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RESPONSIVE, LOW COST LAUNCH OF NANOSATELLITES AND TECHNOLOGY DEMONSTRATIONS

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Dynetics, Inc., in support of the U.S. Army's Space and Missile Defense Command (SMDC) and in partnership with the Colsa Corporation, is developing the Multipurpose NanoMissile System (MNMS) to fully enable the operationally responsive space goals of the Department of Defense (DoD). The need for on-demand intelligence and communications in remote geographical locations is increasing the requirement for rapidly deployable and tailorable space assets. Today, SMDC is developing multiple nanosatellites (nanosats) such as SMDC-ONE and Kestrel Eye. The personal electronics revolution that has put enormous processing capabilities into small hand-held devices is now being extended into space. Nanosats are emerging as key assets for a broad array of federal agencies including DoD, NASA, the National Science Foundation (NSF) and universities.

I. INTRODUCTION

Currently, nanosat class payloads are launched as secondary payloads on large launch vehicles. While these launches are adequate for test demonstrations, the nanosat's orbital location is confined to the primary payload's orbital destination. More importantly, these launches are scheduled months in advance, and are not able to meet the immediate needs of users. In order to maximize the benefit of the next generation of nanosats, the US Army SMDC recognizes that a dedicated, low cost, small payload launch system is needed to ensure rapid deployment and precise placement of the assets to meet battlefield requirements.

Unlike past attempts in the arena of low cost, small launchers, the MNMS system is designed from the start to meet the operationally responsive mission. It is not simply a scaled down model of an expensive launch system. As illustrated in Figure 1.0, MNMS utilizes:

Figure 1.0. MNMS Launch Concept

- "Automotive like" design utilizes lowest cost materials (steel instead of aluminum or labor intensive composite materials) and manufacturing processes
- Pressure-fed propellants instead of turbopumps
- Reliability and low part count over performance
- Modular assembly for "made to order" capability
- COTS wireless electronic component connectivity
- Rapid validation through extensive tests
- Safe fuel and oxidizer: ethane and nitrous oxide
- "Ship and shoot" approach
- Minimal range requirements

II. MARKET PROJECTIONS

Market elasticity appears to be high for a nano/microsat launch capability. According to the Federal Aviation Administration's (FAA) recent report, "Launch rates may increase beyond forecasted levels if a new microsatellite launch capability emerges…. The emergence of a micro-satellite launch vehicle, with competitive launch costs, may cause microsatellite payloads to shift from the multi-manifest approach to individual launch on these new vehicles. This would result in a larger number of launches."[1]

As seen in Figure 2.0, the FAA report predicts 262 Low Earth Orbit (LEO) satellites will be required over the next decade. If history is a guide, approximately 25% of these will be in the microsatellite class (<200 kg).[1]

There are similar signs and trends in the U.S. government market:

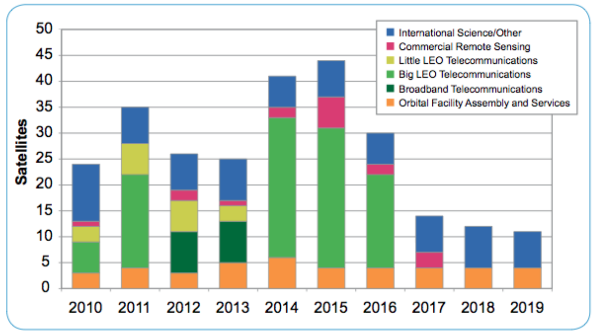

Figure 2.0 FAA LEO Market Projections

- NASA Missions:
    - Franklin/Edison Small Satellite Demonstration Program
    - Venture Class Earth Science Missions

- Continued DoD Push for Small Satellites - "Deputy Secretary of Defense William Lynn…indicated that the responsive space concept will be a major part of the document…..can help us counter threats to our space capabilities. By building systems on small satellites, using modular components, ORS [Operationally Responsive Space] gives us the ability to rapidly augment our space systems"[2]

In addition, explosive growth in this area was evidenced by the participation of over 60 universities and schools (across the U.S. and internationally) at the 7th annual California PolyTechnic Institute cube satellite workshop. The market in this area is clearly growing.[3]

III. SYSTEM OVERVIEW

Through innovative, cost-driven, minimalist design, the MNMS team has applied lean, entrepreneurial practices to the challenges of space launch. The result of this effort is an operationally responsive system, providing on-demand tactical launch options for the battlefield commander.

