MAE 298 Aeroacoustics – Final Project
Review of Techniques for Predicting Aeroacoustics of Aerospace Vehicles During Launch, Ascent, and Abort

Logan D. Halstrom

Graduate Student

Department of Mechanical and Aerospace Engineering

University of California, Davis, CA 95616

I. Introduction

Define launch vs ascent vs abort
History of aeroacoustic testing in aerospace vehicles.[5]
analytic modeling for propulsion acoustics.[2]

II. Experimental Methods

One of the most straight forward methods of predicting aeroacoustic vibrational effects on aerospace vehicles is through full-scale testing of sections or complete models of the flight vehicle. A very detailed summary of design methodologies governing these kinds of test can be found in Himelblau et al. (1970),[5] which will be summarized in the following sections.

The paper specifically addresses the effectiveness of vibrational testing versus acoustic testing of aerospace vehicles. Vibrational testing facilities utilize electromagnetic or hydraulic shakers to apply vibrational loads to test articles. Alternatively, acoustic testing involves placing the test article within an acoustic field, similar to that of the flight condition. At the time of publishing (1970) acoustic testing was relatively new, with its first major usage during the testing of the Titan missile. Some methods of acoustic testing will now be detailed.

II.A. Ground Testing

The most straight-forward of testing methods described by Himelblau is the free-field test, where the test article is subjected to an outdoor, unconstrained aeroacoustic field produced by some source, an example of which is shown in Fig 1. The acoustic source in this example is the exhaust of a blowdown wind tunnel, where a fluid upstream of the wind tunnel is pressurized and then released at supersonic speeds through the test section.[7] This high pressure fluid then exits the wind tunnel at high speeds, creating conditions similar to that of ascent.

In addition to supersonic wind tunnels, static-fire rocket engine tests can also be used as an acoustic source. Thus, in the early days of aeroacoustic testing, test could be performed for reduced cost by "free-riding" an already existing wind tunnel or rocket engine test.

Acoustic tests can also be performed in more contained facilities. One example is a reverberant test facility, which is a large chamber surrounded by noise-producing horns.[8] These horns allow the production of acoustic vibrations similar to the flight conditions to which sections of the test vehicle can be subjected.

Another method of testing, which was utilized in the ascent certification of the Apollo program lunar and command modules, is the progressive wave facility. This facility is a chamber with a large number of ducts connecting the test chamber to the outside of the structure, which is excited by an acoustic source (See Fig 2). The ducts are independently operable to allow control of the acoustic conditions inside the test chamber.[12] This method combines the realistic acoustic source advantages of the free-field test method with some level of source control as found in the reverberant chamber method.

Himelblau demonstrates that these aforementioned acoustic testing methods are superior to traditional vibrational testing methods due to a number of factors:

1. Vibration spectra that are more similar to flight conditions

2. Test article is not constrained at vibration force application points

3. Ability to test large structural article allows more similar modal characteristics to flight

However, he also states that there are still some limitations when it comes to acoustic testing. First, it can be difficult to select the proper vibration spectrum for flight condition matching, especially when the acoustic source is a "free-ride" wind tunnel or rocket engine test that is not specifically designed for the acoustic experiment. Additionally, free-field and progressive wave tests may be sufficient in the longitudinal direction parallel to the flow direction, but may not achieve the correct flow characteristics in the circumferential direction perpendicular to the flow. Finally, the propagation speed of the acoustic test are most likely not identical to that of the flight condition.

For these reasons, it is usually necessary to perform a full-scale flight test as the final certification, which Himelblau details and which is summarized in the next section.

II.B. Flight Testing

A full-scale test flight of an aerospace vehicle is a very expensive operation. For this reason, Himelblau states that it is highly important to have sufficient instrumentation onboard in order to clearly determine the cause and location of a failure if one occurs. This is vital in minimizing redesign costs in the case of a failure.

