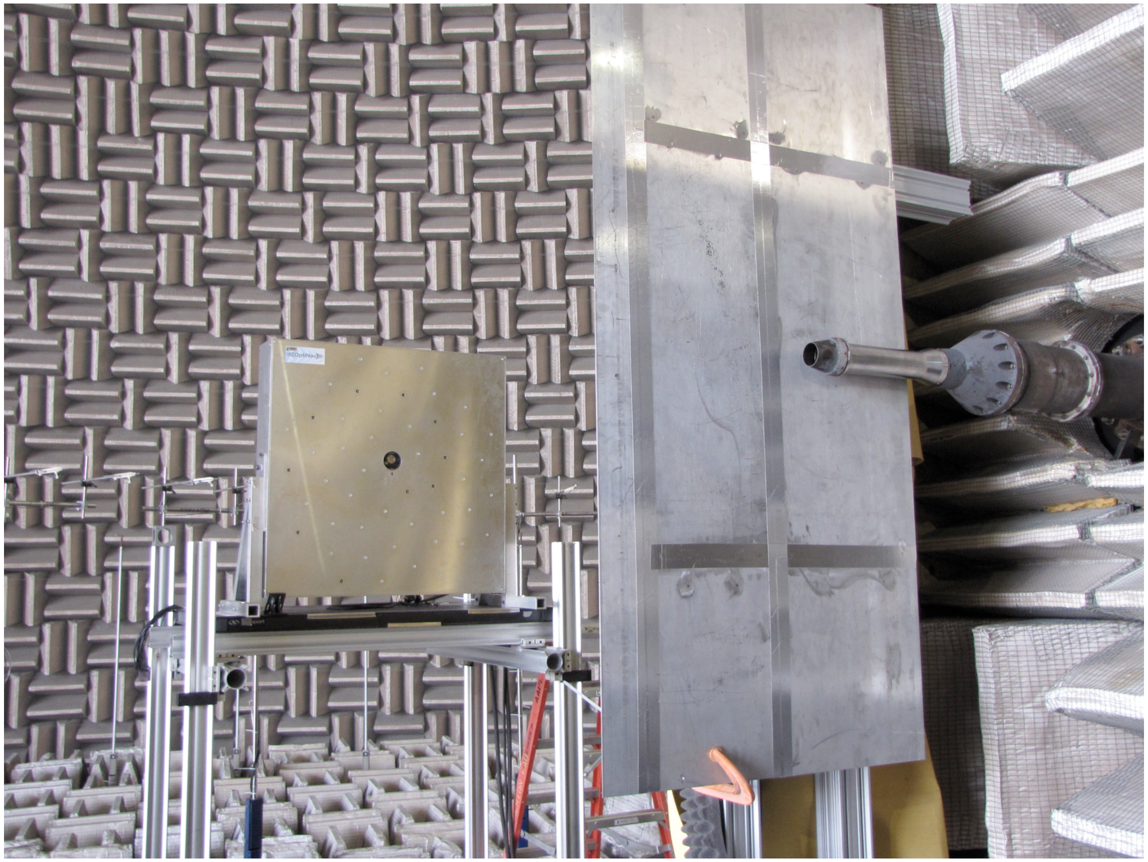


SMC016 Nozzle
Cold Supersonic Jets



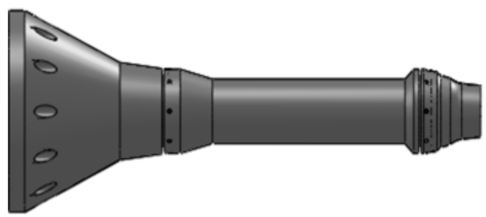


Array Location for Shielding Surface Tests

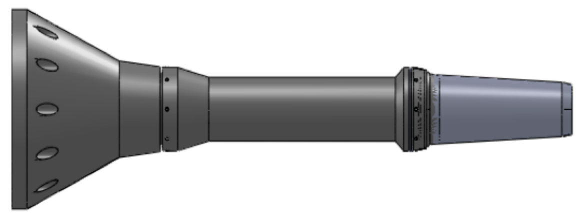


Array on a stationary stand
55 jet diameters away
broadside to the jet

Jet Operating Conditions



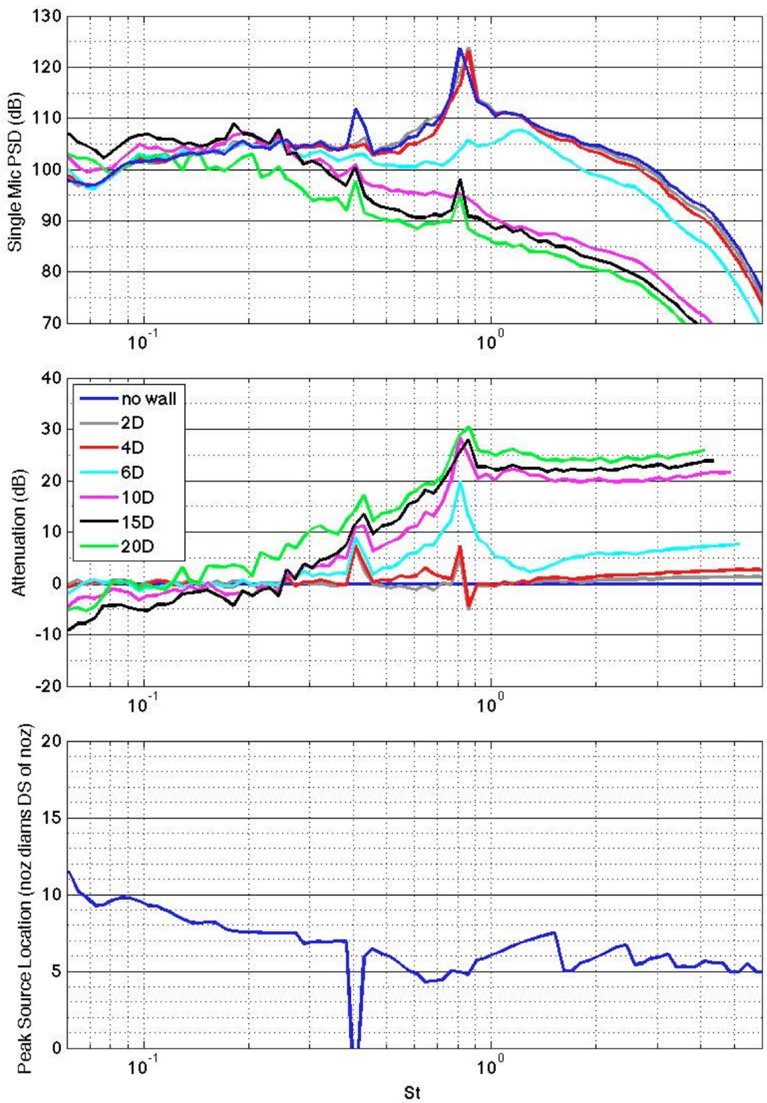
SMC000 Nozzle
convergent



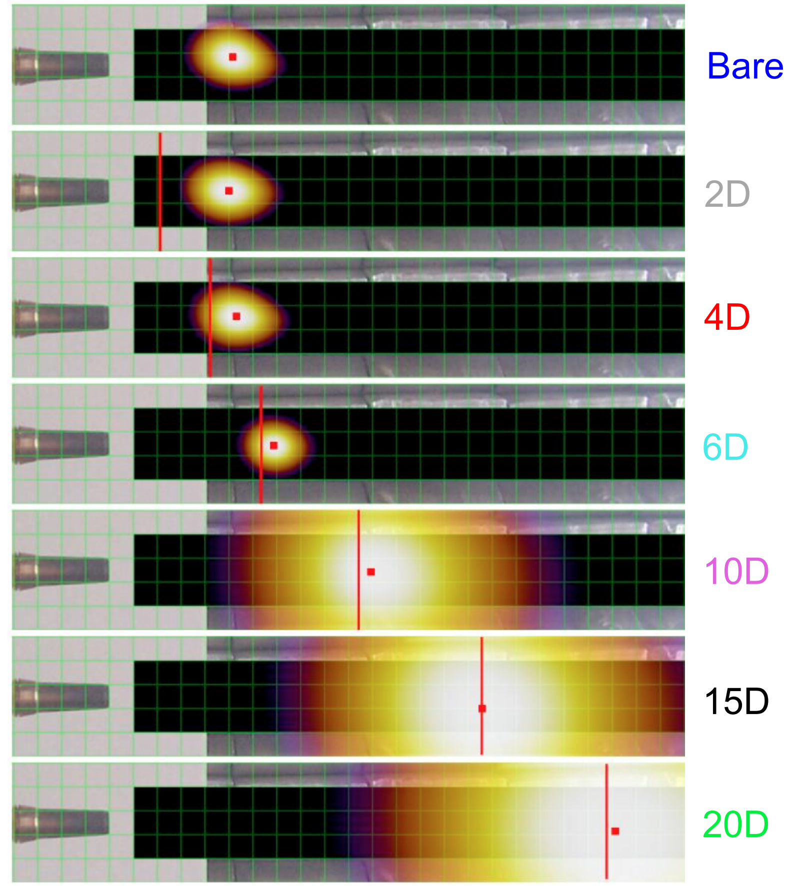
SMC016 Nozzle
convergent-divergent
M_d=1.5

