SUMMARY of APL SATELLITES

This year marks the tenth anniversary of the Applied Physics Laboratory's satellite program. In 1958 W. H. Guier and G. C. Weiffenbach of the Laboratory staff used the doppler shift of the radio signal from Sputnik I and knowledge of their geographical position to calculate that satellite's orbit parameters, marking the entry of APL into satellite technology. Since that time APL has fabricated 36 satellites and has seen the successful launching of 29 of them. These satellites have advanced the science of geodesy and given the U.S. Navy an all-weather world-wide navigation system.[1]

This article briefly surveys the satellites made at APL over the past decade and enumerates their more noteworthy achievements.

In recognition of the importance of space science, the Laboratory formally organized the Space Development Division under the direction of R. B. Kershner late in 1959; this was changed to a Department in 1966. One of the original assignments of the Space Development Division was to design and construct satellites as part of the satellite navigation program proposed by F. T. McClure. Dr. McClure, noting the results of Drs. Guier and Weiffenbach, suggested their application to the converse problem: knowing the orbit parameters of a satellite accurately, and observing the doppler shift of a signal from the satellite, derive the position of the observer.*

Drawing on its technical staff assembled for the Navy Surface-to-Air Missile Program, APL set about building its first satellite. This satellite, appropriately labeled Transit 1A, was launched from Cape Canaveral (later renamed Cape Kennedy), Florida, on September 17, 1959. The 270-pound satellite flew only a suborbital trajectory because the third stage of its Thor-Able vehicle failed to ignite; but all 1A systems operated as planned during the 24-minute flight, and enough data were gathered to indicate the practicality of the satellite doppler tracking technique.

The table below categorizes the primary missions of APL artificial Earth satellites and gives the numbers of satellites launched for each mission:

Primary Mission	*Number of Satellites Launched*
Navigation/Geodesy	22
Geodesy	4
Ionospheric Research	3
Orbital Environment (Science/Engineering)	3
Orbital Dynamics (Science/Engineering)	2
Particles and Fields and Ultraviolet Astronomy	2

Figure 1 groups the 36 satellites built at APL by the year in which they were launched. It also indicates the satellite profile and the mission success.

Figure 2 presents the operational status history of the satellites fabricated at APL. Of the 29 satellites that attained orbit, 27 have met their principal objectives. A few items on Fig. 2 are worth highlighting. The longest operational life of any APL satellite is that of Transit 4A; in fact, this satellite has had the longest operating life of any satellite ever launched by the United States. Launched on June 29, 1961, it is still transmitting. Surely the oddest in-flight behavior of any of APL's satellites is that of Transit 4B. It was launched in November 1961; on August 2, 1962 the satellite ceased transmitting. Then on March 23, 1967, after nearly five years of silence, a Navy Tracking station reported signals at 150 MHz from an unidentified satellite that was later confirmed to be Transit 4B. Since then signals have been received

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[1]R.B. Kershner, "Present State of Navigation by Doppler Measurement from Near Earth Satellites," *APL Technical Digest* **5**, 2, Nov.-Dec. 1965, 2-9.

*For this conception Dr. McClure, now Associate Director of the Laboratory, was presented the Invention Award of the National Aeronautics and Space Administration on January 17, 1961.

