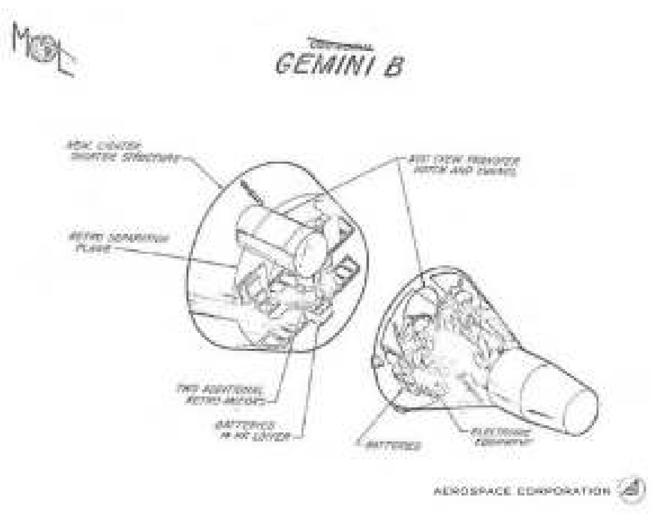
USAF Manned Orbiting Laboratory Early Flight Test on Titan IIIC-9
By Brian Etheridge

Introduction

The USAF Manned Orbiting Laboratory (MOL) Program was announced in December 1963 for the purpose of establishing the utility of manned space operations by the military; however, most observers understood that the USAF's primary, if not almost exclusive, emphasis would be on reconnaissance activities.


Artist's depiction of the orbiting MOL. *Credit: National Reconnaissance Office (NRO)*

Douglas Aircraft was selected to build the MOL, using a modified Gemini (Gemini B) capsule to provide access for the two-person MOL crew. Unlike the original Gemini capsules as launched on modified Titan II's, Gemini B had modifications to allow the astronauts movement to and from the MOL while on orbit. Accordingly, early qualification of the Gemini B Heat Shield and its new egress hatch was a high priority to ensure crew safety.



Martin Marietta was chosen to provide the MOL/Gemini B launch vehicle, a modified version of the Titan IIIC called Titan IIIM, which would have more powerful Solid Rocket Motors (SRMs) to accommodate the MOL's weight requirements and to provide an upgraded Flight Control System that could be Man-Rated.

The MOL's 10 ft. diameter cylinder would match that of the Titan's core, and would weigh in at about 32,000 lbs. distributed over its 72 ft. length. Adding the Gemini B to the top of the 'stack' increased the overall payload length to about 83 ft. with a combined weight of about 36,400 lbs. This combination of length and weight represented a payload challenge unlike anything previously launched by Titan.

Titan IIIC-9 with Simulated MOL & Gemini B at VIB Rollout. Credit USAF

At the beginning of the MOL Program, flight planners agreed that an Early Flight Test (EFT) was necessary to minimize concerns about the new Gemini B Heat Shield/Access Hatch and to establish the integrity of the Titan core launch vehicle before committing resources to a full-scale development program. Since the Titan IIIM existed only on paper, it was decided to create a MOL mockup from an available Stage 1 taken from the Titan II ICBM Program, and launch this structure with a Gemini B on an existing flight proven Titan IIIC. Although the diameter of the MOL Mockup was identical to the MOL's diameter, at only 40 ft. long, it was little more than half the planned MOL's length and not nearly as heavy. However, this Titan II Stage 1 was immediately available and considered fully adequate to support qualification of the new Gemini B Heat Shield. Secondary mission objectives included validating the core structural integrity and the Flight Control System of an existing Titan IIIC as a 'stepping stone' to the Titan IIIM.

The Gemini B was mated to the forward end of the MOL Mockup, and several smaller satellites and experiments were installed inside the MOL mockup to utilize available 'free rides', due to excess booster lift capacity. Thus, the primary objectives of the MOL/HSQ Mission focused on qualifying the Gemini B Heat Shield; however, validating the Titan core's ability to handle such a lengthy and heavy forward structure was also considered important.

