Aerospike Nozzle Research

Aerospike Information Sources:

* <https://en.wikipedia.org/wiki/Aerospike_engine>
* http://www.hq.nasa.gov/pao/History/x-33/aero\_faq.htm

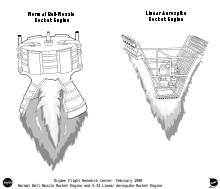
Aerospike Engine Definition:

The **aerospike engine** is a type of [rocket engine](https://en.wikipedia.org/wiki/Rocket_engine) that maintains its [aerodynamic](https://en.wikipedia.org/wiki/Aerodynamic) efficiency across a wide range of [altitudes](https://en.wikipedia.org/wiki/Altitude). It belongs to the class of [altitude compensating nozzle](https://en.wikipedia.org/wiki/Altitude_compensating_nozzle) engines.

* A vehicle with an aerospike engine uses 25–30% less fuel at low altitudes, where most missions have the greatest need for [thrust](https://en.wikipedia.org/wiki/Thrust).
* A spike (or “plug”) uses an exhaust nozzle that can be thought of as a conventional bell shaped nozzle turned inside out. The aerospike nozzle is a truncated version of an ideal spike.
* The air flow around the aerospike nozzle exhaust is constrained by the ambient pressure resulting in performance that is optimal for all altitudes of the nozzle flight.

Difference between Traditional Engine Bell vs. Aerospike Engine Bell:

Instead of firing the exhaust out of a small hole in the middle of a bell, an aerospike engine avoids this random distribution by firing along the outside edge of a wedge-shaped protrusion, the "spike", which serves the same function as a traditional engine bell. The spike forms one side of a "virtual" bell, with the other side being formed by the outside air—thus the "aerospike".



Disadvantages of Traditional Bell Nozzle Design:

* Flow separation at the walls of the nozzle near the exit when operating at low launch altitudes (launch) can lead to loss of performance and possible structural failure of the nozzle due to dynamic loads.
* Usually a compromise altitude must be used for the design point of a bell nozzle.

Disadvantages of Aerospike Design:

* Extra weight for the spike
* Heavier structural construction in some applications
* Manufacturing difficulties
* Increased cooling requirements due to the extra heated area
* The larger cooled area can reduce performance below theoretical levels by reducing the pressure against the nozzle
* Aerospikes work relatively poorly between Mach 1-3

Advantages of Aerospike Nozzle:

* Shortened nozzle length for the same performance, or increased performance (higher Expansion area ratios) for a given length
* Improved performance at sea level or low altitudes
* The relatively stagnant region in the center of the nozzle can possibly be used for installation of gas generators, turbopumps, tanks, auxiliary equipment, and turbine gas discharges
* A segment combustion chamber design approach can be used, easing development effort (individual segments can be built and tested during the early phases) and improving combustion stability
* Because the flow is directly exposed to ambient pressure, its expansion is directly coupled to the external environment (continuous altitude compensation with no moving parts)
* Has a very high area ratio nozzle (high vacuum performance)
* Can operate efficiently and safely at sea level
* You can truncate the aerospike nozzle and the thrust which is developed by the base pressure build up almost entirely makes up for the thrust loss due to the decrease in nozzle surface area.

Possible ways to improve some problems associated with Aerospike Design:

* You can offset the performance loss caused by truncating the ideal spike to save weight by pumping secondary flow (about 1% of primary flow) into the base region to elongate the wake which then forms an aerodynamic contour similar to the truncated structure.

Variations of Aerospike Design:

Toroidal Aerospike: the spike is bowl-shaped with the exhaust exiting in a ring around the outer rim. In theory this requires an infinitely long spike for best efficiency, but by blowing a small amount of gas out of the center of a shorter truncated spike, something similar can be achieved.

Linear Aerospike: the spike consists of a tapered wedge-shaped plate, with exhaust exiting on either side at the "thick" end. This design has the advantage of being stackable, allowing several smaller engines to be placed in a row to make one larger engine while augmenting steering performance with the use of individual engine throttle control.

How to define area ratio of an Aerospike nozzle:

1. For a toroidal plug, the total throat area divided by the area of the circle whose radius is the outer edge of the toroid would be the geometric area ratio
2. By running a one dimensional equilibrium (ODE) model of the expansion and comparing it to the performance of the plug, you can find what ODE area ratio give that performance and that would be the equivalent performance based area ratio for that plug.

Successful Aerospike Launch:

In March 2004, two successful tests were carried out at the NASA Dryden Flight Research Centre using small-scale rockets manufactured by [Blacksky Corporation](https://en.wikipedia.org/w/index.php?title=Blacksky_Corporation&action=edit&redlink=1), based in [Carlsbad, California](https://en.wikipedia.org/wiki/Carlsbad,_California). The aerospike nozzles and solid rocket motors were developed and built by the rocket motor division of [Cesaroni Technology Incorporated](https://en.wikipedia.org/w/index.php?title=Cesaroni_Technology_Incorporated&action=edit&redlink=1" \o "Cesaroni Technology Incorporated (page does not exist)), north of Toronto, Ontario. The two rockets were solid-fuel powered and fitted with non-truncated toroidal aerospike nozzles. They reached apogees of 26,000 ft (7,900 m) and speeds of about [Mach](https://en.wikipedia.org/wiki/Mach_number) 1.5.