Nozzle	Setpoint	NPR P_t/P_{amb}	TSR T_s/T_{amb}	M_a V/c_{amb}	M_j V/c_{local}
SMC000	3	1.20	0.95	0.50	0.51
SMC000	7	1.86	0.835	0.90	0.98
SMC000	27	1.36	1.76	0.90	0.68
SMC000	46	1.24	2.70	0.90	0.55
SMC000	9010	3.18	0.74	1.18	1.40
SMC016	11606	2.75	0.76	1.13	1.29
SMC016	11610	3.67	0.72	1.31	1.50
SMC016	11617	4.32	0.76	1.41	1.61

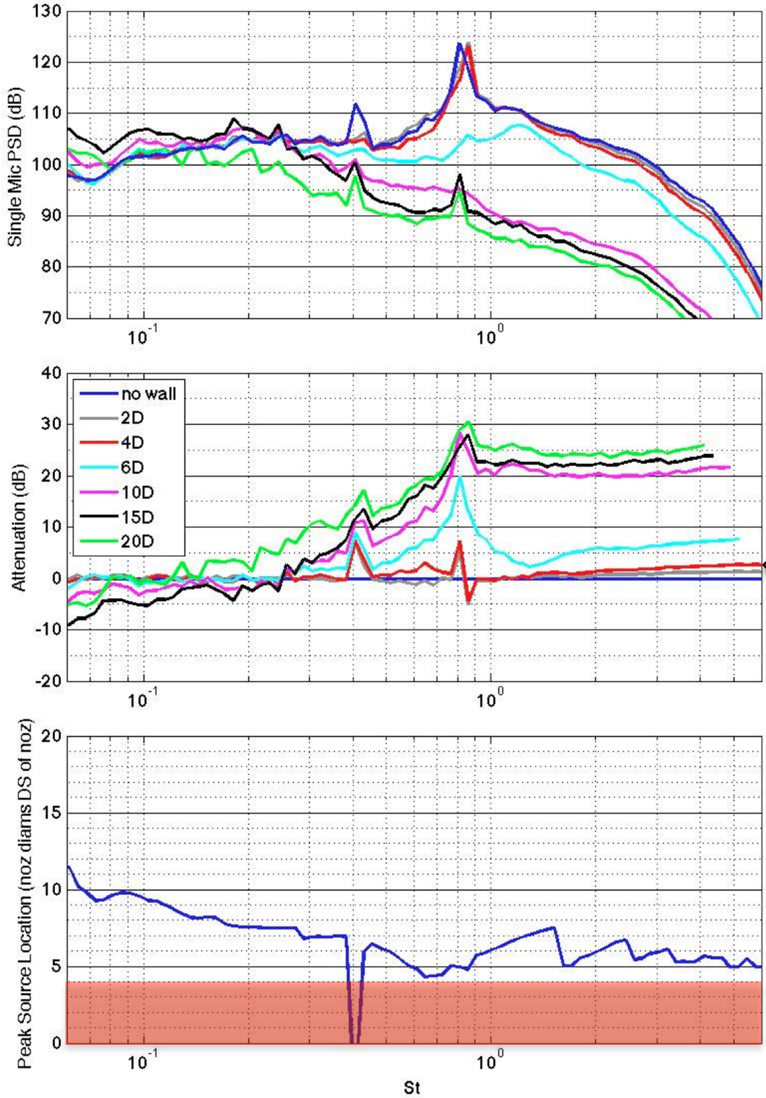
Shielding Data Obtained on Over-Expanded Supersonic Jet



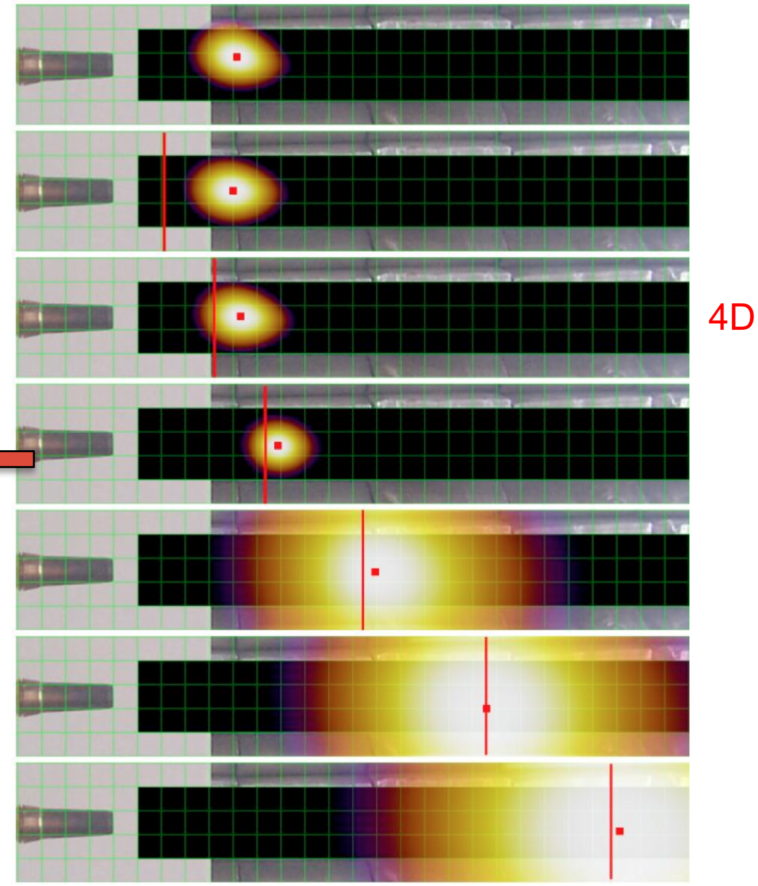
SMC016 Nozzle
M_j=1.29
r/D=3



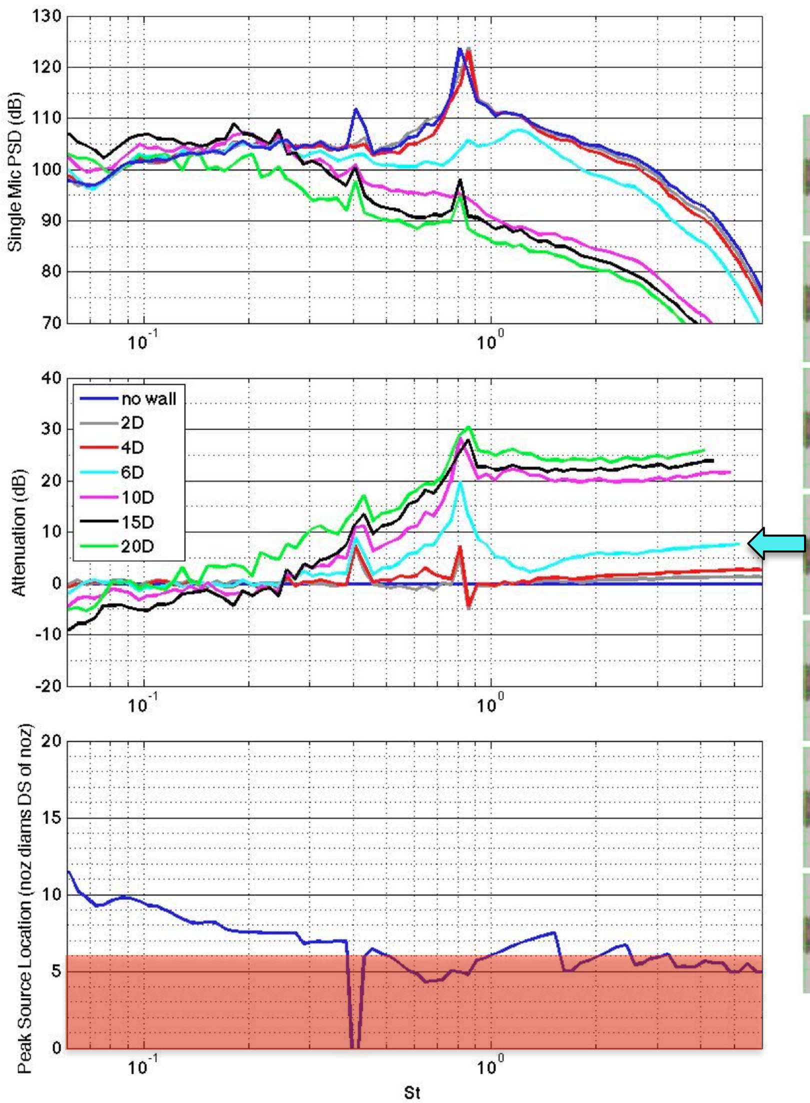
Shielding Data Obtained on Over-Expanded Supersonic Jet