MOL/HSQ Mission Profile

The Titan IIIC-9 (MOL/HSQ) Mission began just before 9 am EST on November 11, 1966 with a perfect Lift-Off from Launch Complex 40 of the USAF Eastern Test Range at Cape Canaveral, Florida. Performance of Stage 0, I, II, and 1st Burn of the Stage III (Transtage) main engines were all within predicted limits, resulting in a vehicle altitude of about 100 miles. Of particular interest was how well the Titan Stage 0 Load Relief Autopilot handled the effects of Aerodynamic Pressure with such a long structure. The Autopilot performed perfectly and kept aerodynamic loads well within acceptable levels.

Launch of Titan IIIC-9 with MOL/HSQ Payload November 11, 1966

Unlike most Titan missions, the Transtage 1st Main Engine Burn (1st Burn) left the remaining vehicle configuration pitched down toward the earth to allow the Gemini B/Heat Shield test to proceed with the proper reentry angle. Less than 30 seconds after 1st Burn shutdown, while the Transtage Attitude Control System (ACS) maintained the proper attitude, the Gemini B was separated successfully from the MOL Mockup.

Three forward thrusting retro rockets had been attached to the 'up' side (off target) of the vehicle on the forward end of the MOL Mockup, and two additional forward thrusting retro rockets were attached similarly to the 'down' side (on target), shown as item 15 in the nearby General Arrangement diagram. All five of these rockets were simultaneously fired at Gemini B separation to provide adequate clearance from the Gemini B before pitching the vehicle up in preparation for Transtage Main Engine 2nd Burn. In addition to providing separation, the asymmetric retro rocket arrangement was intended to impart a 2 deg/sec pitch up motion to the vehicle to conserve ACS propellant for the remainder of the mission. The ACS then stabilized the vehicle in the proper pitch up position allowing 2nd Burn to begin. At the end of 2nd Burn, the vehicle was in an elliptical orbit with apogee of 165 nautical miles. Later, 3rd Burn circularized the orbit at the apogee altitude.

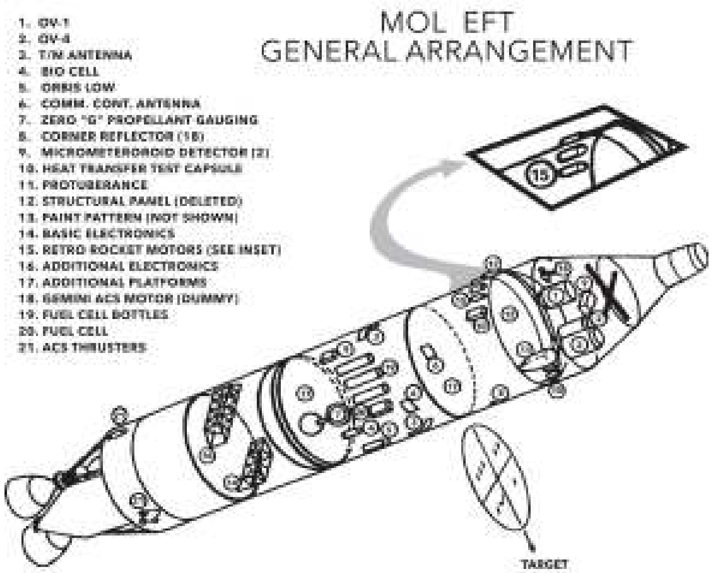
The ACS then executed a series of maneuvers in support of the 'free rider' satellites to be ejected into orbit. After all of the satellites were ejected, the mission called for four more orbits to support the 'free rider' experiments that remained onboard the MOL mockup while the ACS provided 'station keeping' services, i.e., keeping the Target position always pointing down. However, the ACS ran out of propellant during the 4th orbit before the end of the planned mission. Fortunately, all Primary and Secondary Mission Objectives were achieved before ACS propellant depletion.

Discussion & Analysis

Why did the ACS run out of propellent and cause an early end to the mission? Analysis of the flight telemetry data quickly showed where the first problem occurred. Just after the Gemini B separation, the retro rockets failed to cause the expected 2 deg./sec. upward pitch rate; in fact, a pitch down rate of ½ deg./sec. was observed! The ACS compensated for this, but in so doing used too much propellant. So, what caused the retro maneuver to rotate in the opposite direction?

As mentioned previously, this mission had by far the longest payload Titan had ever flown. The long payload with its distributed weight caused the longitudinal center of gravity (CG) of the entire structure to move forward well beyond the normal CG position on previous Transtage missions. Even with the forward CG, the position of the retro rockets on the front end of the MOL Mockup was still about 30 ft. forward of the CG.

