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Apr 1st, 8:00 AM

LOFT-1 Mission: New Concepts For Educational and Commercial Spaceflight

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THE LOFT-1 MISSION

New Concepts For Educational And Commercial Spaceflight

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The Launch Operations Flight Test One (LOFT-1) was originally conceived by E'Prime Aerospace Corporation (EPAC) of Titusville, Florida, as strictly an administrative pathfinder toward satisfying all governmental requirements for conducting commercial spaceflight activities from the Cape Canaveral Air Force Station (CCAFS). As the program progressed from early June 1987 toward the original launch date set in the Fall, the complexion of the flight changed dramatically to one of a bonafide scientific mission. Four individual educational/commercial organizations agreed to provide experiments. As such, LOFT-1 would mark the first launch of a privately developed and funded suborbital vehicle carrying payloads from the CCAFS.

The University of Alabama in Huntsville, by way of participants within the Industrial and Systems Engineering Department, volunteered to serve as a focal point for all LOFT-1 payload design and integration tasks. In addition, UAH went on to design and develop its own experiment. Given only a few short months between conception of the mission and the originally planned flight date of October 14, 1987, it was necessary to define a close-knit team, literally from across the nation, to make the mission possible within the original time constraint.

The UAH team developed a set of design criteria for all flight experiments, including the launch/recovery environment and physical envelopes. An overall project critical path was developed using operations research networking methods. Hardware space and weights were allocated and a preflight test program outlined, including a full-scale vehicle flight test and payload drop tests. The entire effort culminated with final payload fit and integration testing at a UAH ISE Department Laboratory according to the originally established timeline.

The four flight experiments consisted of the Data Collection And Telemetry System (DCATS) developed by UAH; the Flight Environment Monitoring System (FEMS) developed by Weber State College (Ogden, Utah) in conjunction with QSI Corporation in Logan; the Advanced Materials Flight Experiment (AMFE) developed by Utah State and Morton Thiokol Wasatch Operations; and the Brookwood Advanced Biology Experiment (BABE) conceived by Brookwood High School of Snellville, Georgia.

The "Santa Maria" sounding rocket vehicle was likewise conceived, designed, and developed for this mission by North Coast Rocketry, under contract to EPAC. Vulcan Systems, a North Coast subcontractor, developed the solid rocket motor (SRM). Testing of the various vehicle and payload components was conducted independently across the country prior to final assembly and integration testing in Huntsville.

LOFT-1 OBJECTIVES AND MISSION PROFILE

As the mission name implies, the Launch Operations Flight Test was conceived to allow EPAC to demonstrate their organizational, planning, and procedural abilities. As such, the mission is to simulate launch of a larger payload-carrying vehicle and involve interfacing with all the necessary Eastern Space and Missile Center (ESMC) and other Government entities. Even before launch, the exercise has proven to be successful by identifying key issues to be resolved for any commercial flight from a Government facility.

The basic mission profile, that of a simple unguided ballistic, suborbital flight remained unchanged and consists of a powered flight phase (with thrust supplied by the Vulcan SRM), a coast phase to apogee (approximately 17,000 feet predicted dependent upon launch inclination), a short ballistic decent phase, recovery system deployment and subsequent parachute drift/decent phase, and finally a water splash-down and recovery phase. Throughout each phase of the mission, data will be recorded on board and telemetered to ground receiving stations indicating the status and altitude of the vehicle along with information concerning performance and the condition of on-board systems. The data systems will be discussed in more detail later. Typical vehicle performance is shown in Table 1.

SEA LEVEL LAUNCH, 75-DEGREE INCLINATION, ZERO WIND DRIFT

Time, Seconds	Velocity, FPS	Altitude, Ft.	Range, Ft.
0.0	0.0	0.0	0.0
2.0	641.5	603.1	124.4
4.0	1294.5	2501.5	664.3
4.4	1380.5	3016.1	813.1
*** MOTOR BURNOUT ***			
8.0	932.5	6879.4	1959.2
16.0	553.6	12417.6	3795.5
34.0	59.5	16561.3	6007.0
37.0	91.9	16484.2	6201.1
*** RECOVERY SYSTEM DEPLOYMENT***			
45.0	55.6	16082.0	6388.2
87.0	53.8	13777.0	6392.4
147.0	51.3	10623.1	6397.7
167.0	50.5	9605.5	6398.5
277.0	46.5	4280.4	6406.3
332.0	44.7	1773.3	6409.9
352.0	44.1	1106.0	6410.9
367.0	43.8	226.7	6412.2
372.1	43.5	0.1	6412.5

TABLE 1 - TYPICAL ALTITUDE AND RANGE PREDICTIONS FOR LOFT-1

Increased emphasis has been shifted to the tracking and recovery of the payload section which will require EPAC to mount an ocean-going recovery team. As first conceived, recovery of the "payload" was optional since it did not directly influence success of the pathfinder-type mission. Incorporation of the flight experiments, however, required additional planning to insure their recovery.