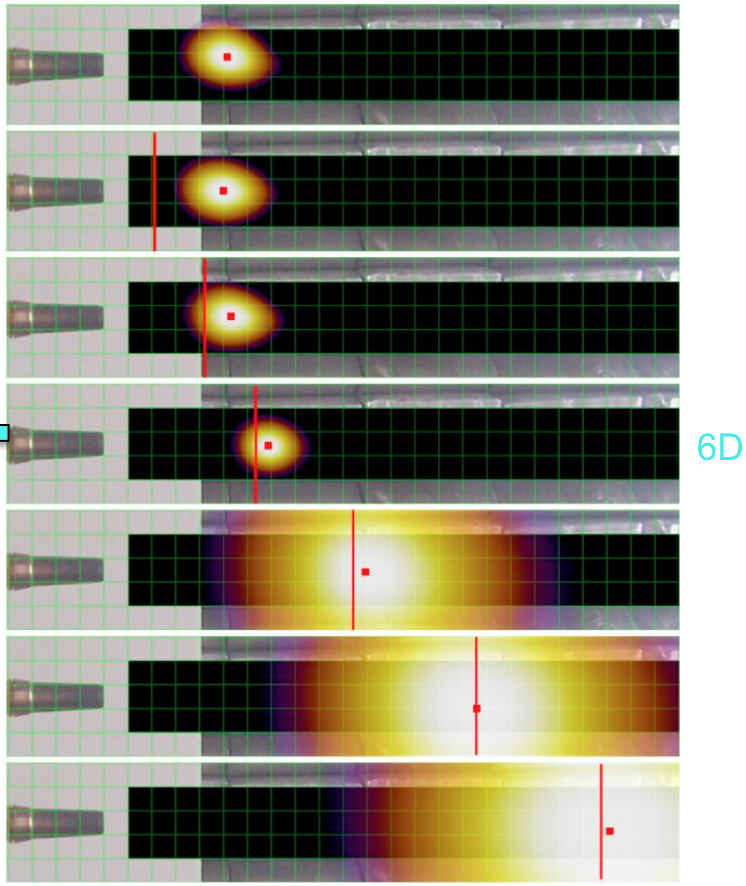
SMC016 Nozzle
M_j=1.29
r/D=3



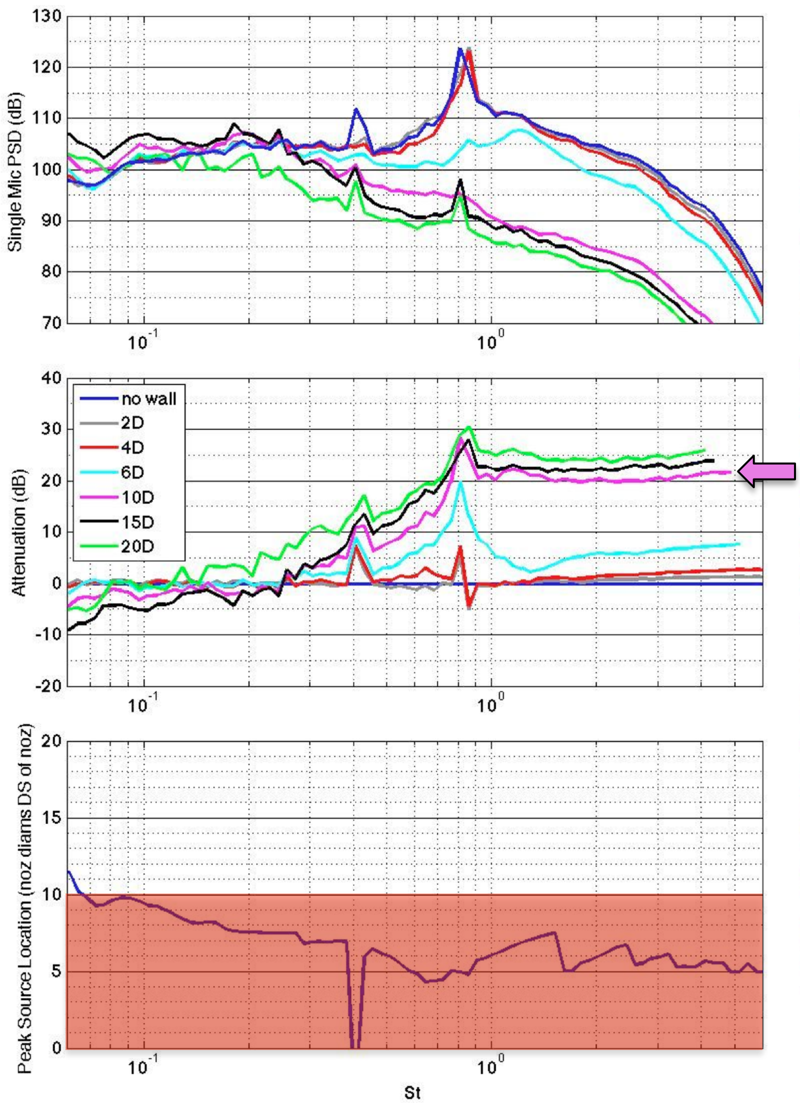
Shielding Data Obtained on Over-Expanded Supersonic Jet



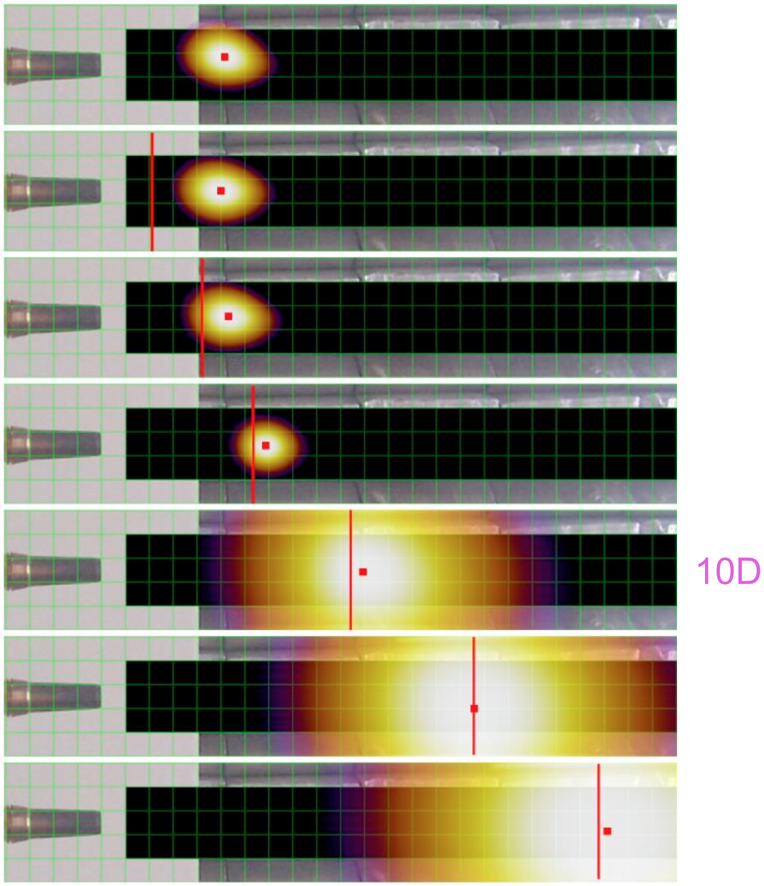
SMC016 Nozzle
M_j=1.29
r/D=3



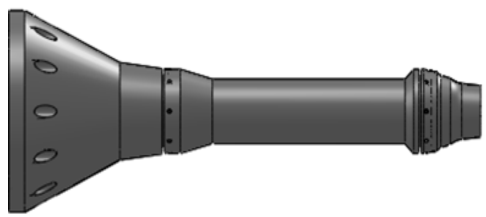
Shielding Data Obtained on Over-Expanded Supersonic Jet