The MNMS uses non-toxic liquid propellants that do not require cryogenic cooling below 0°F – ethane and nitrous oxide. These propellants, which remain liquid at non-cryogenic temperature under their own significant vapor pressure, eliminate the need for turbopumps or complex tank pressurization hardware. The self-pressurizing - or VaPak - propellants used for all three main stages are storable, commonly available and easily handled. The rocket motor is submerged in the nitrous tank to reduce interstage mass and simplify propellant feeds for the motor and Liquid Injection Thrust Vector Control (LITVC).

The use of propulsion modules with common components decreases the production costs of the MNMS (see Figure 3.0). The MNMS uses the same tank design for all three main stages. Using common, high-strength stainless steels for the structure reduces manufacturing and material costs. The tanks are manufactured with equipment and techniques currently used to make commercial pressure vessels such as Dewars, fire extinguishers and storage hoppers. Finally, the all liquid first- and second-stages incorporate essentially the same engine, thrust vector control, and feed systems. The engine, which Dynetics designed and developed, is pressure-fed.

All these design features reduce costs and system complexity, simplify operations and promote responsiveness. These capabilities do not exist today, but are essential for a truly responsive space capability, and we are confident of achieving these goals.

IV. CONCEPT OF OPERATIONS

The MNMS system is being developed to operate from any range The system's modular design is highly configurable and can be augmented using existing Army assets such as the solid rocket motors from the Army Tactical Missile System (ATACMS) and the Multiple Launch Rocket System (MLRS) to increase its payload capacity. In addition to its nanosatellite payload delivery capabilities, the MNMS can be used for a number of applications such as:

- Hypersonic test vehicle for new technology aerospace components
- Suborbital launch vehicle
- Missile defense sensor exerciser
- Long range strike with small conventional munitions

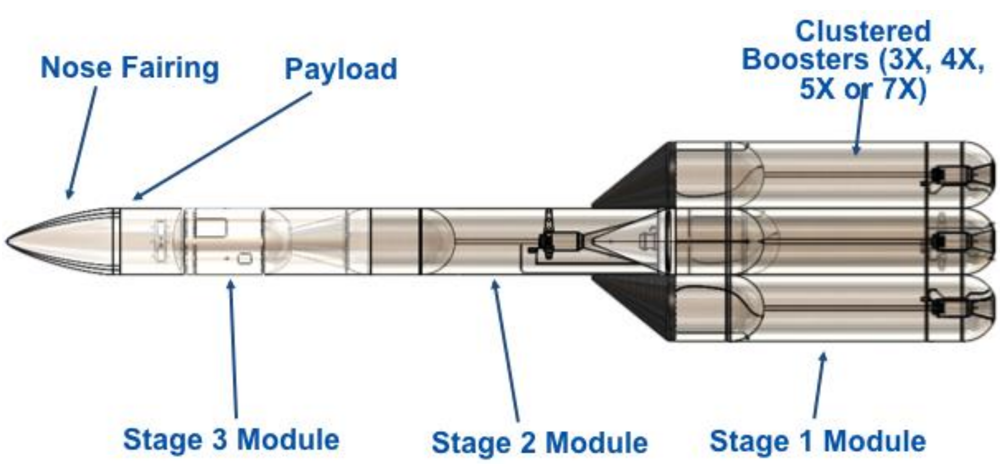

Figure 3.0 MNMS Modular Booster Concept

V. MODULAR BOOSTER DEVELOPMENT

The MNMS modular booster utilizes a 24" diameter stainless steel tank. The use of Nitrous and Ethane eliminate a separate pressurization system. Figure 4.0 illustrates the booster design.

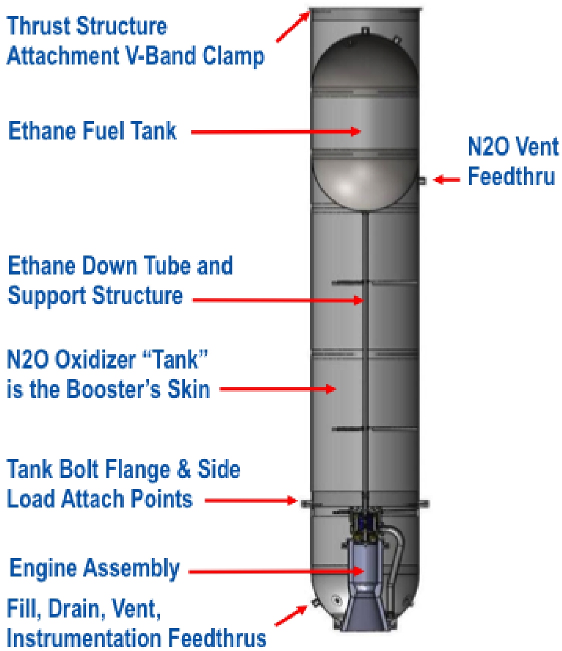

Figure 4.0 MNMS Booster Cutaway

The MNMS booster has undergone a rigorous development program over 18 months. The MNMS program was divided into three major phases: small scale horizontal engine development, full scale horizontal engine development, and full scale vertical booster development.