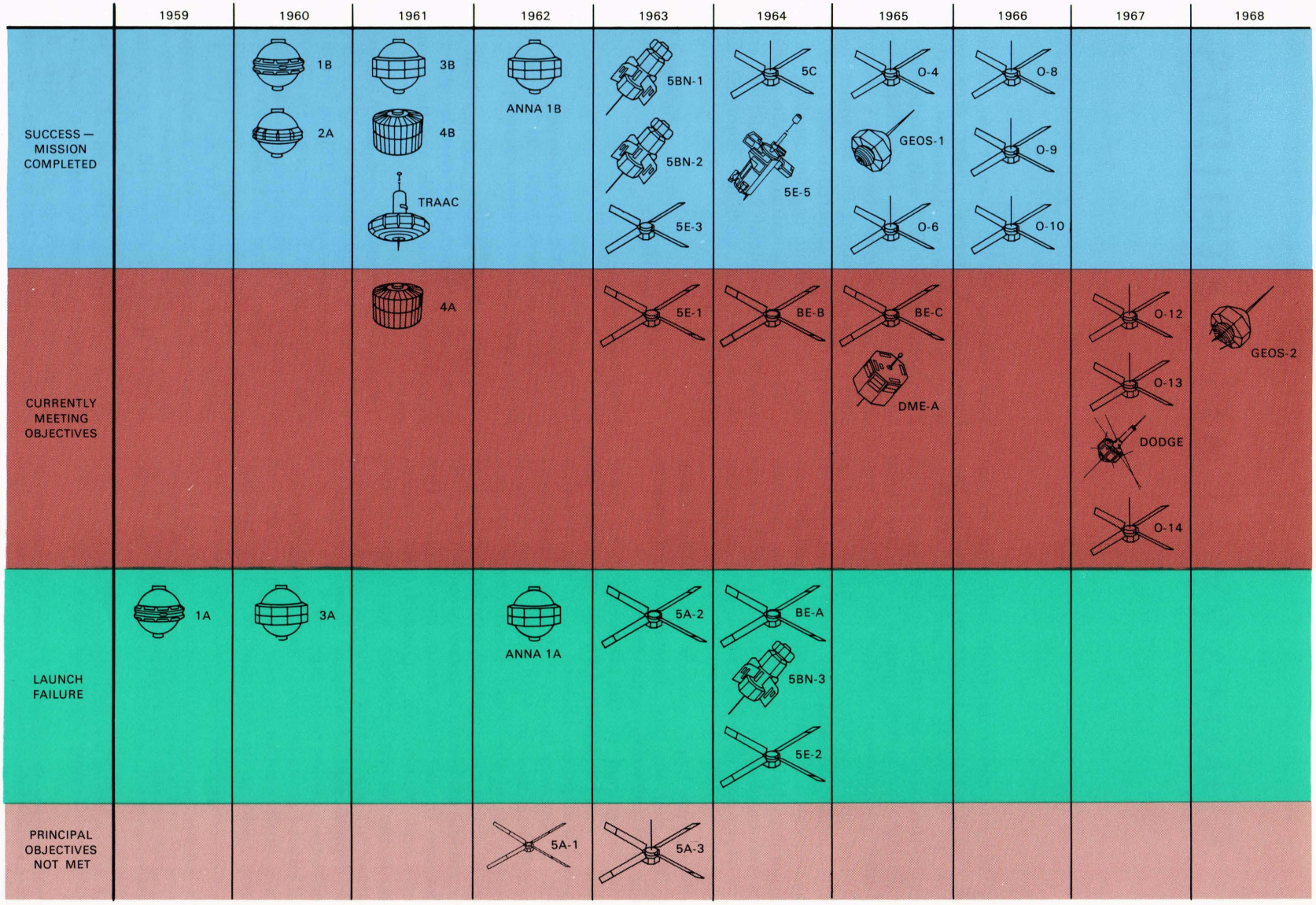

Fig. 1 — APL Satellite Profiles Showing Degree of Success and Arranged by Year of Launching.

