LANGLEY WORKING PAPER

ASTRONAUT TRAINING EXPERIENCE UTILIZING THE
LANGLEY LUNAR LANDING RESEARCH FACILITY

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A training program performed by six astronauts utilizing the Langley Lunar Landing Research Facility (LLRF) is described. This facility provides the capability for flying a piloted, rocket-powered vehicle in a simulated lunar gravity field. The principal purpose of the training was to familiarize the astronauts with the handling characteristics of a lunar landing type vehicle in preparation for more extensive training in the Lunar Landing Research Vehicle (LLRV) at the Manned Spacecraft Center. The training, which was performed during January and February 1967, provided an average of 10 flights for each astronaut. This paper is intended to serve as a record of the program and as a reference for future training plans.

INTRODUCTION

The Langley Lunar Landing Research Facility (LLRF) provides the capability for performing simulated lunar landings with a manned, rocket-powered vehicle. The principal use of the facility has been to study handling qualities requirements for lunar landing type vehicles (refs. 1 and 2). Experience in training pilots for research operations suggested that the facility would be valuable in training potential Lunar Module (LM) pilots.

A group of three astronauts trained and participated in research operations in the fall of 1966. One flight Research Center pilot who had considerable experience in flying the Lunar Landing Research Vehicle (LLRV) also flew the LLRF vehicle during this period. His comments on the similarity of the handling characteristics of the LLRF and LLRV led, in part, to the use of the LLRF for training of astronauts in preparation for more extensive training at the Manned Spacecraft Center (MSC) in the LLRV. This paper summarizes the training of six astronauts using the LLRF from January 9-February 3, 1967.
DESCRIPTION OF FACILITY

The facility utilizes an automatic traveling bridge crane that supports five-sixths of the weight of the research vehicle (shown in fig. 1) as it is flown in a test volume approximately 180 feet high, 360 feet long, and 42 feet wide. A detailed description of the facility is presented in reference 3.

The vehicle is rocket-powered and weighs 12,000 pounds, including a pilot and 3000 pounds of fuel. The major structural element is a box-like tubular steel framework with landing gear "oleo" shock struts attached to the four corners. The propulsion system, including tankage and associated plumbing, is located inside the frame. A two-man pilot's compartment and electronic control equipment are centrally located on top of the frame. The propulsion system which is pressurized with gaseous nitrogen, uses a monopropellent of 90 percent hydrogen peroxide. The main motors, located near the bottom of the frame, produce a thrust that can be throttled from 6000 to 600 pounds. Twenty smaller rocket motors, each preflight adjustable over a range of thrust from 125 to 25 pounds, are distributed about the exterior of the vehicle frame to produce attitude control torques. The flight control system characteristics were adjusted to match as closely as possible those of the LLRV. A comparison of the control system characteristics for the two vehicles is presented in table I.

The controls and displays available to the pilot are shown in figure 2. Two pilots can be seated side by side in the modified helicopter cab. The flight instruments, roll-pitch angle indicator, yaw indicator, altimeter, rate of climb meter, and angular and linear rate meters, are located on the right side of a central display panel. The remaining gages monitor vehicle subsystems. The pilot flies the vehicle using a Lunar Module (LM) type three-axis attitude controller with his right hand and an LM type T-handle throttle control with his left hand.

Two available modes of operations were used in this training program. The first, referred to as the "live flight," mode is the normal operating mode in which the bridge crane is servoed to follow the vehicle's motions in response to its main engine thrust vector. The second, referred to as the simulation mode, does not use the main thrust engine. Instead, the lifting thrust is simulated by a cable tension which is commanded by an electrical signal generated as a function of throttle position. This tension is added to the normally commanded tension which is equal to five-sixths the weight of the vehicle. Horizontally, the vehicle is towed by the traveling crane which responds to electrical signals generated as functions of vehicle pitch and roll attitude. Since all the fuel is available for the attitude system, flight time is considerably increased compared to the live flight mode. Because the bridge crane has to develop a cable angle in order to accelerate the vehicle horizontally and because the support cables become pendulous there are some errors in horizontal vehicle response in this mode. However, the increased operational time makes this mode valuable for pilot indoctrination and familiarization.
TRAINING PROGRAM AND SCHEDULE

Training Schedule

The suggested training schedule (summarized in table II) was based on previous experience in checking out new research pilots and included a minimum of one "simulation flight" and six "live flights" for each astronaut. The schedule provided for the training of the astronauts in pairs to minimize the overall time required to complete the program. Descriptive photographs and written material describing the operation of the LLRF were provided the astronauts before their arrival for training.

Training Program

Flight training operations were preceeded by a short briefing on operational procedures and a "cockpit checkout." In the initial flight operations, one man flew the vehicle while the other observed from the copilot's seat. This procedure was followed until each astronaut was familiar with the operating procedures. For the remainder of the program the astronauts alternated, at their discretion, between flying the LLRF vehicle and a helicopter made available by the Flight Mechanics and Technology Division for general proficiency flying.

