
Current Technology: The Conventional-Bell (CB) Nozzle
- 1915: The Conventional-Bell rocket nozzle (the de Laval nozzle) was first utilized by Robert Goddard with early rocket experiments
  - Today: The CB nozzle is still the “gold-standard” of all rocket nozzles, and is used on virtually all space-launch rockets
- Problem: The CB nozzle can only be optimized at one altitude
  - Performance losses exist throughout most of a rocket’s trajectory

Proposed Technology: The Dual-Bell (DB) Nozzle

How it works
- DB ‘Mode 1’ operation (low altitude):
  - Nozzle flow expands out to the end of the first bell, optimized for lower altitudes
- DB ‘Mode 2’ operation (high altitude):
  - Nozzle flow expands out to the exit plane, at the end of the second bell
- Goal: The nozzle plume is never significantly over- or under-expanded, as with a CB nozzle, resulting in higher propulsive efficiency

Who Cares?
- All space-launch organizations desire higher performing rockets
  - This translates into the delivery of higher mass payloads to Low Earth Orbit (LEO)
  - Nozzle performance has a significant effect on a rocket’s overall performance
  - Decreasing the cost of delivering payloads to LEO has been a vision for NASA and the private sector for several decades

Near-term challenges for DB nozzle researchers:
- Conduct significantly more experimental research with reacting flow
- Conduct nozzle research in a relevant flight environment

Phases of the Flight-Test Campaign
- Phase I: Conduct flight tests to survey the freestream flow field conditions near the nozzle exit plane (under the NASA F-15B PFTF)
- Phase II: Conduct flights while operating cold flow through the DB nozzle, as well as with the CB nozzle (for a quantitative comparison)
- Phase III: Conduct flights while operating reacting flow through the DB nozzle, as well as with the CB nozzle (for a quantitative comparison)

Top-Level Goals
- Develop methods to reliably control dual-bell altitude compensation, and demonstrate those methods in a relevant flight environment
- Develop and validate the design and analysis tools required for DB rocket nozzles
- Develop the F-15B PFTF flight testbed and the flight test techniques required for advanced rocket nozzles
- Develop DB performance databases, and databases of flight research with advanced nozzles

State of the Art: The Dual-Bell (DB) Nozzle
- 1949: The DB nozzle was first conceived (NASA-JPL)
- 1993: The first DB static-test experiments were published (Rocketdyne)
- Today: Numerous organizations around the world have studied the DB nozzle analytically, continuing to predict greater performance
  - Some organizations have complemented their analytical effort with static test data, to compare against their performance predictions
  - Analytical and experimental research is also being conducted at NASA-Marshall, in the Nozzle Test Facility (NTF)

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The "Big Picture": Plans Flight Testing the Dual-Bell Nozzle
- Although predicted to be higher performing, the DB nozzle must be proven in a relevant flight environment
  - Captive-carry flight testing will enable a more detailed investigation into the nozzle plume behavior and performance at several conditions
    - Captive-carry flight-testing will also enable the propulsion assets to be protected for future testing
  - The NASA F-15B Propulsion Flight Test Fixtures (PFTF) was developed for captive-carried flight tests with advanced propulsion systems
    - DB nozzle testing can leverage this flight-proven capability