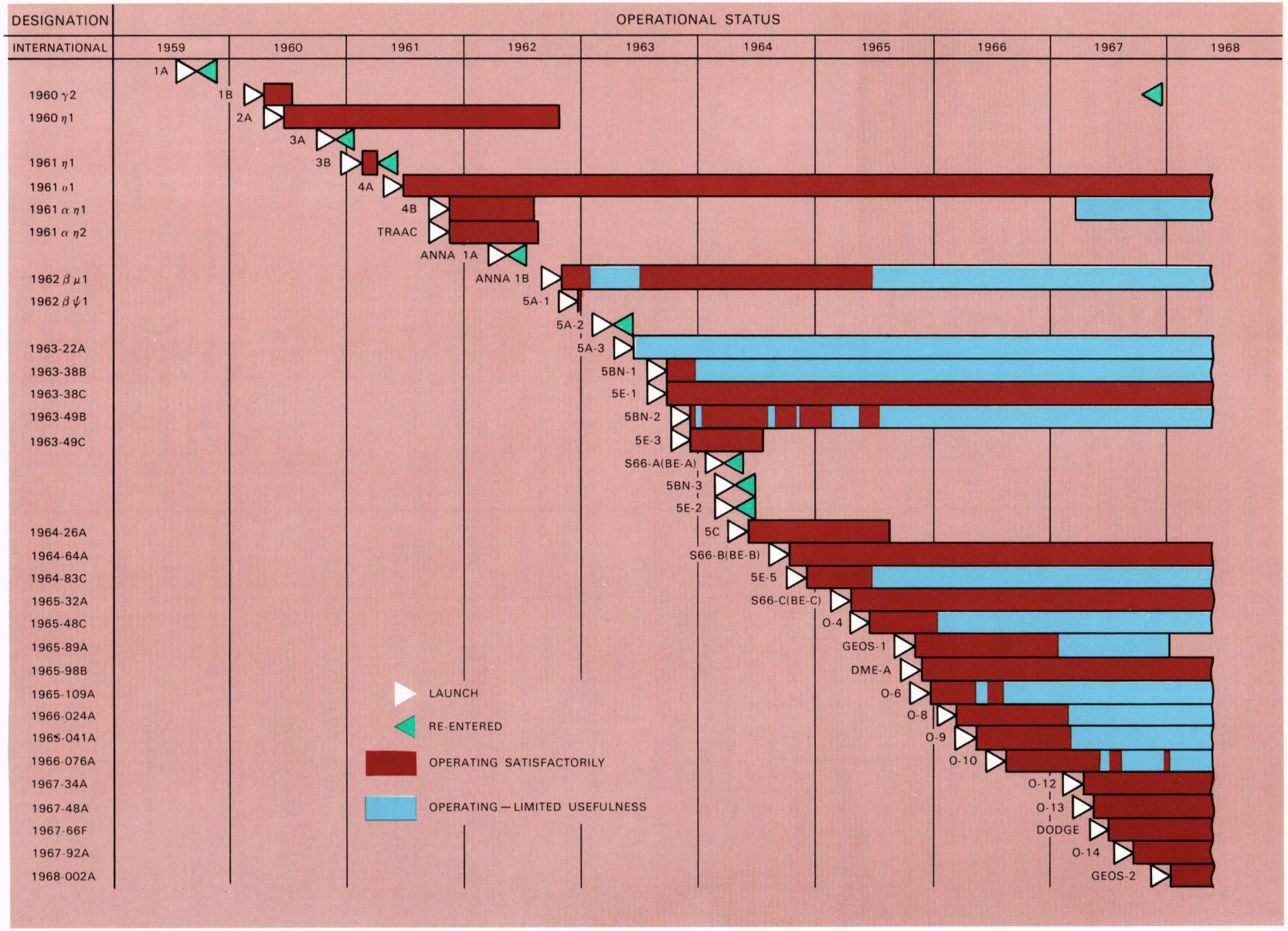

Fig. 2 — Operational Status History of the 36 Satellites Fabricated at APL.

from all four doppler channels on 4B. Signals are obtained when the satellite is in full sun orbits.

The first five satellites built at APL had essentially the same external configuration—a sphere with a belt about the equator on which were placed the solar cells. The antennas were painted onto the body of the satellite in logarithmic spirals. A similar configuration was used for the ANNA 1A and 1B satellites.

