

(NASA-TM-111265) FLIGHT CONTROL
AUGMENTATION FOR AFT CG LAUNCH
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FLIGHT CONTROL AUGMENTATION FOR AFT CG LAUNCH VEHICLES

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ABSTRACT

(Long)

BACKGROUND

The Space Shuttle was only the first step in achieving routine access to space. Recently, the NASA Marshall Space Flight Center (MSFC) has been studying a whole spectrum of new launch vehicles (L/V's) for space transportation. Some of these could transport components of the Space Station to orbit, and some could take us to Mars and beyond to boldly expand our frontiers of knowledge.

In all our future launch vehicle (L/V) designs, decreasing the structural weight will always be of great concern. This is tantamount to increased payload capability, which in turn means reduced cost-per-pound to orbit. One very significant increase in payload capability has been defined. In a L/V recently studied at MSFC it has been shown that a sizable weight savings can be realized by a rearrangement of the internal propellant tanks. Studies have been conducted both at MSFC and at Martin Marietta Corporation, maker of the Space Shuttle External Tank (ET) which show that a very substantial weight can be saved by inverting the relative positions of the liquid hydrogen (LH2) and the liquid oxygen (LOX) propellant tanks in a particular L/V studied.

As the vehicle sits on the launch pad, in the conventional configuration the heavier LOX tank is located on top of the lighter LH2. This requires a heavy structural member between the two tanks to prevent the lighter LH2 tank from being crushed. This configuration also requires large, long, and even drag producing LOX feed lines running the length of the vehicle on the exterior fuselage. If the relative position of the propellant tanks is inverted, both the heavy structural separation member and the long LOX feed lines could be deleted.

While the structures community at MSFC was elated with this finding, the LOX tank aft configuration gave the vehicle an aft center-of-gravity (cg) location which surfaced controllability concerns. In the conventional configuration the L/V is controlled in the ascent trajectory by the gimbaling of its rocket engines. Studies have been conducted at MSFC which showed that the resulting aft cg configured L/V would not be adequately controllable with the engine gimbaling alone.

PROBLEM STATEMENT

It is known that the controllability of an aft cg L/V is decreased. Today, more aft cg L/V's are appearing. In addition to an aft cg being caused by an internal rearrangement of propellant tanks, aft cg L/V's are appearing due to heavier rocket engines, and larger numbers of aft engines. Therefore, in the new spectrum of L/V's being considered the controllability of the aft cg configured vehicle must be assessed. When the available control authority has been determined to be inadequate or marginal, some means of flight control augmentation is required.

In this research effort the author has proposed and designed a novel solution to provide the required flight control augmentation for an aft cg configured L/V when needed most in the ascent trajectory, during maximum dynamic pressure. The L/V used in this research is one that has recently been studied at MSFC. The LH2 and LOX propellant tanks in the ET have been interchanged, giving the vehicle an aft cg. It has been determined that engine gimbaling alone does not provide adequate control. The required flight control augmentation is provided by aerodynamic flight control augmentors. This solution not only solves the original problem of augmenting the control of the aft cg vehicle, but also can be used in the marginal control configuration to enhance controllability, as load alleviators, to reduce engine gimbaling requirements, to provide engine actuator failure protection, and enhance crew safety and vehicle reliability by providing more control in engine-out events.

These devices can reduce the wind restrictions. Conventionally, the L/V loads during ascent are alleviated by turning the vehicle into the wind, thereby reducing the flight angle-of-attack. Thus, load relief is accomplished at the expense of trajectory deviation. Load relief control is most necessary when the L/V experiences maximum dynamic pressure and the aerodynamic loads are greatest. This happens to be when the flight control augmentors would provide the most significant assistance. The added control capability through the use of these surfaces allows greater tolerance of wind magnitudes and a minimization of bending moments on the vehicle both during ascent and during launch. For prelaunch, the unfueled vehicle on the pad must withstand peak winds of 75 knots, and fueled at liftoff peak winds of 50 knots. The environmental disturbances are multiplied by 1.5 to account for von Karman vortex shedding effects. Wind profiles show greatest steady wind speeds occur between 20,000 and 60,000 feet with a gust overshoot of up to 50%. The more the engines are required to gimbal, the more engineering design and cost is involved to have the propellant ducts move with the gimbal action while maintaining a full flow of fuel. The extension, compression, and torsion of the propellant ducts become limiting factors of engine gimbaling. Thus, the designed flight control surfaces of this research, provide not only the required control augmentation but a plethora of additional significant benefits.

APPROACH

Current and past uses of launch vehicle aerodynamic surfaces are reviewed. NASA has a rich national heritage of launch vehicles that have used aerodynamic surfaces, both to provide flight stability, and to provide flight control. The Saturn V took us to the Moon wearing 300 square feet of aerodynamic surfaces to provide flight stability. Since landing on the Moon, the wealth of smart materials and advanced composites that have been developed allow for the design of very lightweight, strong, and innovative L/V flight control augmentors. Today there are a myriad of L/V's actively launched from over 15 geographic sites. Aerodynamic surfaces currently being used by other nations on L/V's have been reviewed.

