Hypersonic Unidentified Aerial Objects

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ABSTRACT

Recent reports describe observations of unidentified objects of ~10-meter size moving at hypersonic speeds of ~10 km s^{-1} (Zhilyaev et al. 2022ab). Concern has been raised by Loeb (2022) that such speeds, if true, would have caused a bright optical fireball as are created by incoming meteors. But neither a fireball nor a "meteor trail" was observed, raising doubt about the existence of the claimed hypersonic objects. Here we describe an addendum to Loeb's paper regarding aircraft engineered with a nanoscale frontal cross-sectional area that drastically reduces the air "plow-through" and energy deposition, thereby minimizing any "meteor trail" as is achieved by stealth drone aircraft. Similarly, spacecraft for interstellar travel benefit from nanoscale frontal cross-sections to minimize the number of impacts by interstellar atoms and dust.

1 INTRODUCTION

Zhilyaev et al. (2022ab) report detections with multiple digital cameras of unidentified aerial phenomena (UAP), providing evidence for their existence as actual physical objects rather than optical illusions. These reports are similar to numerous reports by pilots of hypersonic aircraft. The observations suggest both bright and dark objects of size 3 to 12 meters moving at speeds of 2 to 15 km s^{-1}, i.e., supersonic, at distances of 10 to 12 km (Zhilyaev et al. 2022ab, Loeb 2022). If true, these UAPs constitute a hypersonic technology that raises implications for national security and for the possibility of extraterrestrial origin.

Loeb (2022) correctly emphasizes that a three-dimensional object moving at such speeds would plow through air molecules generating hydrodynamic friction and shock waves. At speeds of ~10 km s^{-1} this hydrodynamic friction can lead to a "meteor trail" from the heating and excitation of air molecules and atoms as well as ionization. The shock wave also leads to audible sonic booms. However, Zhilyaev et al. (2022ab) report no such "meteor tail" nor sonic boom. Thus, a conflict of interpretations has emerged.

2 HYPERSONIC HYDRODYNAMICS AND OPTICAL EMISSION

A hypersonic aircraft obviously rams into air molecules, imparting momentum and kinetic energy to them. The rate at which energy is deposited into the air is reiterated by Loeb (2022), defended here. The frontal cross-sectional area, *A*, of the aircraft plows into air displacing an air mass, M, at a rate of

$$dM/dt = \rho A v,$$

where ρ is air density and v is the velocity of the object. The mean density of air at sea level is $\rho = 1.2$ kg m^{-3} and UAP speeds are reported to be approximately, $v \sim 10$ km s^{-1}. A supersonic aircraft imparts a velocity to the (relatively stationary) air molecules approximately equal to the speed of the aircraft, thereby giving them kinetic energy at a rate,

$$P = ½ \rho A v^3 \qquad (1)$$

Loeb (2022) provides nominal values for scaling:

$$P \approx 1.5 \text{ TW } (A/10 \text{ m}^2)(\rho/0.3 \text{ kg m}^{-3})(v/10 \text{ km s}^{-1})^3 \qquad (2)$$

Loeb (2022) provides nominal values for ambient air density (0.3 kg m^{-3}) and velocity (10 km s^{-1}) suitable for an elevation of 10 km. Of course, Eqn. 2 should include a coefficient that accounts for the aerodynamic effects resulting from the shape of the front of the aircraft that affects the turbulence, viscosity, and detailed energy-transfer effects. Thus, Eqn. 2 offers accuracy only within an order of magnitude. Brown et al. (2002) find that meteors emit light that is approximately 1/10 of the power in Eqn 2.

3 THIN FRONTAL CROSS SECTIONS

Crucially, Loeb (2022) adopts a scale for the frontal cross-sectional area of the moving object of $A = 10\ m^2$, as shown in Eqn. 2 here. However, actual supersonic aircraft are engineered with a small frontal cross-sectional area, A, indeed to reduce the plow-through of air and the resulting shock wave. This design reduces energy losses to the air, minimizes shock waves and sonic booms, and thus provides stealth for reconnaissance and military purposes.

Instead of a cross-section area of 10 m^2, an advanced technology may design a leading "wing" structure with a thickness of only 0.1 m or 0.01 m. A 1 cm thickness, and a width of 10 m across, yields a frontal cross-sectional area of only, $A = 0.1\ m^2$, which is 1% of the nominal cross section in Equation 2. One may consider more extreme frontal thicknesses of 1 mm or even micron size, which would cause frictional energy in the air of only one thousandth and one millionth as much as supposed by Loeb. A civilization thousands of years advanced could plausibly construct such millimeter-thick front noses on aircraft.

This limiting case would be an aircraft's frontal cross section with a thickness comparable to carbon nanotubes, only ~50 atoms thick. The thickness of roughly 10 nm, while also ~10 meters wide, gives a cross-sectional area of $10^{-7}\ m^2$. This frontal area is 10^{-8} of that considered by Loeb (2022). With this nominal cross-section area, Eqn. 2 becomes:

$$P \approx ½\, \rho\, A\, v^3 = 15\ kW\ (A/10^{-7}\ m^2)\ (\rho/0.3\ kg\ m^{-3})\ (v/10\ km\ s^{-1})^3 \qquad (3)$$

Thus, the power delivered to the air is nominally only 15 kW, spread over a long line of length ~10 km each second. This is so little energy density as to be difficult to detect. Of course, any thin design requires stabilization and great strength (Loeb, 2023), either passively such as provided by airplane wings, or actively as with rockets.

