

Supplementary Material

1 SUPPLEMENTARY FIGURES

Figure S1. The DSMC mesh: (a) - whole domain , (b) - nozzle region.



Figure S2. NS mesh: (a) – whole domain, (b) – nozzle region.



Figure S3. Scheme of the initial section of traditional (**a**) and X-shaped configuration (**b**) for a highly underexpanded jet and gray scale visualization of the DSMC simulations of the density field (**c**). a: I - free supersonic expansion zone, II - compressed layer, III - supersonic flow behind the reflected shock, IV - subsonic flow behind the Mach disk. 1 – jet boundary, 2 – barrel/incident oblique shock, 3 – reflected shock, 4 – Mach disk.



Figure S4. Number density, velocity, temperature distributions along the flow axis for case 3. a_0 is the sound velocity in the chamber.



Figure S5. Number density, velocity, temperature distributions along the flow axis for case 2. a_0 is the sound velocity in the chamber.



Figure S6. Number density, velocity, temperature distributions along the flow axis for case 1. a_0 is the sound velocity in the chamber.



Figure S7. The axial density variation, DSMC results.



Figure S8. Number density (a) and Mach number (b) distributions along the flow axis for case 3.



Figure S9. X-, Y- and Z-temperature components' distributions along the flow axis $(1 - T_x, 2 - T_y, 3 - T_z, 4 - T)$ and translational nonequilibrium degree R_n along the flow axis (curves 5) for case 1 (a) and case 3 (b).