The flight control requirements analyses of the experimental aft cg configured L/V of this research have been conducted to determine the amount of flight control augmentation required. Based on these determined control requirements, the above reviews, the generated

vehicle mass properties, and ascent trajectory data, candidate flight control augmentors have been designed. These have been fabricated, along with experimental launch vehicle test articles. A static wind tunnel test program and a dynamic wind tunnel test program have been conducted at MSFC for these candidate flight control augmentors and the host experimental aft cg L/V. The wind tunnel test programs have produced data for the static stability and dynamic stability derivatives. The wind tunnel test data has been reduced and utilized to conduct the vehicle static stability analyses and dynamic stability analyses. Results are compared to DATCOM generated analytic data.

The best candidate designs are then chosen to demonstrate the augmented control authority achievable with the use of the flight control augmentors. Figure 1 shows the flow chart of this conducted research effort. Figure 2 shows the fabricated aft flight control augmentors tested on the experimental L/V in the wind tunnel at MSFC. Figure 3 shows the fabricated forward flight control augmentors tested on the L/V. Figure 4 shows the experimental L/V wind tunnel test article with aft devices attached. Figure 5 shows the experimental L/V test article with forward and aft devices attached. Applications to other flight vehicles, and future work to build upon this research are discussed.

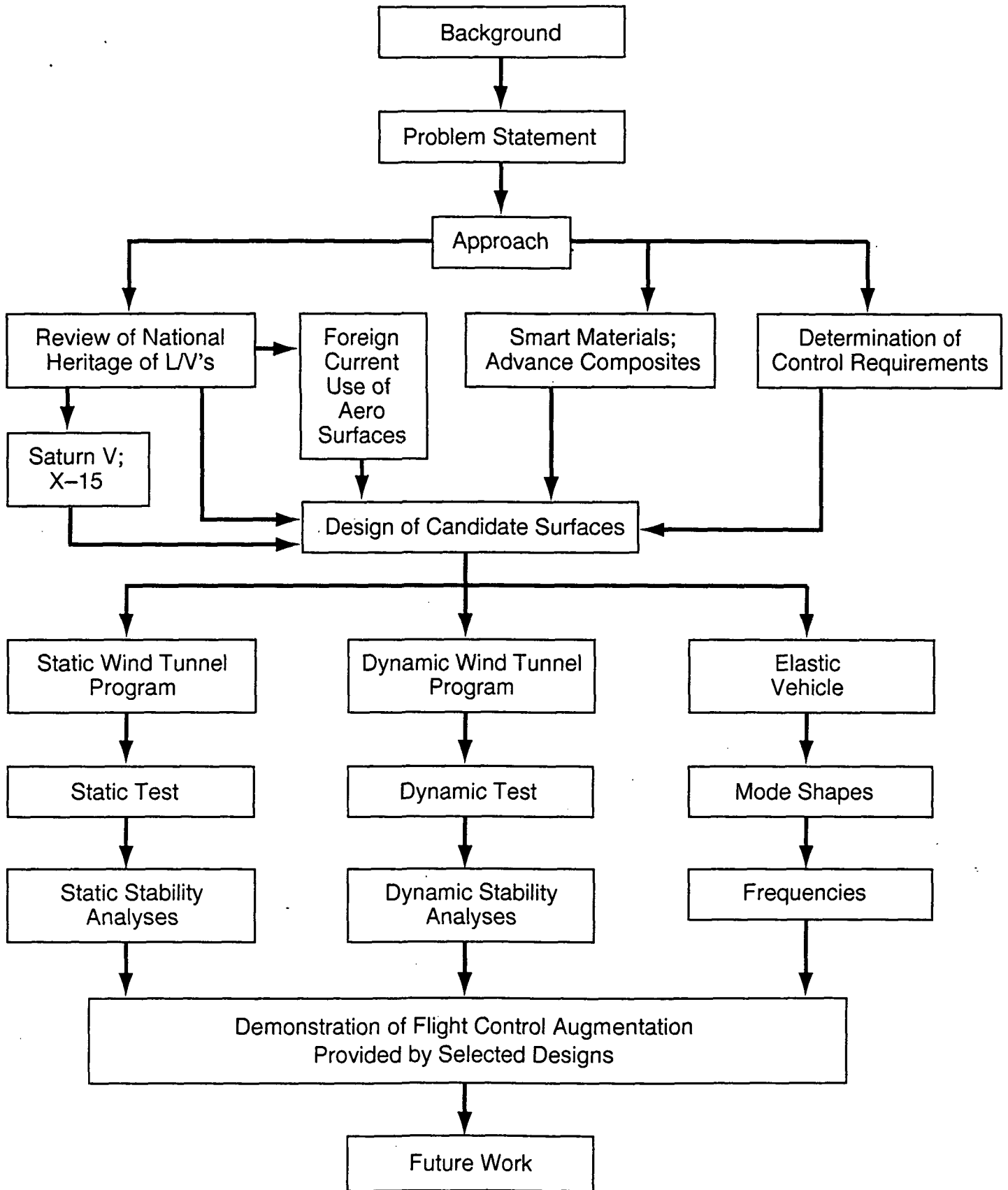


Figure 1. Flow chart of conducted research.