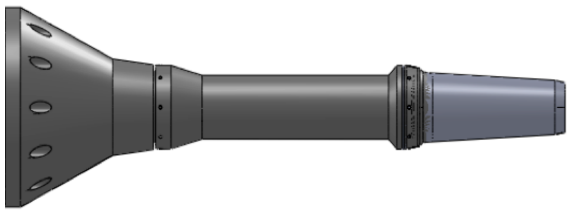
SMC016 Nozzle
M_j=1.29
r/D=3



Jet Operating Conditions



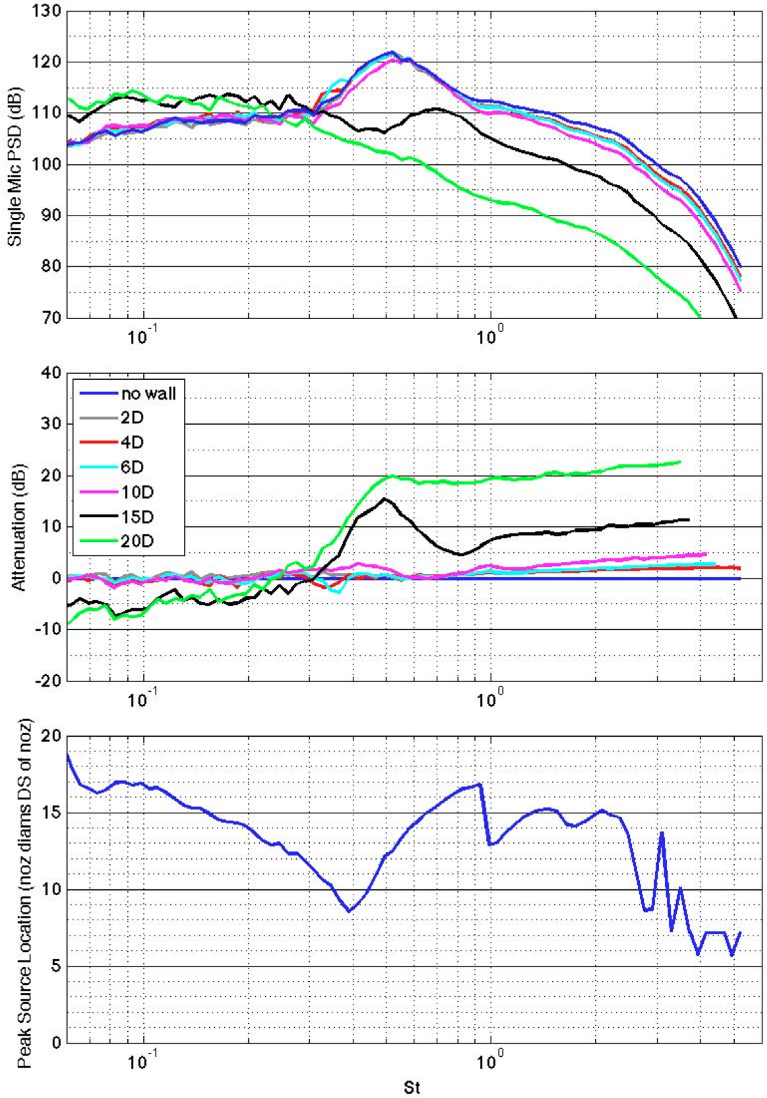
SMC000 Nozzle
convergent



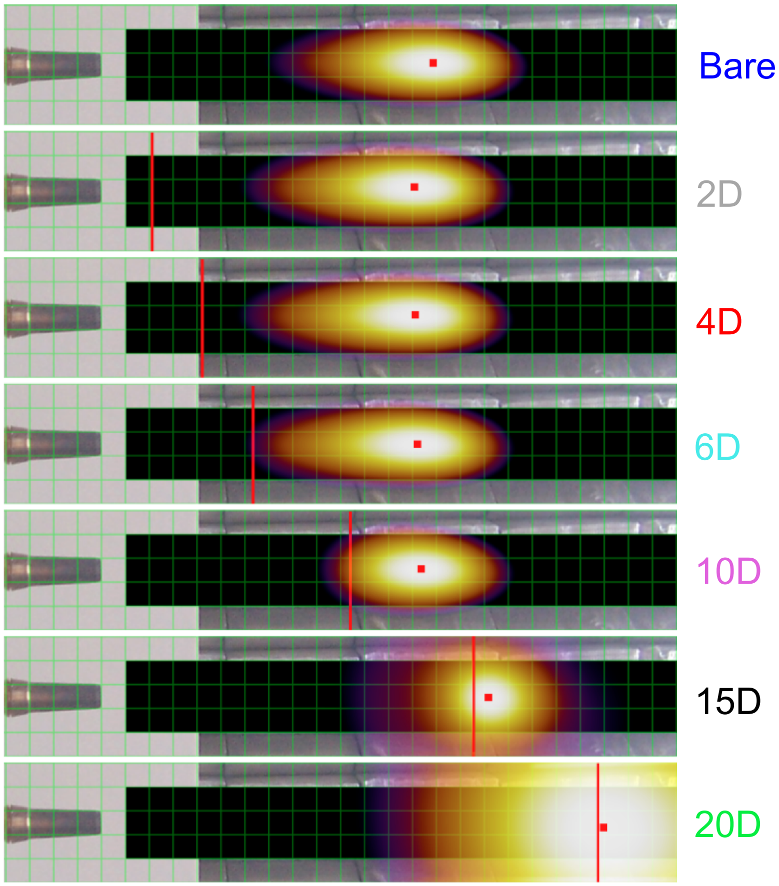
SMC016 Nozzle
convergent-divergent
M_d=1.5

Nozzle	Setpoint	NPR P_t/P_{amb}	TSR T_s/T_{amb}	M_a V/c_{amb}	M_j V/c_{local}
SMC000	3	1.20	0.95	0.50	0.51
SMC000	7	1.86	0.835	0.90	0.98
SMC000	27	1.36	1.76	0.90	0.68
SMC000	46	1.24	2.70	0.90	0.55
SMC000	9010	3.18	0.74	1.18	1.40
SMC016	11606	2.75	0.76	1.13	1.29
SMC016	11610	3.67	0.72	1.31	1.50
SMC016	11617	4.32	0.76	1.41	1.61

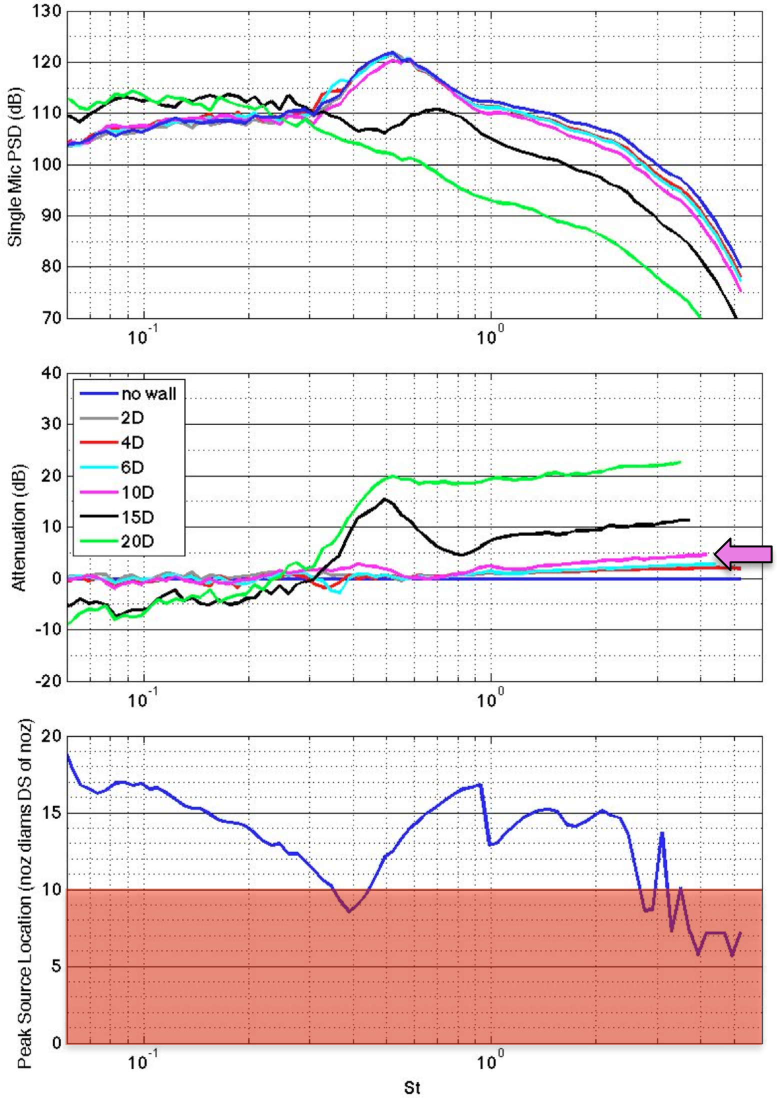
Shielding Data Obtained on Under-Expanded Supersonic Jet



