The N5G Inertial Navigation System in the B-52 Hound DogMissile
A System Overview

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Background – Throughout the duration of the Cold War, the B-52 Bomber was an essential element of America's triumverate strategic arsenal – air, sea and land. In conjunction with Polaris submarines traversing the ocean depths and Minuteman missiles deep in silos under the ground, there were always B-52s high in the air ready to launch missiles at a signal from Headquarters.

The strategic weapon carried by the B-52 was the GAM-77 Hound Dog missile. Although the B-52 traditionally carried conventional ordnance in its bomb-bay, the strategic Hound Dog was a self-propelled, maneuverable, self-guided, air-to-ground standoff missile, mounted one under each wing of the B-52. The mission of the Hound Dog-equipped B-52s was to aid in the strategic offensive through destruction of enemy targets without exposing the aircrew or the B-52 to enemy defenses.

The Hound Dog missile was guided to its target by a highly-accurate on-board Inertial Navigation System (INS): the N5G all-attitude stable platform manufactured by the Autonetics Division of North American Aviation. The N5G was an outgrowth of the INS intended for the Navajo missile.

Guidance by the use of inertial navigation was judged by the military to be a critical necessity in America's waging of strategic warfare. The inertial navigation system was, and still is, the only navigation means which is totally self-contained, and independent of external inputs. Thus, it cannot be jammed, spoofed, or affected by anything the enemy may seek to do. The U.S. had invested heavily in INS development in the early years of the Cold War, and the success of this technology proved extremely advantageous.

The GAM-77 program go-ahead was given in 1958 and the system became operational in the late 1959. Five B-52s per squadron on alert status were equipped with two GAM-77s each, and rotated through a 14-day alert period.

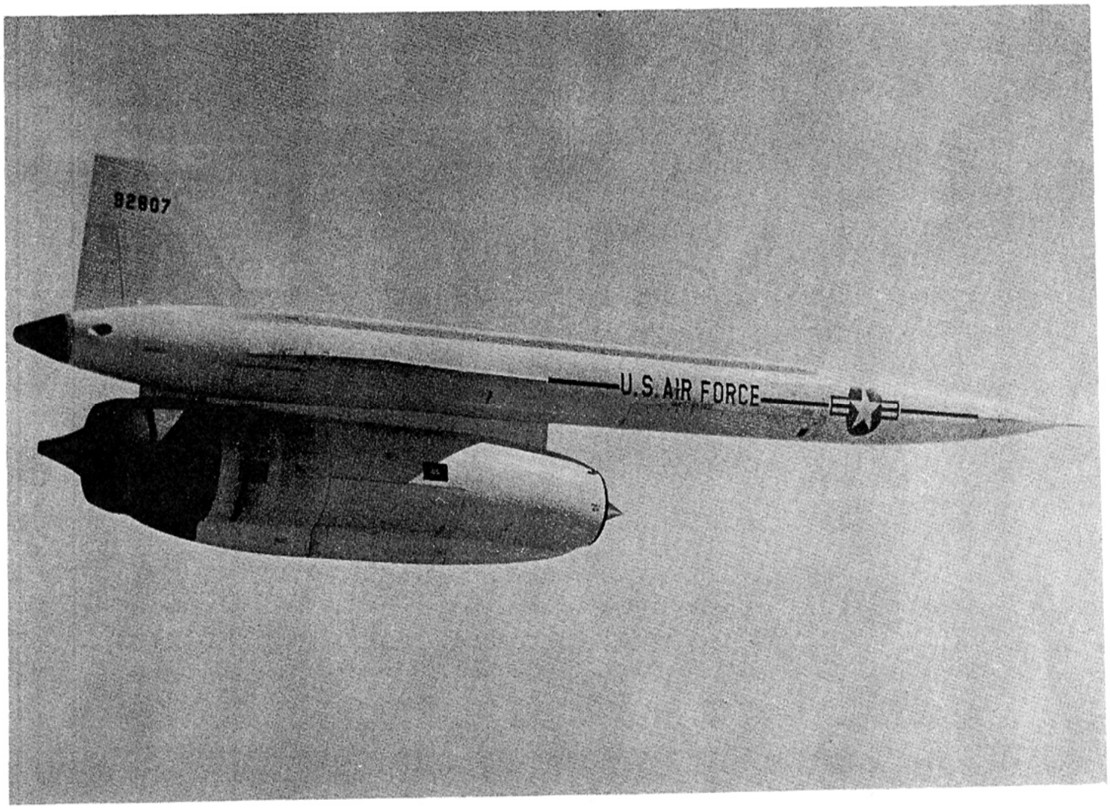

Fig. 1, GAM-77 Hound Dog Missile

GAM-77 Hound Dog Missile. - (See Fig. 1.) Each of the two GAM-77s is mounted on a pylon under a wing, inboard of the inner engine. The missile is powered by a J-52 turbojet, pod-mounted engine, mounted below the missile body. The pylon attaching the missile to the wing contains the astrotracker and stays with the B-52 after launch separation.