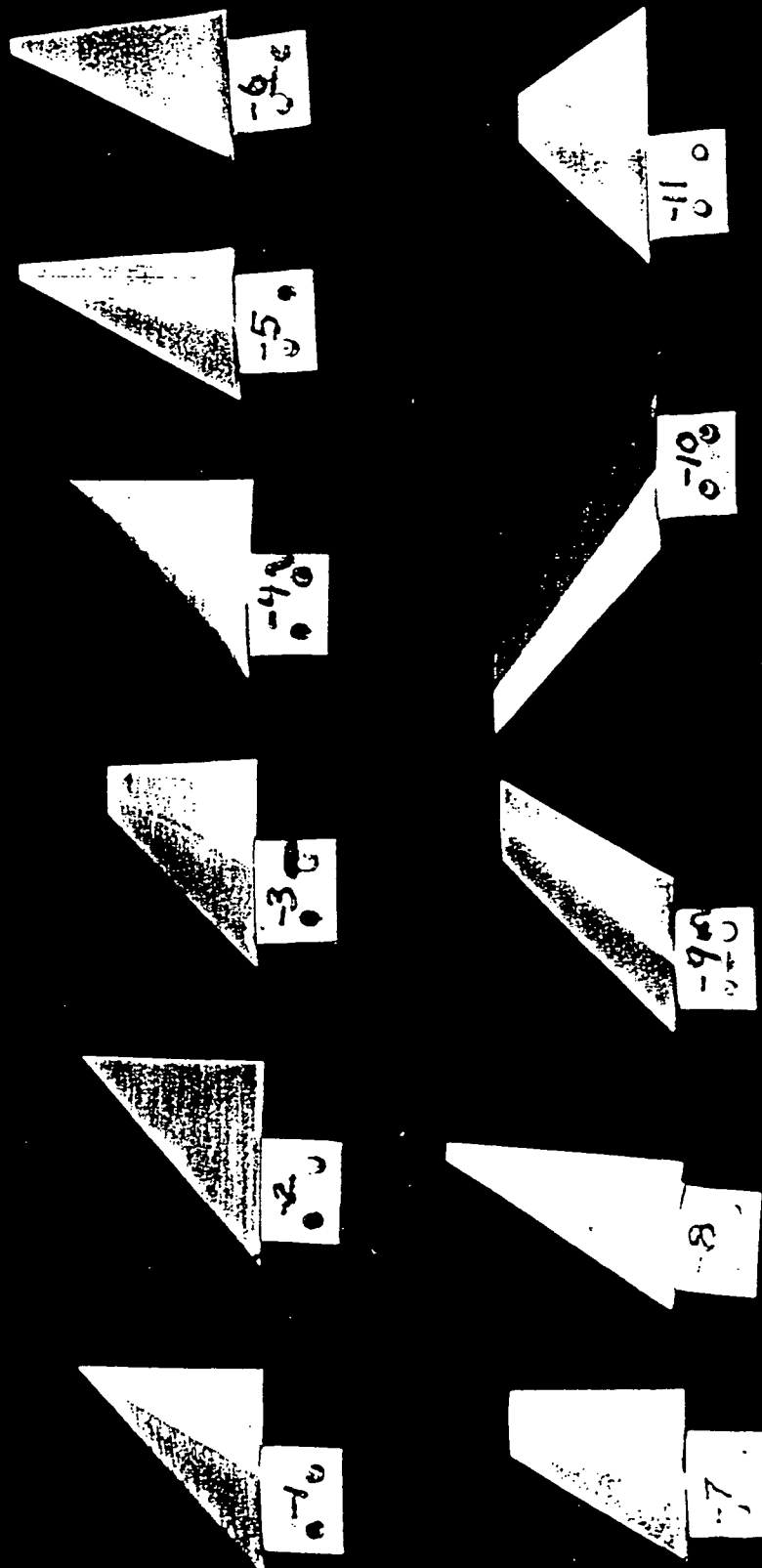


FIG 2.
FABRICATED AFT LAUNCH VEHICLE FLIGHT
CONTROL AUGMENTATION DEVICES

ORIGINAL PAGE IS
OF POOR QUALITY



FIG 3.
FABRICATED FORWARD LAUNCH VEHICLE FLIGHT
CONTROL AUGMENTATION DEVICES



FIG 4.
FABRICATED LAUNCH VEHICLE WIND TUNNEL
TEST ARTICLE WITH FLIGHT CONTROL
AUGMENTATION DEVICES ATTACHED AFT



NASA
National Aeronautics and Space Administration
Test Launch Vehicle

FIG 5.
FABRICATED LAUNCH VEHICLE WIND TUNNEL
TEST ARTICLE WITH FLIGHT CONTROL
AUGMENTATION DEVICES ATTACHED AFT
AND FORWARD