The first flight operation was performed in the simulation mode. This provides approximately seven minutes of lunar landing simulation flying. A significant additional amount of experience was gained through use of the attitude control system in maintaining the vehicle in a level attitude while positioning it before each run.

Sufficient fuel was available for up to eight slant trajectory landing maneuvers from altitudes of 50 to 100 feet combined with translations of up to 200 feet. The first maneuver in a flight was usually initiated at a 50-foot altitude in order to give the pilot maximum visual cues. Subsequent maneuvers were started at altitudes up to 100 feet at the pilot's choice.

Flights in the live mode of operation were started after one or two flights in the simulation mode. The standard maneuver task (defined as a straight-in approach) was used until the astronaut wished to vary the task. This maneuver, started from near hover condition at altitudes from 100 to 150 feet, required a combined descent and translation to a landing at a point about 200 feet down range. After landing, the vehicle was lifted under manual control of the bridge crane to an altitude of 50 to 150 feet depending on fuel remaining. After the pilot yawed the vehicle 180 degrees, a similar descent and translation maneuver was accomplished in the opposite direction. The pilot's task exercised pitch control and throttle control with roll and yaw used only to correct any vehicle drift in these axes. An average of five such basic flights (10 landings) were performed by each astronaut before the task was varied.
One variation in task, tried by each astronaut, involved a turnaround maneuver after the initial descent and translation. The vehicle was then translated in the opposite direction at 20 to 30 feet altitude and landed. This maneuver afforded the pilot an opportunity, during the turnaround, to more fully exercise roll and yaw control. A unique maneuver used once was the straight-in approach initiated and flown with the vehicle yawed 90° to the flight path. Since the pilot's seat is located on the right side of the vehicle, the pilot chose to initiate the translation with right roll to maximize his visibility. Normally all flights were performed using the rate command attitude control system; however, on one flight the direct or acceleration command mode was used.

RESULTS

The purpose in presenting flight training results is not to reveal individual performances but to illustrate what was achieved in the program. Trajectories of the live flights are presented in terms of range and altitude coordinates of the flight path. Additional information is tabulated to show total time required to land and maximum range and altitude velocities. The components of velocity (horizontal and rate of descent) at touchdown for each landing are presented in relation to the LM velocity touchdown boundary. This information is presented in figures 3 to 14 showing the trajectories first and the landing velocities second.

A summary of the astronauts' flights is presented in table III. The program of 60 flights was completed in 12 operational days with a maximum of 9 flights in one day. A minimum of two flights in a day was caused by a vehicle malfunction and subsequent weather conditions which forced cancellation of the day's operations. A single 10- to 11-hour shift of three engineers and 32 technicians supplied direct operational support for the program. Approximately 180,000 pounds of 90 percent H₂O₂ (3000 pounds per flight) was consumed during the program.

Observations on Training

A number of observations on performance of the astronauts during the training program are summarized in this section: (No attempt has been made to rate relative importance of the specific comments.)

1. All of the astronauts adapted quickly to flying the vehicle which has thrust-to-mass ratio only one-sixth of that which they are accustomed to flying. The operation of the main lifting thruster in the direct or acceleration command mode presented only minor difficulty. Throttle control obviously impaired flight performance in only one instance. This flight was impaired by a pilot induced oscillation (PIO) on the first live flight for one astronaut.

2. All of the astronauts relied heavily on out-of-the-window motion cues rather than the instrument displays in performing the flight maneuvers; however, several of the subjects found that supplemental use of the rate of climb meter provided an aid in height control.
3. Several astronauts commented, and the comments were verified by data analysis, that they initially misused the rate command capability of the attitude control system. This misuse was a tendency to operate in a pulse mode as in the acceleration or direct mode of control. That is, they would momentarily deflect the side-arm controller to develop a rate, then move the stick back to zero, and repeat the cycle until the attitude angle and the translational velocity desired was obtained. The pilots immediately recognized that this was wasteful of fuel.

4. Using visual, out-of-the-window motion cues, all astronauts recognized some difficulty in zeroing horizontal velocity before touchdown.

5. Pitch attitude control was the major attitude control task since it controlled the down-range or principal direction of translation. While this task was a major one, the large down-range distances involved allowed the pilot considerable latitude in his control of down-range velocities and positions. In contrast, roll control was a minor task since it controlled cross-range translations. Initially, however, the pilots had to devote some attention to roll control in order to prevent exceeding the narrow lateral limits of the flight envelope. Yaw control was of very little concern to the pilots during translation. Typically, the pilots allowed the yaw attitude to drift 15° to 20° during translation and landing.

CONCLUDING REMARKS

This report is a record of the astronaut training program's accomplishments. It is intended to help guide planning for future training. Since the ultimate value of the LLRF astronaut training program cannot be determined by the Langley Research Center personnel who conducted it, no attempt has been made in this paper to do so. However, from an intimate observer's point of view, it appeared that each astronaut gained some appreciation for the flying characteristics of a lunar-landing type vehicle. A proper estimate of the value of this program to the LLRV training program is left to the astronauts and other MSC personnel so engaged.
REFERENCES