Missile Navigation and Control

Guidance System - The purpose of the missile guidance system is to continuously calculate the position of the missile and thereby provide control signals to the missile's flight control system for guidance of the missle to its intended target.

The astrotracker and the INS are two subsystems which make up the guidance system, and are interconnected before missle separation from the aircraft pylon. The astrotracker (located in the pylon) searches for and then tracks the manually selected sun or star for heading alignment of the INS during captive flight. The purpose of the astrotracker is to provide the initial azimuth alignment reference for the INS. This is accomplished by searching for and tracking a selected star (night-time, or the sun (day-time). (See figure 2)

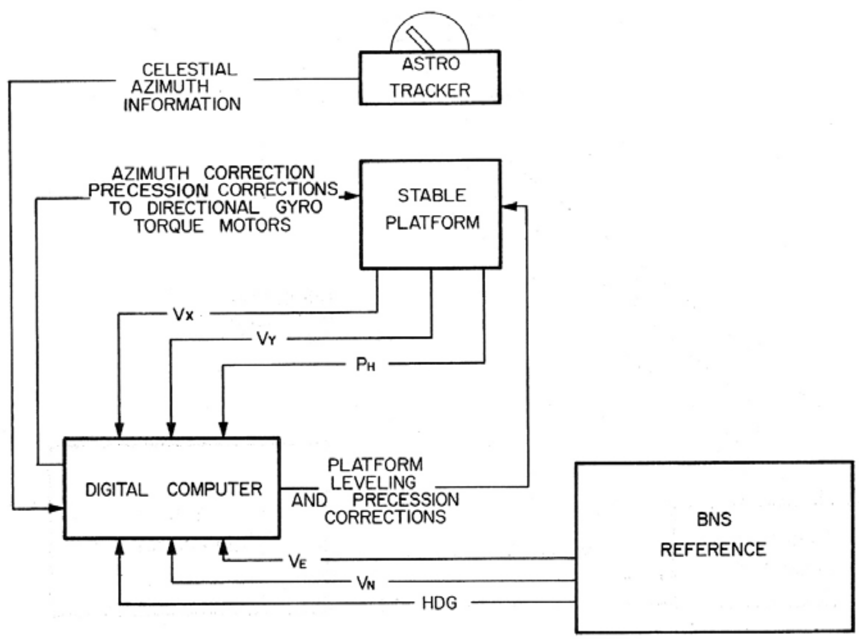

Figure 2 - Typical Inertial Guidance System (Showing Astrotracker References)

After initial alignment via signals received from the B-52, the missile can be launched, and its guidance system will operate as a pure, self-directed inertial system, with the INS providing the necessary steering and control signals required to guide the missile to the designated target.

The Hound Dog missile is equipped with an N5G Inertial Navigation System (INS). The INS features a triad of three very accurate accelerometers aligned along the earth's coordinate axes (north-south and east-west, relative to True North) and maintained in this orientation by the gyroscopes in the N5G stable platform in which they are housed. After activation the outputs of the accelerometers are integrated once to obtain the change in velocity (V = at) along each axis. The resultant velocities are then integrated to obtain the distance travelled (d = vt) along each axis. The N5G INS thereby provides data on the missile's acceleration, velocity and position to the on-board guidance, control, arming and fuzing systems. This N5G stable platform is physically located at the approximate center of gravity of the missile. When the missile is attached to the pylon, the platform is mounted directly underneath the pylon-mounted astrotracker. (See Fig. 2-A)