After considerable post-flight analysis, the answer became inescapable; the retro rockets generated an expanding thrust plume that impinged on the forward end of the MOL Mockup, providing an unexpected force perpendicular to the vehicle centerline, and in opposition to the intended effect of the retro rocket thrust. The rated thrust of the all of the retro rockets was 500 lbs.; therefore, the predicted torque (force x moment arm) of the extra top side retro rocket was expected to be about 500 lbs. x 5 ft. = 2,500 ft. lbs. The unexpected impingement torque had to be larger and in the opposite direction from that of the intended retro rocket torque to cause a pitch down motion. The Author's analysis indicates that the unexpected impingement torque needed to be about 3,225 ft. lbs. to cancel all of the predicted retro rocket torque and provide the actual downward pitch rate of ½ deg./sec. Dividing the impingement torque by its 30 ft. moment arm indicates that the implied impingement force was between 105 lbs. and 110 lbs. Note that the impingement effects of the other four symmetrically positioned rockets would have cancelled each other without affecting vehicle rotation.



However, to this day, there remain uncertainties about the intended MOL Mockup retro maneuver. With such a significant impingement action, it is likely that the rated retro rocket thrust did not fully translate into the desired pitch up torque. Thrust plume friction together with the energy from the plume particles/molecules was significant enough to produce a counterproductive torque. If some of the retro rocket's energy was 'consumed' in applying the impingement force, the actual useful retro rocket thrust should be less that the 500 lb. rating. If less than full retro rocket thrust contributed to the intended pitch up maneuver, then the implied impingement force would also be reduced.

As it turns out, all we really know from flight data is that the impingement torque had to be greater than the actual retro rocket torque to result in the downward pitch rate of the MOL Mockup vehicle. Additionally, with such significant retro rocket thrust plumes acting on the MOL Mockup, some erosion of the vehicle's alloy skin would not be surprising. Of course, this too will remain something of a mystery since no applicable flight measurements were taken, and no post-flight retro rocket tests were conducted.

Yet another problem showed up in the flight telemetry data that added to the increased ACS propellant usage. ACS thruster performance was found to be degraded for the same reason: thrust plume impingement. The longitudinal CG of previous Transtage missions had always been within 2 ft. to 3 ft. of the ACS thruster location, shown as item 21 in the General Arrangement diagram. Therefore, any effects of ACS thruster plume impingement were not obvious. However, on this Transtage mission segment the CG was over 13 ft. forward from the CG location of previous missions, and caused significantly reduced ACS thruster torque (known as control authority), but not significant enough to produce a net torque in the opposite direction as with the retro rocket. However, planned ACS maneuvers would now require additional propellant to accomplish. Also, the excessive ACS burn time caused thruster propellent valve damage due to 'heat soak back'. This further reduced thruster performance causing yet more rapid propellant usage to achieve the required maneuvers.

The challenging MOL/HSQ Mission taught much to the relatively new Titan III Team, which included the author. Some say that 'experience is the best teacher'; others say that 'experience is the teacher of last resort'. In any event, the 'lessons learned' from this mission would prove invaluable on Titan III missions to come, e.g., the original bipropellant ACS was replaced with a less costly and more robust monopropellant ACS system. Fortunately for Martin Marietta and the Titan team, all of this valuable knowledge and experience was gained, while still fully achieving all Primary and Secondary MOL/HSQ Mission Objectives. (For more detail on the MOL/HSQ flight results and the fate of the 'free riders', see the now declassified post-flight report at: http://www.dtic.mil/dtic/tr/fulltext/u2/378020.pdf

Epilog

Of course, the actual MOL and Titan IIIM never made it from the drawing board all the way to the launch pad; before having any additional test flights, the MOL Program was terminated in 1969. The Nixon Administration decided that budget pressures of the Vietnam War, funding the previous Administration's new Great Society Programs, and escalating MOL Program cost estimates, simply did not warrant both the USAF (MOL) and NASA (Skylab) continuing to pursue parallel manned space programs. Hence, after considerable Administration infighting, the decision was made that the USAF would rely solely on satellites to satisfy their reconnaissance requirements and NASA would have the 'charter' for all manned space activities. MOL and Titan IIIM became just a distant but still exciting memory.