INTEGRATION MANAGEMENT

Graduate students within the UAH ISE Department undertook (with faculty oversight) various management and integration tasks of the LOFT-1 project and in several cases, applied these to classwork. Graduate students Sam McNully, J.R. Phipps, and Pam Worthington, under the direction of Dr. Michael Dorsett, prepared a critical path analysis of the overall project. Both forward and backward pass data were used in the network. The CPM analysis, done in conjunction with Matt Steele of North Coast Rocketry and Wayne McCain, UAH Payloads Integrations Manager, helped identify most of the significant tasks of the project, some of which could have been oversimplified without the analysis. Some 135 individual tasks were identified in the early study, several of which were later expanded into additional subtasks.

Dr. Robert A. Brown, UAH ISE Department Chairman, and Dr. Jack R. Walker, Associate Professor, assisted in establishing a LOFT-1 Payloads Integration Laboratory at the UAH campus. Dr. Brown allocated some department equipment for payload checkout and test, while Dr. Walker undertook the day-to-day oversight of student activities and provided consultation regarding project details. Communication of project requirements, schedules, and design details were somewhat strained since several of the principals were physically located away from the Huntsville campus and travel was constrained. Additionally, most of the work had to be accomplished during the summer term which is traditionally lacking student and faculty availability. Nevertheless, it was possible to successfully define the overall project and payload requirements sufficiently during the first two months to allow completion according to the original 5-month schedule. Credit must be given to the coordination of the students involved and the assistance afforded by the faculties and advisors at UAH, Weber State, Utah State/MTI, and Brookwood High School. Figure 2 illustrates the LOFT-1 organization and how the various groups interface.

As the project progressed, various components and subsystems were tested individually in Utah, Colorado, and Georgia in addition to Alabama where eventually all flight hardware was shipped for final assembly and checkout. Active participation was had among the UAH, North Coast, and Vulcan personnel and the payload principal investigators. Schedule coordination and progress review was on-going with EPAC who concentrated on preparations for a launch at CCAFS. The launch was originally slotted to originate at CCAFS LC-37 where future EPAC-A and EPAC-B launches are contemplated. However, after review of the improvements necessary to reactivate that site and upon recommendation from ESMC, the launch site was changed to LC-47, the site of similar-sized, weather reconnaissance sounding rockets on a regular basis. This facility is almost optimum for the LOFT-1 mission in that its layout and electrical conveniences closely match those needed. One drawback to the LC-47 facility is its limited viewing area. Guests and visitors for the launch will likely be stationed rather remote to the launch site.



LOFT-1 Organization

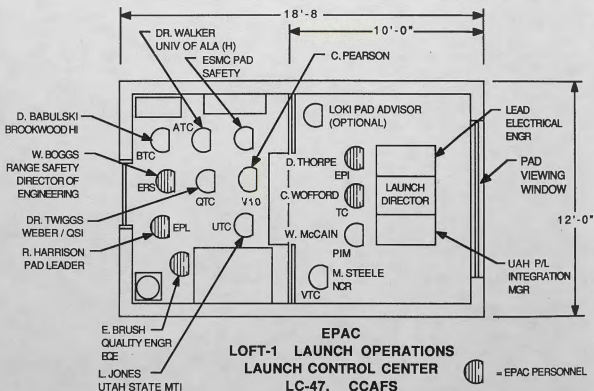
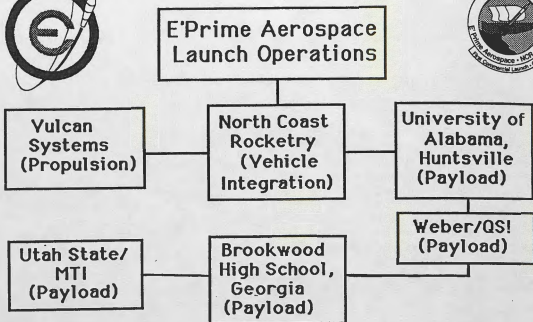