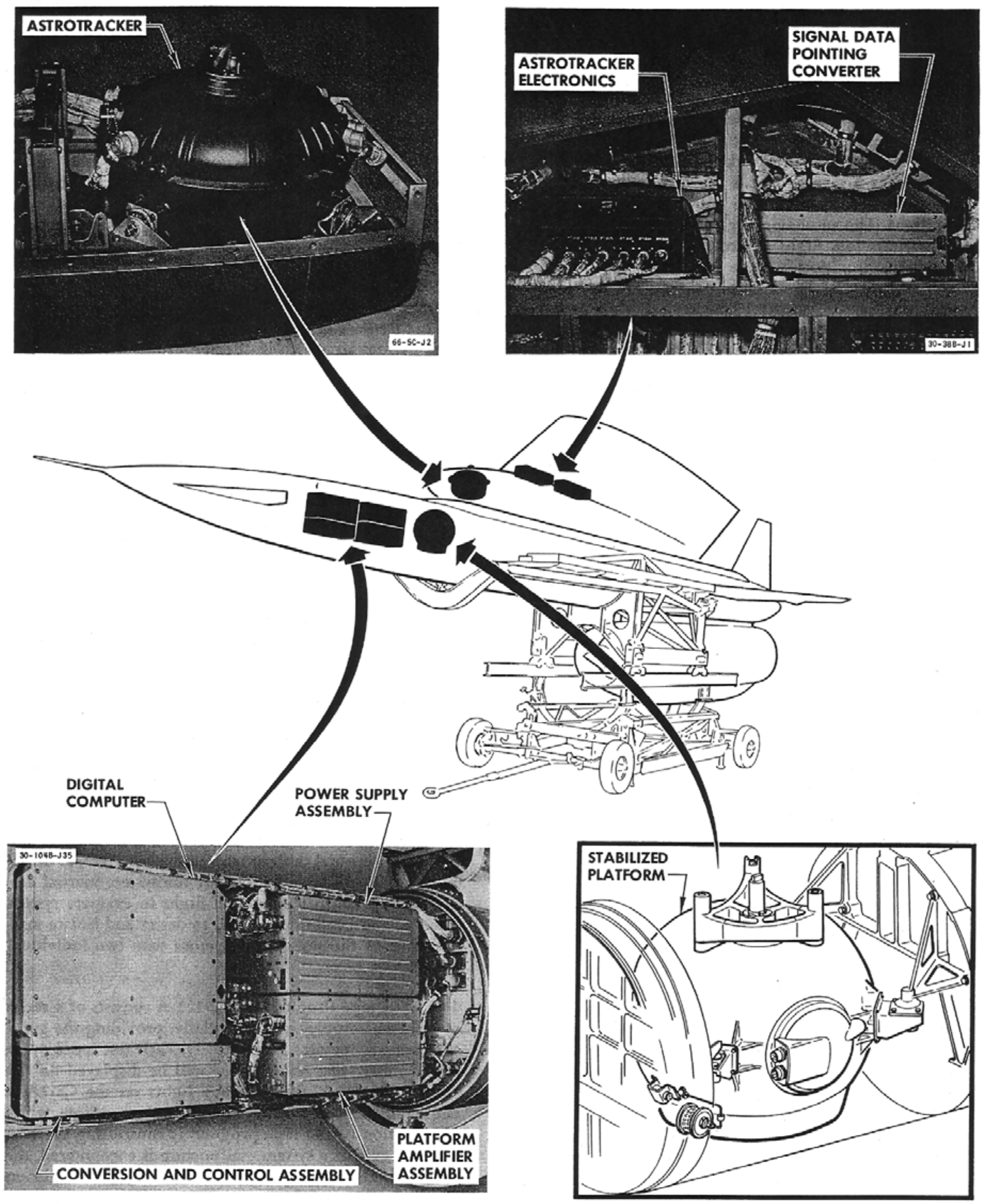

Figure 2-A Guidance System

The leveling operation for the N5G requires the comparison of north-oriented velocities from the B-52 nav system with the missile's platform-oriented inertial values; missile position, maintained by the computer in terms of platform x, y, and z factors, are related to a true-north-oriented earth.

The primary means for azimuth alignment employs celestial observations made by the pylon-installed astrotracker. Celestial bodies are used as an azimuth reference from which to measure the azimuth orientation of the stable platform (See Fig. 3).

Alignment accuracy of the guidance system depends upon accurate initial inputs from the navigator's data panels of the Greenwich Hour Angle, Sidereal Hour Angle, and Declination for the selected celestial body.