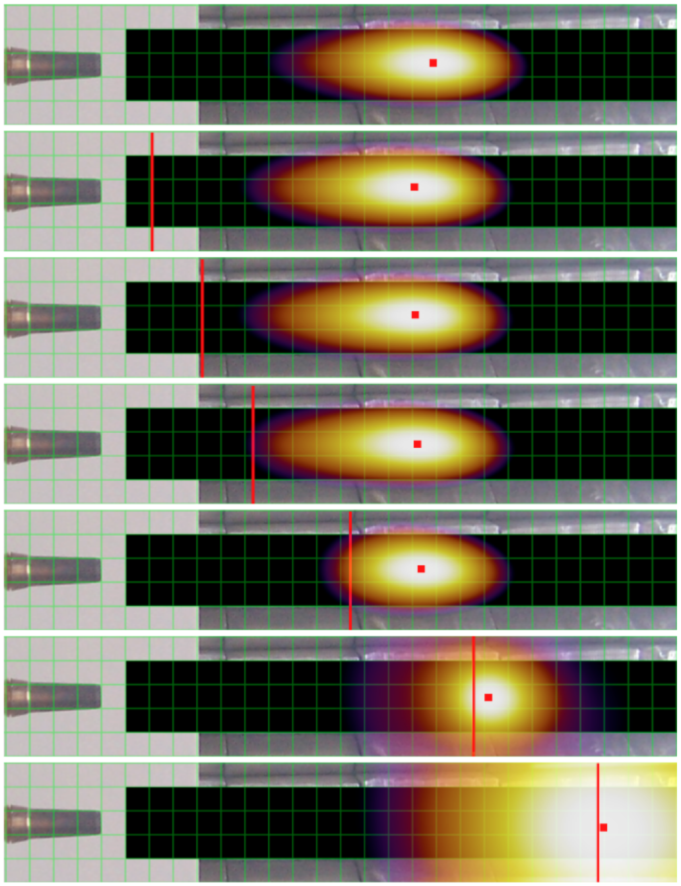
SMC016 Nozzle
M_j=1.61
r/D=3



Shielding Data Obtained on Under-Expanded Supersonic Jet

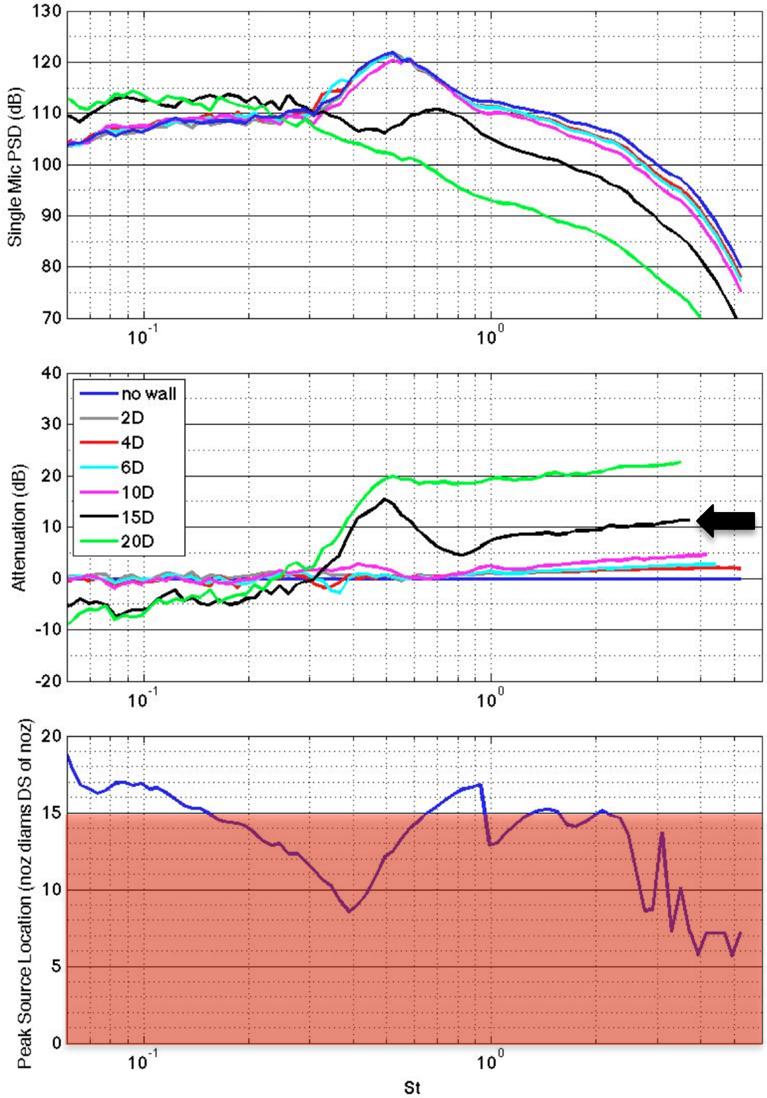


SMC016 Nozzle
M_j=1.61
r/D=3

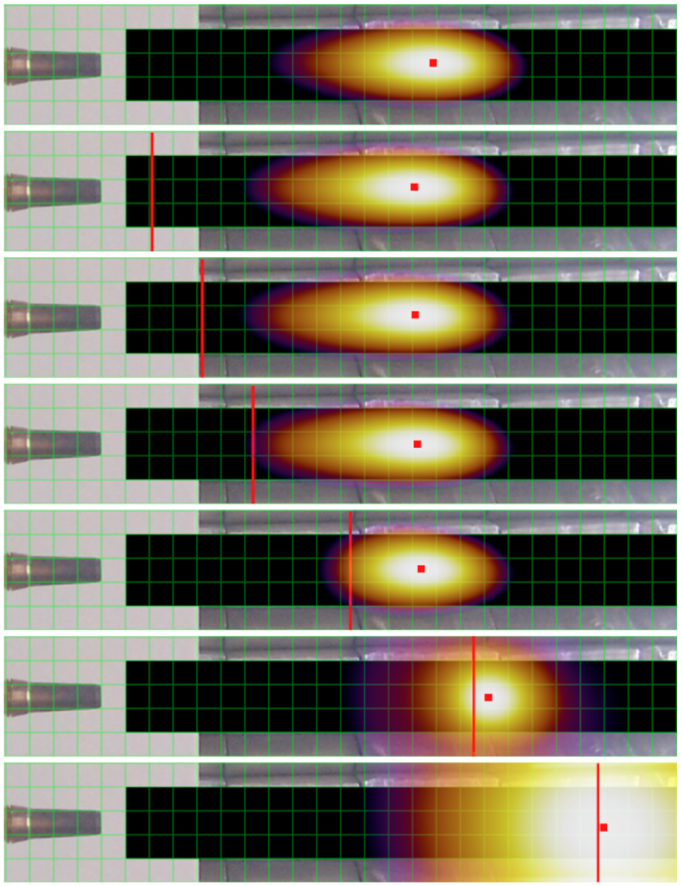


10D

Shielding Data Obtained on Under-Expanded Supersonic Jet

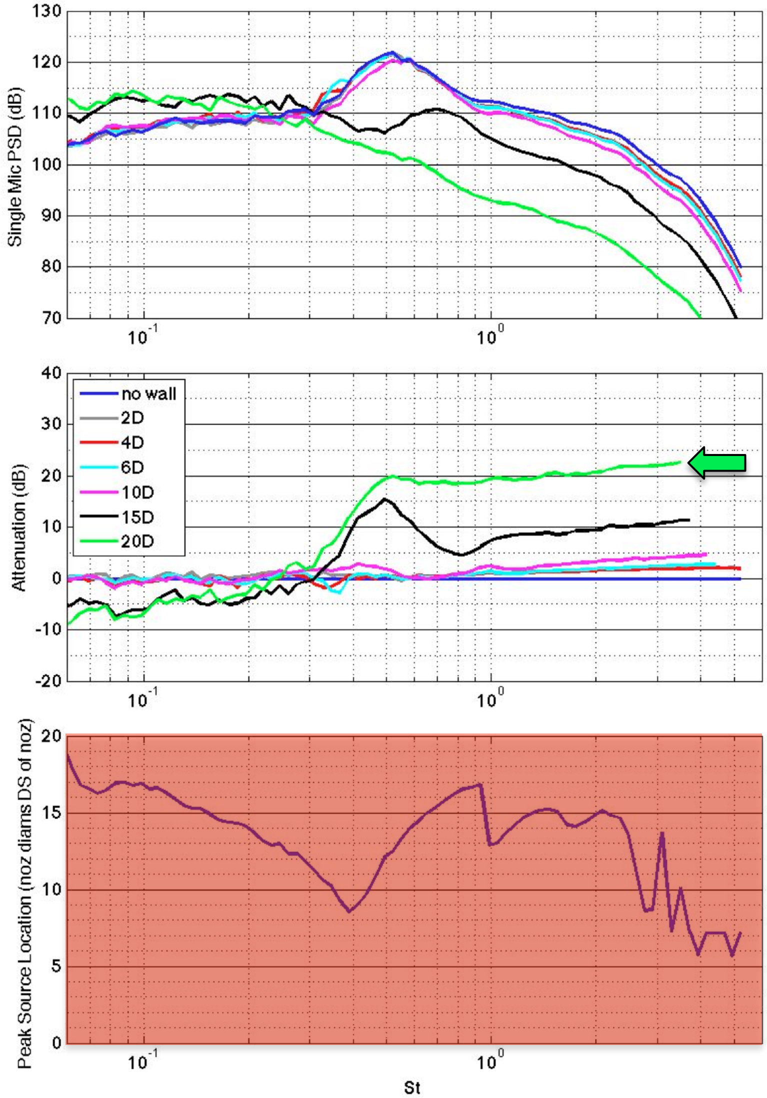


SMC016 Nozzle
M_j=1.61
r/D=3



15D

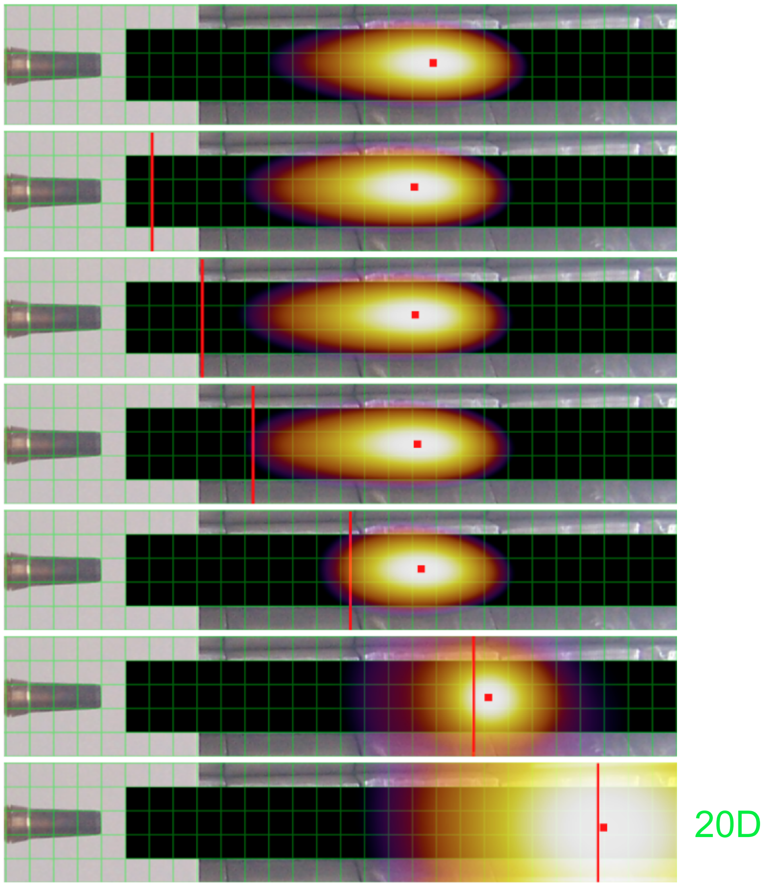
Shielding Data Obtained on Under-Expanded Supersonic Jet