Himelblau reveals that calculations of aeroacoustic effects on structural integrity require a vast amount of data sampling, which was especially constraining in 1970 with limited bandwidth telemetry computers. For modern tests, the transmission limitation is somewhat alleviated by modern computers, but there is still the additional consideration that many different tests will be running simultaneously during the test flight (e.g. structural, aerodynamic, etc), and sensor bandwidth must be budgeted between all of these.

III. Analytical Methods

IV. Wind Tunnel Testing

IV.A. Ascent

IV.B. Abort

V. Computational Methods

V.A. Computational Fluid Dynamics

V.B. Computational Aeroacoustic Analysis

VI. Conclusions

References

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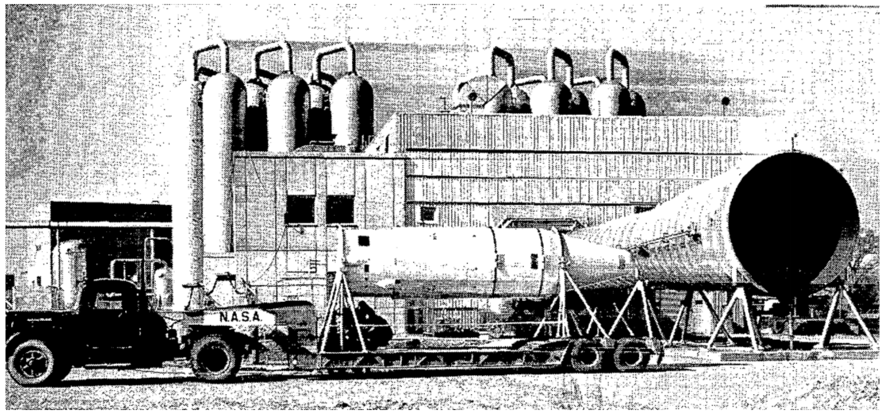

Figure 1: Acoustic test of the OGO spacecraft near the discharge nozzle of a large blowdown wind tunnel[5]

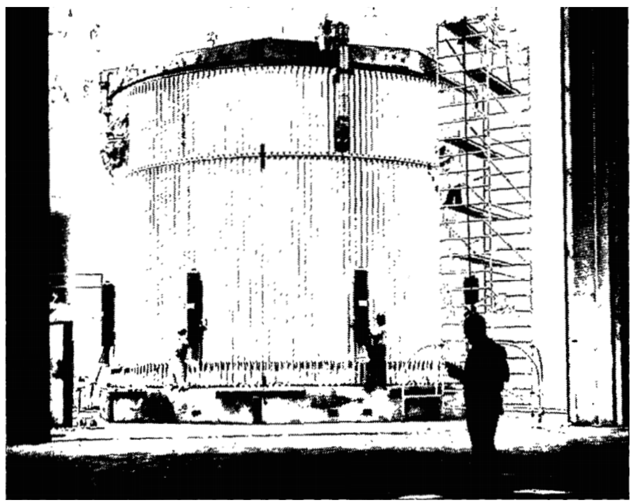

Figure 2: A Laboratory acoustic test of the thrust structure, aft skirt, and interstage of the S-II stage, Saturn V launch vehicle in a reverberant test facility[5]

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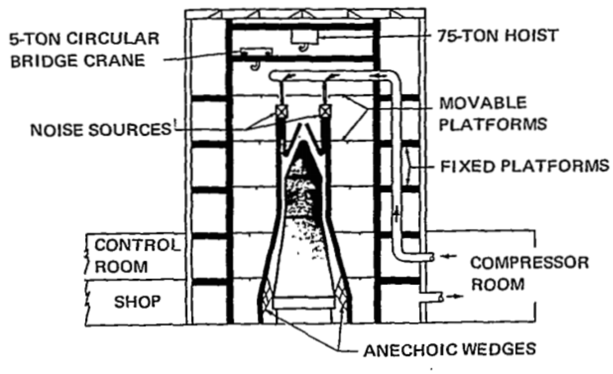

Figure 3: Laboratory acoustic test of the Apollo spacecraft in a progressive test facility[5]

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