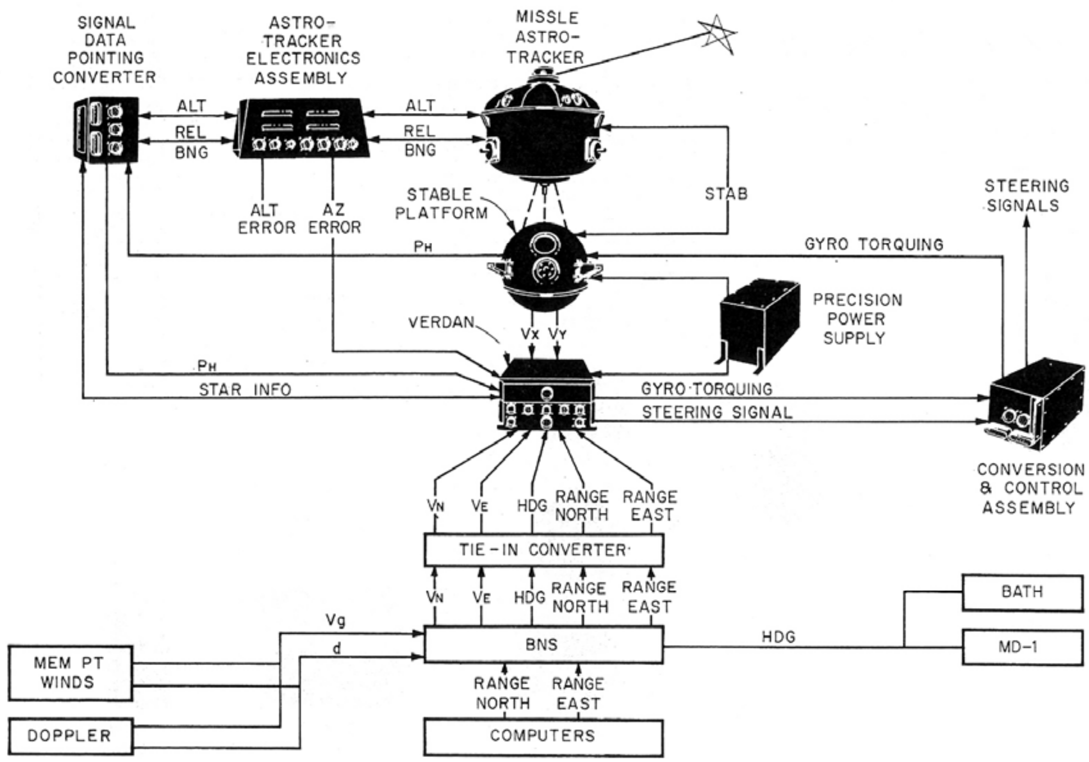

Figure 3 - Azimuth Alinement

B-52 Navigation and Tie-in Signals to the Missile

The primary heading reference in the B-52 is its AJN-8 Heading and Vertical Reference System, which incorporates a stable platform and provides accurate True Heading, the basic source for which is the MD-1 astrocompass. Ground speed values from the Doppler are required for optimum platform operation. To determine the aircraft ground speed, the Doppler reflects a radar signal off the terrain below the aircraft.

In magnetic-slaved operation, the N-1 compass provides magnetic heading (referenced to the flux valve) and feeds it to the AJA-1 True Heading converter, where magnetic variation is calculated, based on the aircraft's position, and the resulting True Heading is sent down to the astrotracker in the missile pylon. Corrections for earth's rate, as well as the ongoing travel of the aircraft over the earth's surface, are continuously applied to the N-1 directional to maintain it's orthogonality to the earth's surface.

The secondary heading reference for the B-52's Bomb Nav System is the J-4 compass system. In magnetic mode, the same flux valve (magnetic-north sensor) is used with the AJN-8 platform and the N-1 and J-4 directional gyro systems.

The outputs of the B-52's Bomb-Nav System are analog and are fed to an A/D converter for inputting into the missile's Verdan digital computer,

At any time prior to missile release, target coordinates can be inserted or changed and either straight-line flight or a pre-programmed maneuver can be selected.

Missile Flight Control System (FCS) –

The GAM-77 flight control system is a modified autopilot, consisting of inertial instruments, the Verdan digital computer, an air data computer, a radar, a terrain avoidance computer, and control surfaces driven by actuators. The system's electro-hydraulic servo system utilizes guidance system commands, pitot-static signals, rate gyros, and verical reference gyro signals to provide automatic stabilization and control of the missile through all phases of its flight - from time of launch until detonation of the warhead at the target.