After these five satellites, APL satellite engineers fabricated drum-shaped and doorknob-shaped configurations before striking the configuration that would come to be characteristic of APL navigation satellites with Transit 5A-1. The 5A satellite series represented a total configuration change. The solar cells, instead of being placed on the body of the satellite, were placed on four hinged panels that deployed after injection into orbit to give the satellite a weathervane-like appearance. The main body of the satellite was shaped like an octagonal prism. The satellite contained a gravity-gradient boom (gravity-gradient stabilization was first attained with Transit 5A-3) that was deployed along the central axis of the satellite after the satellite was magnetically despun. Since the same face of the satellite would always face the earth, after the satellite was gravity-gradient stabilized, directional antennas could be placed on the base of the octagonal prism. The same basic configuration has been carried forward into the operational Navy navigation satellite series; it has also been used on seven other APL satellites. Transit 5A-1 weighed 131 pounds in orbit; the latest navigation satellite weighed 110 pounds.

APL satellites have achieved a number of space highlights; some of these are discussed briefly in the following paragraphs.

1. First Successful Transit Launching—The first successful launching of a Transit satellite (1B in 1960) proved the validity of the satellite doppler navigation system.
2. Geodetic Satellite Launching—The first satellite designed specifically for geodetic research (ANNA 1B) was launched in 1962.
3. Radioisotope Power—Transit 4A was the first satellite to carry a radioisotope power supply into space. Transit 5BN-1 was the first to use a radioisotope generator for all primary power. Transits 4B, 5BN-2, and 5BN-3 also used radioisotope generators.
4. Gravity-gradient Stabilization—Transit 5A-3 was the first satellite to achieve gravity-gradient stabilization. By the spring of 1968, the Laboratory had stabilized 15 satellites using this technique. The Department of Defense Gravity Experiment (DODGE) satellite is three-axis gravity-gradient-stabilized at a near-synchronous altitude.
5. Transit System Operational—The Transit system was declared operational by the U.S. Navy in July 1964. It was the first, and at present is the only, satellite navigation system in use.
6. Satellite Ultraviolet Astronomy—The ultraviolet telescope on 5E-5 made the first comprehensive ultraviolet survey of the heavens from orbit in 1965.
7. First Full-disc Color Photograph of the Earth—A DODGE TV camera made the first full-disc color photograph of the earth on July 25, 1967, using a three-color filter wheel system.

Navigation accuracy requirements stimulated a substantial Laboratory effort in the area of geodesy and in the development of ultrastable crystal oscillators. The stability of an APL flight oscillator is comparable to that of the best laboratory crystal oscillators. Data obtained from a variety of orbits have been used to continuously improve the mathematical model of the Earth's geopotential field. ANNA 1B was the first purely geodetic satellite ever launched. All of NASA's active geodetic measurement satellites were designed and fabricated by the Applied Physics Laboratory.

The Navy's satellite navigation system has been continuously available to its users in the submarine and surface fleets since July 1964. In 1965, the system was shown to be a useful aid to aircraft navigation. A technique whereby the relative positions of two earth-bound viewers may be determined with great accuracy using information from a single satellite pass has been developed and is currently being evaluated as an aid to field combatants.

Engineering and scientific data from Laboratory satellites have contributed materially to numerous studies concerning the solar spectrum, long- and short-term variations in solar intensity, high-energy particle measurements, and electron density measurements. Numerous papers concerning the Earth's artificial radiation belt, the magnetic tail, and papers correlating magnetic tail and radiation belt observations have been written based on data from Satellites 5E-1 and 5E-5. Scientists from 37 countries with a total of 102 tracking stations are participating in worldwide ionospheric structure studies under the direction of NASA using the broad range of frequencies transmitted by the Laboratory's BE-B and BE-C satellites.

The DODGE satellite is providing fundamental data concerning a number of gravity-gradient stabilization configurations. DODGE is also providing optical data concerning thermal bending of long cylindrical booms and making measurements of the Earth's magnetic field at near-synchronous altitude.