The horizontal engine development was undertaken in a step-wise approach including boilerplate 2,500 lbf engine testing followed by a series of flight weight tests (see Figure 5.0) at Dynetics' commercial rocket test facility.

The development program also included parallel wind tunnel testing as is illustrated in Figure 6.0. This testing was completed in the NASA Marshall Space Flight Center's Trisonic Wind Tunnel and was used to validate the flyability of the concept.

Full-scale vertical booster testing shown in Figure 7.0 was conducted at the US Army test facility at the Redstone Arsenal in Huntsville, AL. The testing series was broken up into

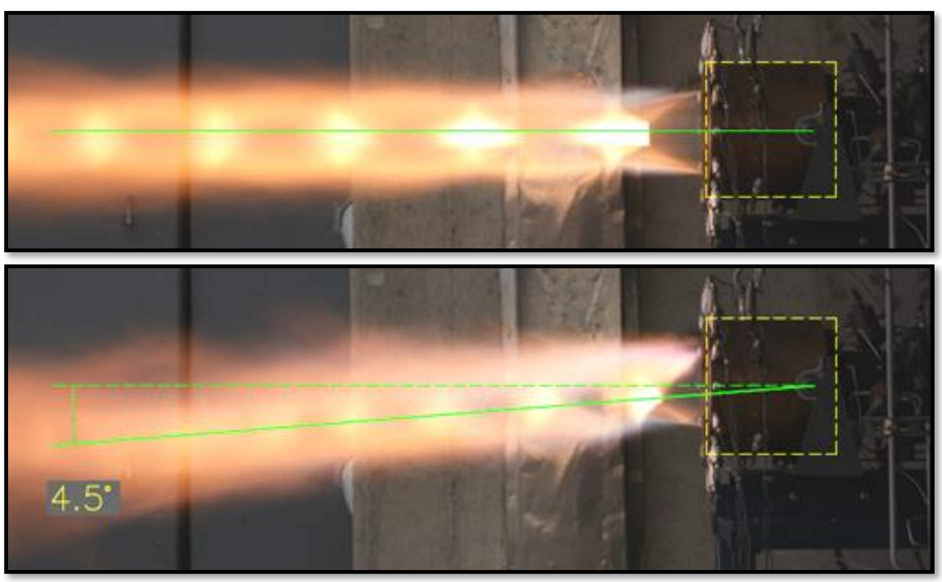

Figure 5.0. MNMS Engine Testing

three categories: gN2 test check outs, cold flows, and hot fire tests. These checkouts served to leak check the booster and to verify basic operation of components. The final gN2 checkout step on each booster was to blowdown gN2 through the main engine assembly at actual tank run pressures to demonstrate basic operation and control.

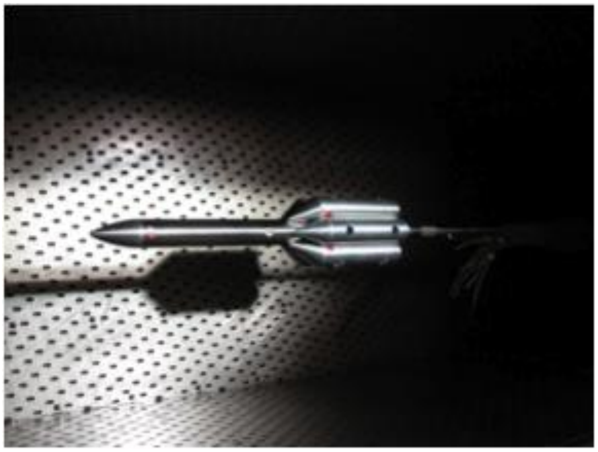

Figure 6.0. MNMS Wind Tunnel Tests

Figure 7.0. MNMS Vertical Full Scale Booster Testing

Cold flow tests were carried out using a combination of CO2, ethane, and nitrous oxide fluids. These tests were necessary to characterize flow rates and verify injection hole sizes. Ethane and nitrous oxide were never cold flowed simultaneously for safety reasons.