FIGURE 2 - LOFT-1 ORGANIZATION AND LC-47 BLOCKHOUSE ASSIGNMENTS

SOUNDING ROCKET VEHICLE DEVELOPMENT

The "Santa Maria" sounding rocket vehicle (a name coined by EPAC President Bob Davis to commemorate Christopher Columbus's flag ship and the October 1987 launch date) was designed and developed by North Coast Rocketry as an evolution of their small rocket vehicles already in use in the professional and hobby market. Experience at North Coast ranges from small model rockets (some under 1-pound in weight) to professional involvement with the Army Pershing I-A and Pershing II. The concept for Santa Maria was to utilize state-of-the-art (SOTA) materials and high reliability construction techniques but to achieve low cost by applying methods already proven on North Coast's "production line." North Coast has responsibility for construction of the vehicle airframe and integration of it with the propulsion system and payload section. The motor itself was procured under contract to Vulcan Systems, an arrangement similar with other North Coast vehicles. A vehicle diameter of six (6) inches (see Figure 3) was chosen to accommodate a reasonable size payload section and to allow more realism in the handling and prelaunch/launch activities at EPAC. It was determined that this size would also allow use of typically available composite airframe materials and a motor with sufficient impulse to accomplish the mission requirements.

Vehicle Length, Ins.	114.0
Fin to Fin Span, Ins.	24.0
Diameter, Ins.	6.1
Total Weight, Lbs.	81.0
(Includes Payload)	

Airframe - Fiberglass/Epoxy,
Filament Wound

Nose Cone- Fiberglass/Epoxy,
Layup

Fins (3) - Fiberglass/Epoxy,
Sheet (0.375 Thk)

Altitude, Ft.	17,000
Burnout Velo, M	1.3
Coast To Apogee, Secs	29
Impact Range, Miles	1.5
Impact Velo, FPS	<50
Total Flt. Time, Secs	380

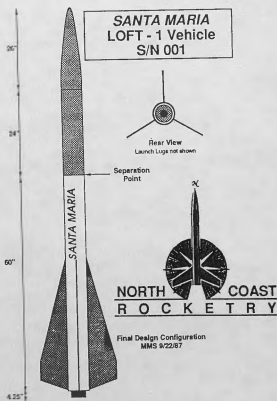


FIGURE 3 - NORTH COAST SANTA MARIA VEHICLE DATA

North Coast also designed and had manufactured (credit to Mr. Jimmy Williams of the Huntsville Area Rocketry Association) a portable launcher for the Santa Maria which was used in a full-scale test flight of the vehicle. This device was to be used at the Cape for the LOFT-1, but when the launch site was changed to LC-47, it was determined that adaptation to and use of the LOKI launcher would afford better control over launch inclination and azimuth settings and required less justification to ESMC. The original launcher served well in the flight worthiness test and will be maintained for possible future portable use.

Compared to other sounding rocket vehicles, the North Coast Santa Maria offers a lower magnitude of cost with potential for increased performance. The vehicle diameter and length can be increased and strap-on boosters or a booster stage added to increase maximum altitude. Enhancement of the Vulcan motor would be straightforward as is discussed in the following section.

THE VULCAN SOLID ROCKET MOTOR

Vulcan Systems, Inc. of Colorado Springs was contracted to develop and supply solid rocket motors to North Coast Rocketry for the LOFT-1 Santa Maria. Initially, requirements called for a relatively high-performance SRM with clustered smoke-generating pods for visual tracking purposes. Once the vehicle diameter was set at six inches, it was decided to incorporate a high-smoke-producing propellant formulation into the main motor and delete the separate smoke generators. This would result in sacrificing motor specific impulse but the overall system would be more reliable. Ballistic studies indicated that a motor producing a total impulse of 3500 pound-seconds was required. The approach was to utilize proven design concepts, SOTA materials and processes, and conservative design margins by building on previous Vulcan designs. Vulcan has a proven track record in the development of "custom" rocket motors for scientific and hobby use, many of which have been built to military specifications. The Vulcan line of motors represent SOTA technology (high performance composite cases and HTPB-type propellants) and have been used by DoD contractors, the Air Force, and several universities and commercial firms. Combined with Vulcan's extensive in-house R&D capability is their fast response time and relatively low overhead. This made Vulcan a natural as the LOFT-1 motor contractor.