Movement about the three axes is controlled by aerodynamic control surfaces. Control of pitch movement is provided by the elevators, roll by the ailerons, and yaw by the rudder, in a canard configuration. These surfaces, powered by the hydraulic actuators, are used to change the flight attitude of the missile. (See Fig 4)

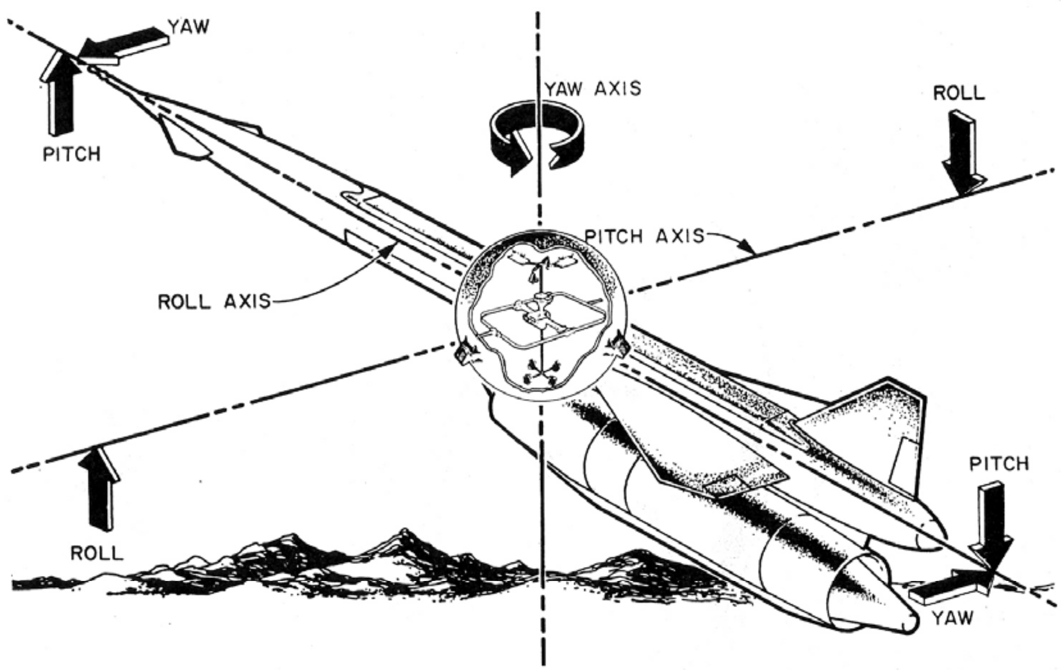

Figure 4 - Location of Stable Platform

During missile cruise, the FCS receives lateral (steering) signals from the guidance system to physically steer the missile. Any undesirable deviation from straight and level flight will be sensed by the vertical gyro, the rate gyro, and/or the lateral accelerometer. After launch, the missile's guidance and control systems are totally independent and irrevocable.

Operation After Launch

This inertial navigation system continuously calculates the position of the missile with reference to its initial position by measuring missile accelerations from the time it is placed in operation during captive flight. The missile's on-board Verdan digital computer transmits steering signals to the flight control system.

The GAM-77 navigation and control system is capable of executing any of six flight-profile modes – inputted by the B-52 navigator prior to the missile launch – to optimally guide the missile to its target. A typical profile is the Hi-Hi-Lo-HI profile (see Figure 5). Most of these profiles culminate in a Dive mode, whereby the missile is directed to a straight-in vertical dive to the target.