This limiting case has dissipated energy rate of $\sim 10^{-8}$ that computed by Loeb and the resulting "meteor trail" will be $\sim 10^{-8}$ as bright, producing a barely detectable trail, if detectable at all. This reduced cross-sectional area achieves the same reduction in brightness as Loeb's guess that the reported distance to the UAPs was overestimated, thereby reducing the speed.

Modern hypersonic vehicles are being designed in this direction. A recent example is the U.S. air force "B-21 Raider", an intercontinental strategic aircraft produced by Northrup Grumman. This supersonic aircraft not only boasts a small cross-section (see Figure 1) but also has aerodynamic shape to promote laminar flow of air above and below the aircraft. This aerodynamic design is specifically engineered to reduce the frictional drag, to minimize the heating of the air, and to minimize the production of sonic shock waves. China has also built hypersonic drone aircraft (Fig. 1).

This edge-on design is a logical attribute of aerodynamic design, as already achieved in hypersonic aircraft. Minimizing the cross-sectional area minimizes the plow-through of air or interstellar particles, and tapering of the body behind the front minimizes shock heating. This geometry allows the leading edge, and trailing body, to hit and impart momentum to the fewest air molecules, producing the least friction and heating.

That leading edge could be built with extra protection as the "bumper" of the craft. That design protects the electronics located behind the leading bumper of the craft to minimize damage from the incoming particles, both in the atmosphere or in space. Advanced civilizations may use lightweight, heat-shielding materials and coatings that are smooth on atomic scales and withstand high temperatures and pressures.

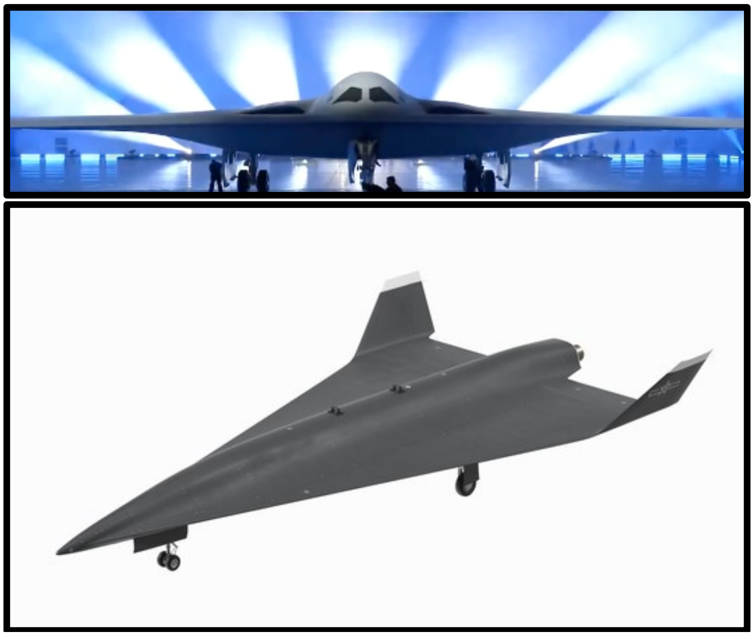

Figure 1. Top: The B-21 Raider stealth aircraft, showing the thin cross-sectional area and aerodynamic design to reduce air friction and shock waves. Bottom: China's WZ 8 Hypersonic Surveillance Drone. Thin frontal cross-sections are vital to reduce air friction and shocks.

4 IMPLICATIONS OF THIN, AERODYNAMIC HYPERSONIC DRONES

The order-of-magnitude calculations above suggest that advanced civilizations could engineer drone, hypersonic vehicles that produce little "meteor trail", "fireball", or sonic boom. Such vehicles traveling at Mach 5 to Mach 10 are consistent with aircraft already being designed and tested by the United States, China, and Russia. Aircraft with thin cross-section, aerodynamic design, and advanced materials can likely render any heating and ionization of the "contrail" to nearly invisible. Advanced extraterrestrial civilizations can certainly improve on our state-of-the-art by reducing further the shock-heating of the air.

Interstellar spacecraft may benefit from this engineering approach. A craft moving through interstellar space plows through interstellar gas and dust. A thin frontal cross section serves the needs of interstellar travel by reducing the interactions and impacts on interstellar electrons, protons, atoms, and dust particles. Indeed, an ideal aircraft would be as flat as possible, perhaps nanometers thick corresponding to a few atoms of thickness, and it would travel edge-on. Alternatively, it can be bent into a cylinder, traveling along its long axis so that the cross-sectional area hitting air is arbitrarily miniscule.

Interstellar spacecraft, including robotic ones, may populate the Milky Way Galaxy. They may include local probes near stars and communication relay stations (e.g., Bracewell 1973, Freitas 1980, Gillon 2014, Hippke 2020, 2021ab; Gertz 2018, 2021, Gertz & Marcy 2022).

A prospective conversion of mass to energy constitutes effectively a Bussard ramjet (Bussard 1960, Fishback 1969, Whitmire 1975). This is a ramjet design that accumulates interstellar hydrogen. Such a ramjet in the Earth's atmosphere can accumulate molecules in the Earth's atmosphere. Thus, the ramjet UAPs may travel at supersonic speeds through the Earth's atmosphere, and they may also propel themselves over interstellar distances with fuel acquired along the way.

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DATA AVAILABILITY

This paper includes no data.

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