Figure 4 depicts the Vulcan N5000-34 motor and Figure 5 shows the thrust-time curve. Basically, the motor consists of five separately cast and cured "Bates" type grains, each with a propellant weight of 4.7 pounds. These grains are bonded into the filament wound motor case. Each has a center-burning CP core and uninhibited ends. The resulting thrust-time trace approaches neutrality. A graphite nozzle/exit cone and forward closure are likewise bonded into the case. Average operating pressure is 400 psi with a MEOP of under 500 psi. The lowest pressure failure point in the system is the bonded-in forward and aft closures which have a 3000 psi blowout pressure. Overall, the motor has extremely high safety margins.

The smoke-rich propellant formulation is HTPB/AP/Zinc, designated as "Navy N-60, Smokey Sam" type. This propellant was formulated and used by the Naval Ordnance Station at Indian Head. For the LOFT-1, it provides a high visibility plume (rubber-tire-black) for tracking. The performance of the

motor (and likewise the performance of the Santa Maria) can be significantly improved by employing a more conventional HTPB formulation. Zinc would be replaced with aluminum and AP. An increase in total impulse of about 53% could be expected within the same physical envelope as the current design.

An interesting feature incorporated into the N5000-34, not common to most SRM's (except for the hobby market), is the pyrotechnic delay fuse and powder charge used to expel the parachute recovery system. By proper timing of the delay column (34 seconds for LOFT-1), the user may provide a hot gas ejection system having a high degree of reliability in lieu of electromechanical timers, etc. This approach has been used in literally millions of production-type rocket motors for the hobby industry.

For the LOFT-1 project, a total of three full-scale motors were manufactured, one of which was flown in the full-scale flight worthiness test on September 19, 1987. Prior to this, several subscale motors were manufactured and either static-tested or flown, all successfully.

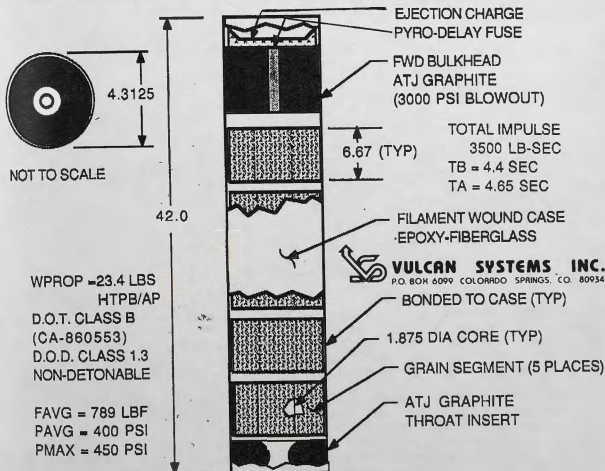


FIGURE 4 - VULCAN N5000-34 SOLID ROCKET MOTOR

VACUUM THRUST VERSUS TIME

VULCAN SYSTEMS, INC. N-5000-34

UAH-ISE DEPT. 1987 *LOFT-1*

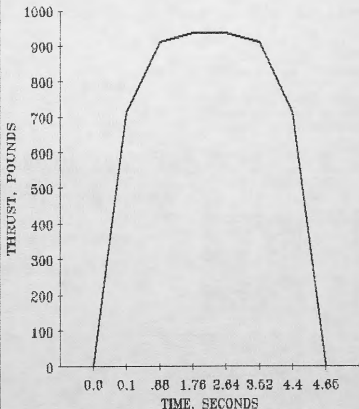


FIGURE 5 - THRUST-TIME TRACE OF VULCAN N5000-34 SRM

LOFT-1 PAYLOAD DESCRIPTION

The payload for the LOFT-1 is housed in a sealed, cylindrically-shaped compartment containing experiments from four sources- The University of Alabama in Huntsville (UAH); Weber State College in Ogden, Utah (in cooperation with QSI Corporation of Logan); Brookwood High School of Snellville, Georgia; and Utah State University in conjunction with Morton Thiokol. The individual experiments were integrated and tested at UAH.

The UAH payload, called the Data Collection And Telemetry System (DCATS) was developed to provide radio telemetry concerning vehicle altitude and performance, and to act as a flotation and recovery aid. After the overall vehicle length was shortened, DCATS was incorporated into the aluminum cylinder used to couple the payload section to the lower vehicle airframe. The system consists of three radio beacons (1-HF, 1-VHF, and 1-UHF) modulated by separate data multiplexers. Six analog channels and four discreets are transmitted. In addition to transmitting data, the beacons will be used with

direction-finding equipment to aid in the location and recovery of the payload section. The beacon transmitters are commercially available exciter boards running at 2-watts RF output on selected Amateur Radio frequencies. The use of these beacons are under the control of a Extra Class Amateur Radio Operator and has been coordinated with the Special Services Division of the Federal Communications Commission (FCC) and the Amateur Satellite Corporation (AMSAT). The DCATS is powered by an on-board 3.5 Amp-Hour NICAD battery pack which is continually charged until launch. Operating time for the system is approximately 2-3 hours.