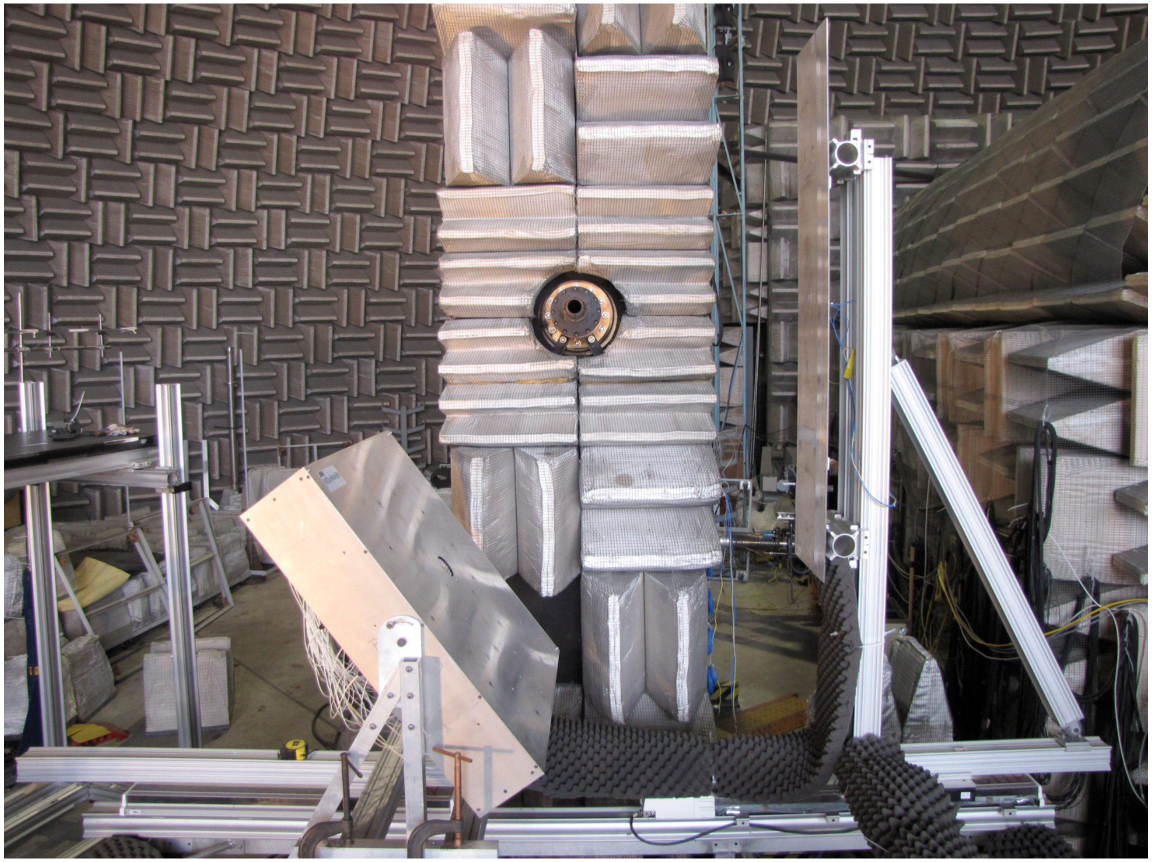
SMC016 Nozzle

M_j=1.61

r/D=3

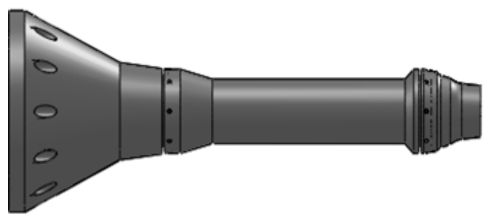


Array Location for Reflecting Surface Tests

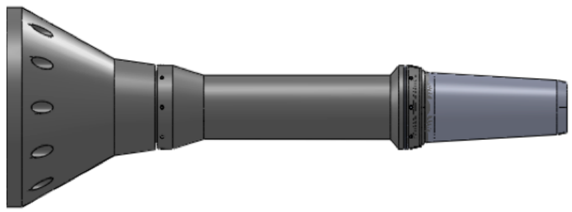


Array on traverse
moving with the surface

Jet Operating Conditions

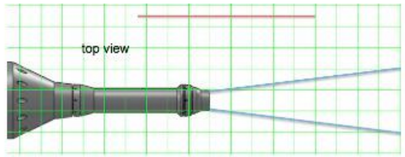


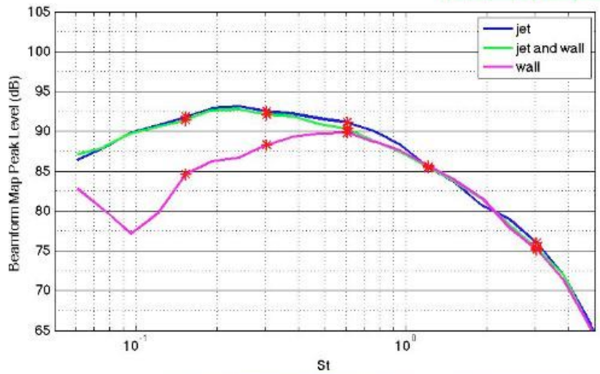
SMC000 Nozzle
convergent

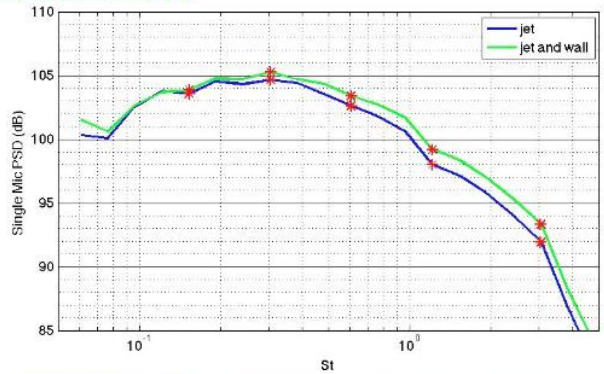


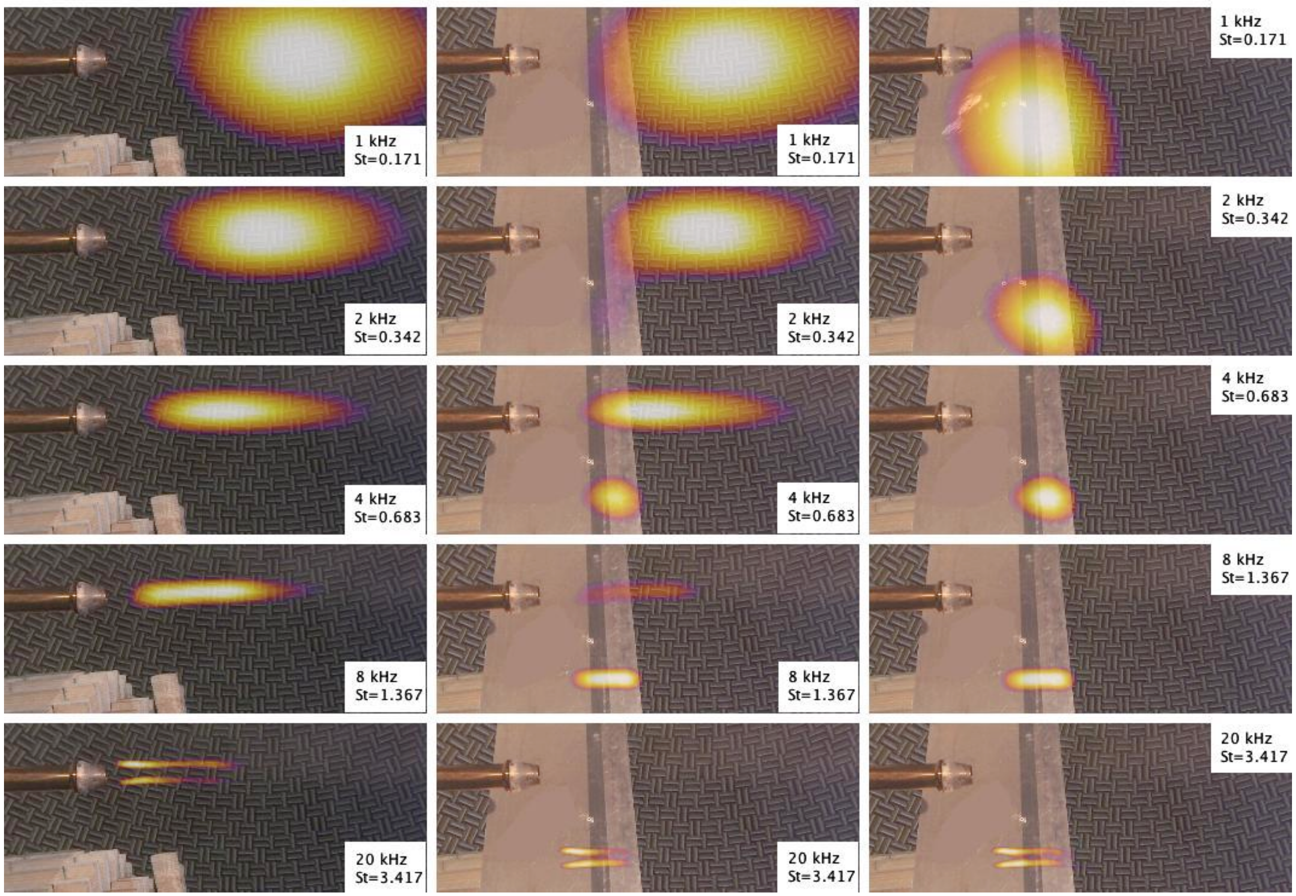
SMC016 Nozzle
convergent-divergent
M_d=1.5

Nozzle	Setpoint	NPR P_t/P_{amb}	TSR T_s/T_{amb}	M_a V/c_{amb}	M_j V/c_{local}
SMC000	3	1.20	0.95	0.50	0.51
SMC000	7	1.86	0.835	0.90	0.98
SMC000	27	1.36	1.76	0.90	0.68
SMC000	46	1.24	2.70	0.90	0.55
SMC000	9010	3.18	0.74	1.18	1.40
SMC016	11606	2.75	0.76	1.13	1.29
SMC016	11610	3.67	0.72	1.31	1.50
SMC016	11617	4.32	0.76	1.41	1.61