There were several short duration hot fire tests and two long duration hot fire tests with a maximum duration of 60 seconds. There was one attempt at an LITVC demonstration test, however this test prematurely cutoff and no LITVC operation was performed.

VI. FUTURE WORK

The MNMS ground development program was a pre-cursor to a proposed flight test program to further demonstrate the propulsion system and MNMS vehicle concept. Some work towards the design of a test flight version of the current test booster has been done already. This would be mostly the same design as the current test booster that has been tested in the vertical test stand with modifications to accommodate fins, a nose cone, avionics package, and features necessary to support a rail-launched, unguided flight test. Figure 8.0 shows one test flight booster concept.

The second phase of the test flight program would be to test fly a multi-booster, two-stage, long range vehicle. This would be a full flight-weight design of the MNMS launch system and would be a guided flight utilizing LITVC for control. The vehicle would be a 3-1-0 version of the MNMS launch system. This test would demonstrate multi-booster functionality on 1st stage and an in-flight stage separation event. The concept of the 3-1-0 test flight vehicle is shown in Figure 9.0.

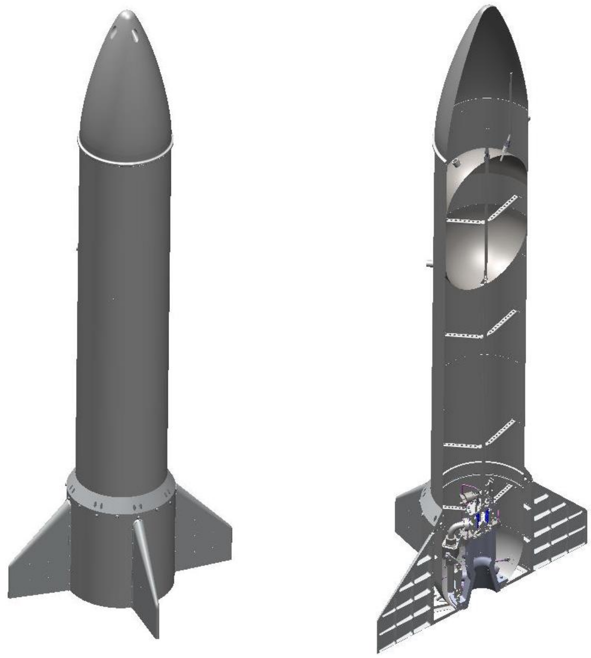

Figure 8.0. Initial Flight Test Booster Concept

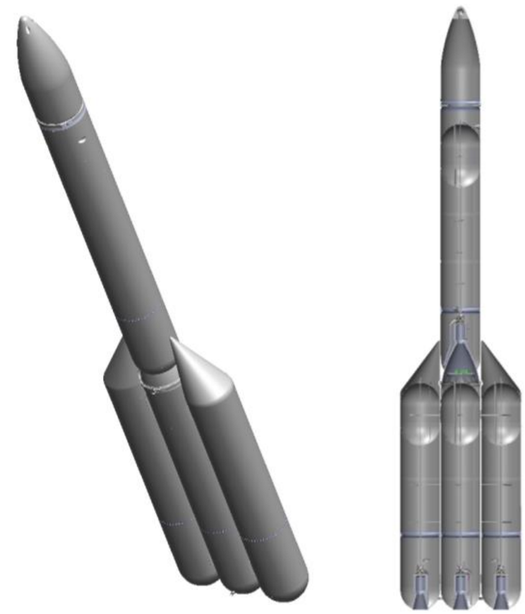

Figure 9.0. Multi-Booster Flight Test Concept

VII. CONCLUSION

Currently, nanosat class payloads are launched as secondary payloads on large launch vehicles. While these launches are adequate for test demonstrations, the nanosat's orbital location is confined to the primary payload's orbital destination. More importantly, these launches are scheduled months in advance, and are not able to meet the immediate needs of users. In order to maximize the benefit of the next generation of nanosats, the MNMS program was initiated to enable a dedicated, low cost, small payload launch system to ensure rapid deployment and precise placement of nanosatellites to meet user requirements.

[1] Commercial Space Transportation Forecast, 2010, Federal Aviation Administration
[2] In Orbit, Military Looks to Small Satellites as Costs for Large Spacecraft Grow, July 2010, National Defense Magazine
[3] Website: http://www.cubesat.org/index.php/about-us/mission-statement