Weber State College students and GSI Corporation have developed the Flight Environment Monitoring System (FEMS) to electronically measure and record vehicle acceleration (three axes), temperature (two locations), and barometric pressure throughout the flight of LOFT-1. The microprocessor-based system will also provide control signals to the Utah State/MTI payload. After flight and recovery of the payload section, these data can be recovered from the computer's RAM and graphic printouts provided to all payload users. The system was derived from a critical-cargo monitoring system in use by GSI to measure transportation of Shuttle SRM segments to the Cape. The LOFT-1 flight will serve to demonstrate its applicability to rocket flight as well. Dr. Bob Twigg has acted as Weber State Faculty Advisor and has several enthusiastic students participating.

A group of Seniors and Juniors from Brookwood High School in Snellville, Georgia developed the Brookwood Advanced Biology Experiment (BABE) with the help of volunteer David Babulski and Brookwood instructor Mrs. Debbie Roberts. The experiment will expose about 100 seeds in the class Angiospermae to the slight increase in radiation had and the acceleration from the LOFT-1 flight. These specimen will then be planted alongside a control group that will never leave Snellville. Effects on the seeds ability to germinate and grow will be studied by the students. The results should add to man's knowledge about cultivating food crops in space. Thirty-two students are participating.

The Utah State/Morton Thiokol package, termed the Advanced Materials Flight Experiment (AMFE) will consist of a thin-film polymer experiment involving the dispersion of particulates in a "low-g" environment. A quick-curing (UV-light) polymer film will be activated near the vehicle's apogee during the low-g coast period. The resulting structure will be returned for study. The LOFT-1 flight will serve as a test-bed for future experiments by demonstrating performance of the specialized flight hardware. The AMFE supports a technology area being investigated by the U.S. Air Force's Astronautics Laboratory (AFAL) at Edwards AFB and others. Although no Air Force funding or sponsorship is involved in the LOFT-1 flight, data will be made available for AFAL review. The AMFE experiment is triggered by the Weber State FEMS. Interfacing tests were successfully conducted during September 1987 in Utah.

The four payloads for the LOFT-1 mission were developed solely with funds of the individual organizations and were not sponsored by others.

Figure 6 shows the space allocation and arrangement of the LOFT-1 payloads. Total payload section weight is 31.8 pounds, including parachute.

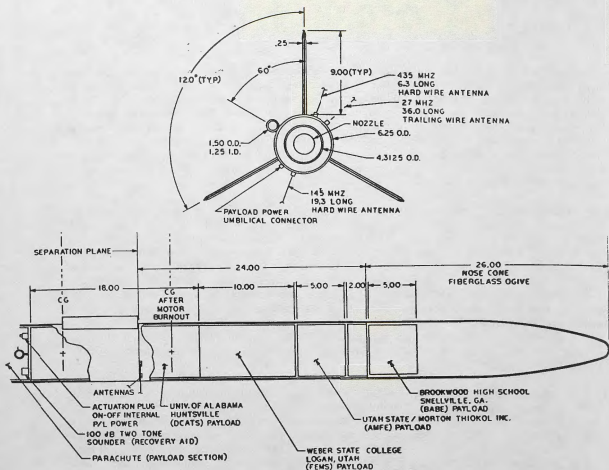


FIGURE 6 - LOFT-1 PAYLOAD SECTION LAYOUT (Courtesy EPAC)

SUMMARY AND CONCLUSIONS

At this writing, the LOFT-1 Mission had been delayed from its original target date of October 14, 1987 due to several administrative details being worked by EPAC and various Government organizations. Since LOFT-1 is to be first of the truly "commercial" space launches from the CCAFS, it was not unforeseen that initial delays might be encountered. In fact, the primary objective of the mission is to identify these obstacles. From that standpoint, the mission has already been declared a resounding success by EPAC even prior to launch.

The nature of the Santa Maria vehicle and its four payloads marks a beginning in economical spaceflight for the commercial and educational community. The vehicle and propulsion system hold potential for straightforward improvements yielding higher altitudes and longer low-g times. The simplistic approaches used make the concept rather unique in the normal "high-tech, high-cost" aerospace world that we are accustomed to. Once this approach is validated, low-cost, spaceflight-centered R&D for small companies, educational institutions, and even individuals will become a reality.