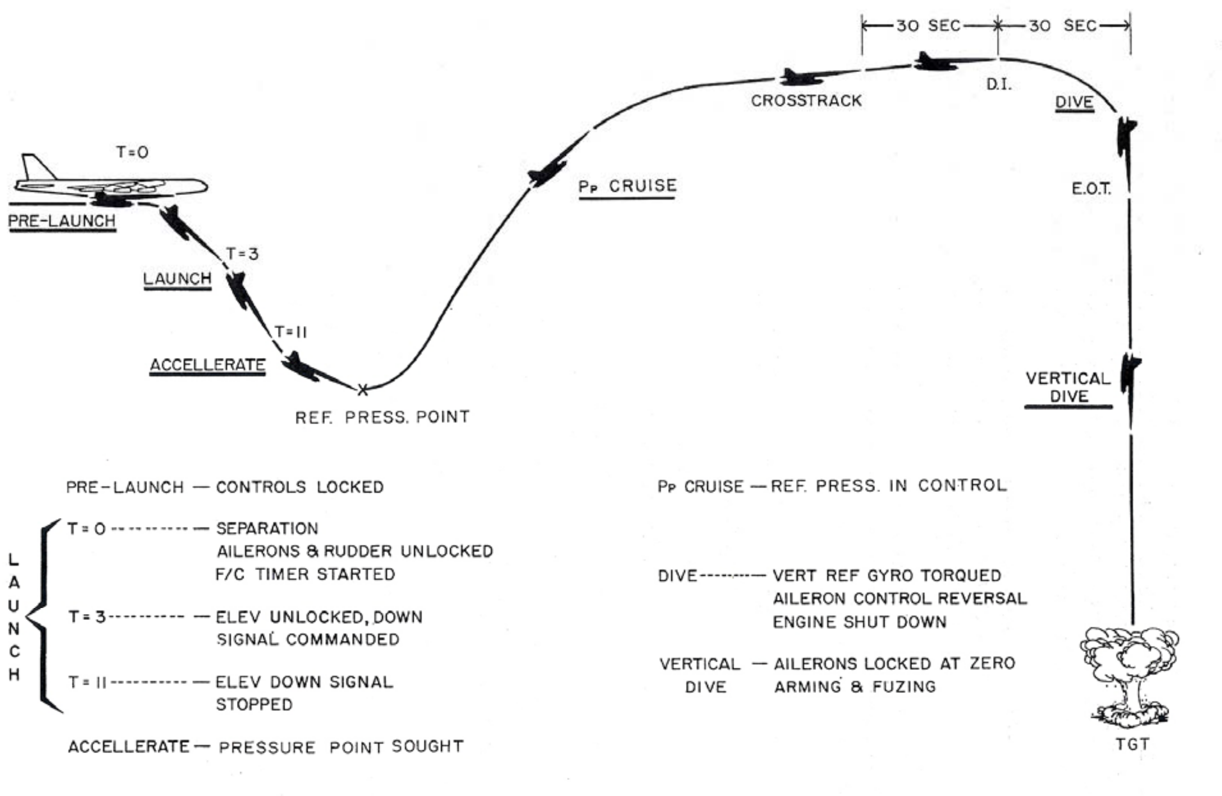

Figure 5 - HI-HI, LO-HI

During the initial portion of free flight, missile speed, altitude, and stability in the three axes are controlled by the flight control system. When the cruise mode is reached, control in the lateral plane is accomplished by means of bank angle commands generated by the guidance system. High or low longitudinal cruise control can be selected for the missile prior to launch.

Low-level Cruise - When the signals applied as pitch command, the missile levels off and maintains the pre-selected altitude until the guidance system detonates the warhead over the target. There is no dive or verical mode in low-level flight.

High-level Cruise - In this mode, the missile is commanded to seek the referenced pitot pressure, and descends or ascends (depending on launch conditions). This mode continues until terminated by a Dive command signal from the INS.

Dive - Started by the dive-initate signal from the INS approximately 30 seconds from target; the engine is shut down and the vertical gyro torqued at a constant rate to allow the airframe to nose over to the straight-in dive attitude.

SUMMARY – The GAM-77 Hound Dog missile carried by and launched from the B-52 strategic bomber, is considered to be one of the earliest, and most successful, applications of Inertial Navigation technology. It was a monumental achievement, not only in how rapidly it was designed, developed and operationally deployed, but for the message of technical competence and superiority it broadcast to the world.

The B-52 strategic bomber, armed with the GAM-77 Hound Dog, was a mainstay of America's nuclear arsenal from 1959 until 1976, when the Gam-77 was phased out and replaced by the SRAM Missile, and later the Air-Launched Cruise Missile.

References:

1. Strategic Air Command Traning Manual, SACM 50-11 "AGM-28 A/B Operational Manual" 30 August 1965, issued by HQ-SAC

2. Strategic Air Command Traning Manual, SACM 55-10 "Combat Training and Navigation Tactical Procedures" 23 July 1962, issued by HQ-SAC

3. Tech. Order 21-GAM77-2-1 Maintenance and Operation Data

Legacy –
An actual Gam-77 Hound Dog missile, removed from its B-52 supporting pylon, has been painstakingly restored by museum volunteer staff, and is on full public display at the Travis Air Museum, Fairfield, CA (off Interstate 80, between San Francisco and Sacramento). An N5G inertial navigation system, fitted with a plastic viewing cover, is also on display alongside the missile. See Photos.