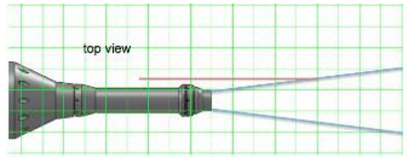


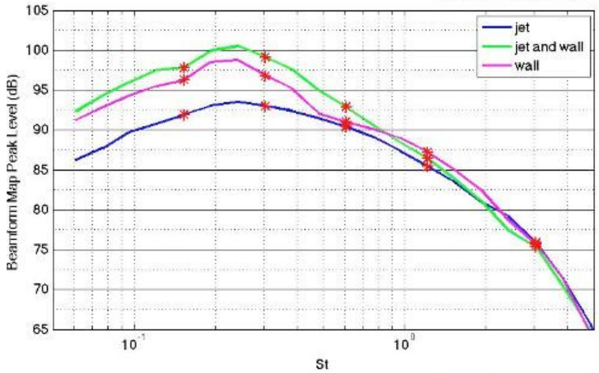


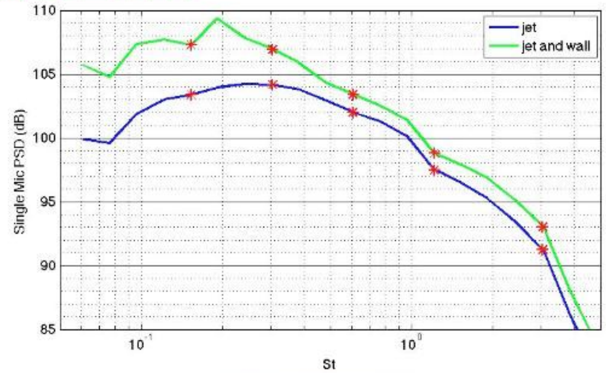


SMC000 Nozzle
M_a=0.9

Reflecting surface at r/D=4 with trailing edge @ 5D

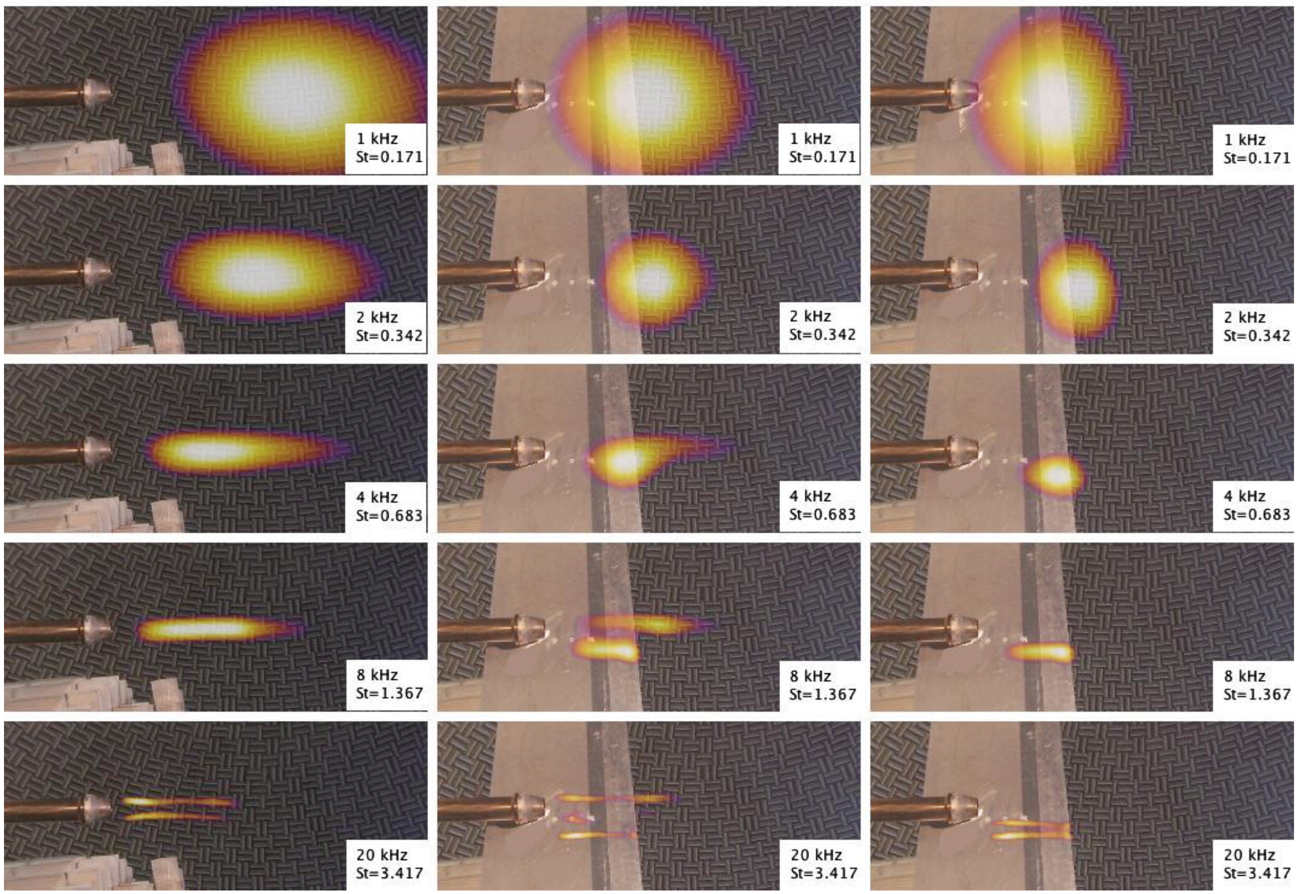






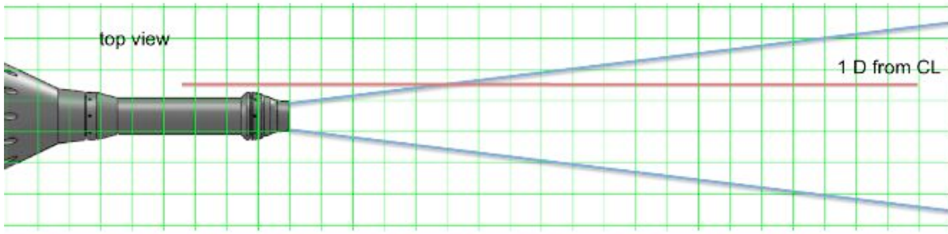
SMC000 Nozzle
M_a=0.9

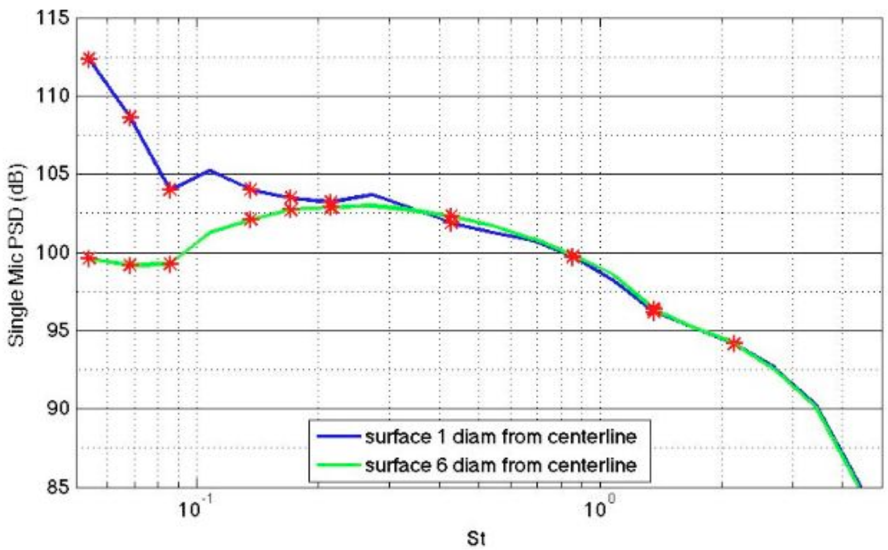
Reflecting surface
at r/D=1 with
trailing edge @ 5D

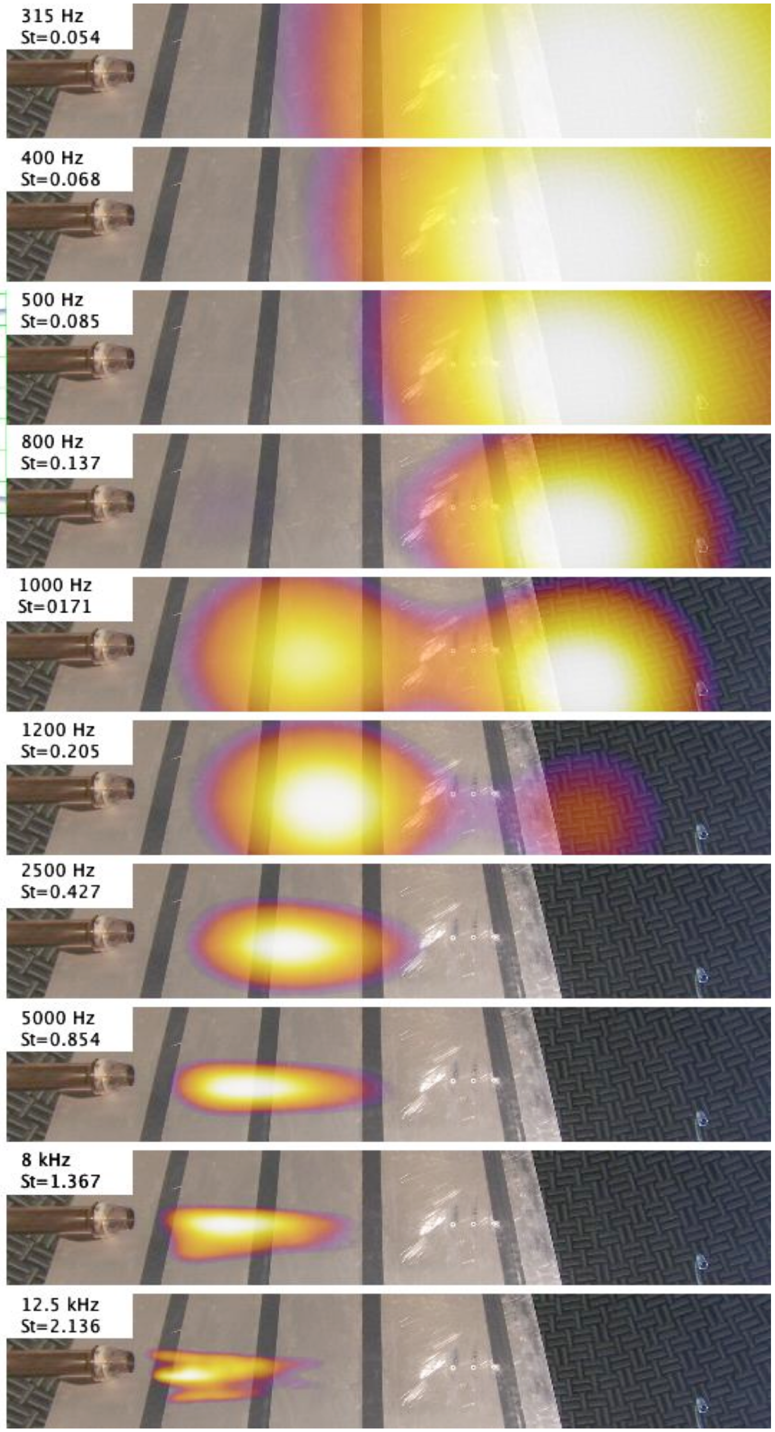


SMC000 Nozzle M_a=0.9

Reflecting surface at r/D=1 with trailing edge @ 20D







Summary

1) Subsonic jets are relatively simple. The peak noise source location gradually moves upstream toward the nozzle as frequency increases.
2) Supersonic jets are more complicated. The peak noise source location moves downstream as frequency increases through a BBSN hump.
3) In both subsonic and supersonic jets the peak noise source location corresponding to a given frequency of noise moves downstream as jet Mach number increases.
4) The noise generated at a given frequency in a BBSN hump is generated by a small number of shocks, not from all the shocks at the same time.
5) Single microphone spectrum levels decrease when the noise source locations measured with the phased array are blocked by a shielding surface. This consistency validates the phased array data and the stationary monopole source model used to process it.
6) Reflecting surface data illustrate that the law of reflection must be satisfied for noise to reflect off a surface toward an observer. Depending on the relative locations of the jet, the surface and the observer only some of the jet noise sources may satisfy this requirement.
7) The low frequency noise created when a jet flow impinges on a surface comes primarily from the trailing edge regardless of the axial extent impacted by the flow.