DELTA LAUNCH VEHICLE INERTIAL GUIDANCE SYSTEM (DIGS)

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The Delta launch vehicle inertial guidance system (DIGS) which has been under development for several years, has now been successfully demonstrated in the launching of Deltas number 89, 90, and 91. This system is one of the improvements made by the Delta Project Office to increase vehicle performance, flexibility, and reliability in order to meet the launch objectives of the 1970s. The decision to convert from the radio guidance system previously used by Delta to a pure inertial strap-down system, was heavily influenced by the advances made in inertial guidance technology in recent years, and the inherent advantages associated with the use of an inertial system. Advantages associated with the use of DIGS in the Delta program are as follows:

- The extensive field support operation required by the radio guidance system can be eliminated, which will ultimately result in a reduced overall program cost
- Spacecraft injection accuracy is improved by at least a factor of two for two-stage missions
- Vehicle mission flexibility is improved through the use of a self-contained guidance system in that boost profile and attitude constraints for antenna pointing are eliminated
- The vehicle ground check-out is simplified because many functions formerly performed by individual hardware devices are performed by the DIGS computer. Devices whose function the guidance computer now performs are: independent first and second stage autopilots, sequencer, programmer, velocity cut-off system, and radio guidance system

The DIGS consists of both hardware and software elements. The hardware is made up of an inertial measurement unit (IMU) and an airborne computer. The IMU consists of three strap-down integrating gyros and three strap-down linear accelerometers, all of which have pulse torque rebalance loops. Data from 20 sensor torque loop cycles are summed and transferred to a computer-holding-register where they are used for controls and guidance computations. The computer utilizes a 24-bit word length and direct readout memory. It has available input discrete sense lines, output discrete signals, digital-to-analog converted signals, and a software controlled priority interrupt system. The software performs both preflight and flight functions. In the preflight mode it performs system alignment, engine slew checks, and a dynamic closed loop simulated flight test. In the flight mode the software performs open-loop sequencing, autopilot control, navigation, closed-loop guidance, and PCM data formatting.

The DIGS has been successfully flown on the last three Delta missions (ERTS-1, IMP-H, and ITOS-D). Extensive data analyses have been completed for the ERTS-1 and IMP-H flights. In examining the flight data, no events were observed that could not be explained. All flights have used the same flight program even though the mission profiles and vehicle configurations were significantly different. For example, the ERTS-1 launch used a two-stage vehicle with nine strap-on solid propellant thrust augmentors to achieve a near polar sun synchronous orbit. The IMP-H launch used a three-stage vehicle, six solid propellant thrust augmentors, and a lengthened first stage to achieve a near-escape orbit. The ITOS-D spacecraft was injected into an orbit similar to the ERTS-1 and had the same vehicle configuration except that it used three thrust augmentors instead of nine.

Typical injection accuracies are shown in the following table for the ERTS-1 and IMP-H missions, respectively. The table shows the apogee, perigee, and inclination deviation from nominal for selected second-stage burn-out points and the expected three-sigma dispersions. The significance of the points chosen for discussion are as follows: For ERTS-1 the second-stage burn-out (SECO-2) is the point at which the spacecraft is injected into orbit; IMP-H had a single second-stage burn and the point that was chosen as the third stage is unguided and predominates as a source of error.

Table 1
Typical DIGS Flight Performance Data

Delta 89 (ERTS-A) At SECO-2			
	Error	3-Sigma	Units
Apogee	2.213	- 5.942, +6.252	km
Perigee	-2.958	-12.87, +12.214	km
Inclination	-0.016	±0.044	degrees
Delta 90 (IMP-H) At SECO-2			
	Error	3-Sigma	Units
Apogee	6.714	-7.948, + 8.604	km
Perigee	1.551	-3.481, + 3.263	km
Inclination	0.005	±0.011	degrees

It is seen in examining the data that the orbit errors observed are of the order of one-sigma for ERTS-1 and two-sigma for IMP-H. The dispersions observed are of the magnitude of the errors expected from thrust tailoff and navigation uncertainties.

In conclusion, the Delta Inertial Guidance System, part of the Delta launch vehicle improvement effort, has become a reality. The system has been flown on three launches and was found to perform as expected for a variety of mission profiles and vehicle configurations.