Air and Space this Week

Item of the Week

The Importance of Space Utilization

Originally appeared August 10, 2020

[KEY WORDS: *Explorer 1*, *Echo 1*, *TIROS 1*, reconnaissance, meteorology, communications]

Ever since the start of the Space Age, Humans have utilized Space and access to it to the greatest extent their technology and economics allow. The return on that investment is much too great to do otherwise. And when it comes to Space utilization/exploitation, "return on investment" can cover a great many benefits!

The Space Age, at least for the United States, began on January 31, 1958, with the launch of our first satellite, *Explorer 1*. [The launch was late in the evening EST, which makes the official launch date February 1, 1958, since the official time of launch is in UT, not EST, the local time of the launch site.] The Explorer series had four other, similar, spacecraft, all made by JPL and all launched by a Juno-1 booster, a re-working of the Army's Jupiter-C MRBM. Launch failures doomed *Explorers 3 and 5*; *Explorers 2 and 4* were successful. These activities, which involved very small satellites on a semi-unreliable booster, occupied much of 1959.

The value of accessing the "High Ground" of Low Earth Orbit (LEO) was well-known prior to the launch of *Explorer 1*; in fact, launching a satellite was one of the objectives of at least two of the nations participating in the International Geophysical Year (1958-9). The USSR beat us to the punch, with successes on *Sputnik 1 and 2* before we could get off the pad successfully. The US military had the only rockets that could come close to putting a satellite into LEO, and the Navy got the initial call to launch using their booster in a program called Project Vanguard. After delays and an extremely embarrassing and public failure with Vanguard TV-3 (aka "Flopnik"), the Army and their Jupiter-C missile got the call. (Khrushchev sneeringly called the TV-3 a mere "orange;" in reality, it was more the size of a grapefruit. So there.) And Vanguard's failure helped with the creation and growth of the fledgling National Aeronautics and Space Administration as the nation's launcher of rockets.

The obvious "low hanging fruit" to be utilized when LEO was in reach fell into three categories: military, meteorological, and communications (navigation would come later). ***All three were pursued with great vigor, and that is the key message of this Item.***

Much of the mission of the first five Explorers was proof-of-concept; the discovery of the Van Allen radiation belts was a bonus. But the military utilization was important even in 1959; *Explorers 4 and 5* were to also study the effects of high-altitude atomic bomb detonations on the upper atmosphere, the idea being that small high-altitude nukes would create a zone of electrons akin to the Van Allen belts that would damage any incoming USSR missiles passing through it. *Explorer 5* failed, but *Explorer 4* was aloft during three of the clandestine tests, code-named Operation Argus, conducted over the South Atlantic. More info on Operation Argos is here, and here.

Meanwhile, a series of secret military launches were conducted in 1959 and subsequent years, with the cover name of "Discoverer." They were really the first launches of the Corona spy satellite program, designed to give high-resolution visual image data for specific sites within the USSR and elsewhere. The first of these launched from Vandenberg AFB on February 8, 1959, so you can see how fast the military programs were developed once we could reach LEO. (Corona would eliminate the need for high-altitude unmanned balloon reconnaissance flights over the USSR (*e.g.* Project Gopher and Project Moby Dick), so no more "UFO" sightings near Roswell or anywhere else downwind of Alamogordo….).

Do not underestimate the importance of satellite reconnaissance in keeping the peace. We keep very close track of treaty-covered weapons systems and so do the other guys, a trust-but-verify system that has (until recently) worked well. And the coverage is complete, and detailed. When I was on the faculty at the University of North Dakota back in the day, some of my military students told me the story of routine road repairs conducted at one of the silo sites in the local missile field. The North Dakota winter is tough on roads, and a contractor sent out a crew to make repairs at one site. Simple stuff, but it would take a while, and the contractor provided a Port-A-Potty for the workers (who couldn't exactly knock on the door of the silo and ask to use the powder room). Within an hour the word sizzled over the communications net that the Soviets had detected an unauthorized structure at missile site XYZ. The contractor had to tip over the offending structure, allowing the blue water to flow out on the ground, in time for the next satellite pass, before order was restored.

Progress was made just as rapidly for the use of satellites to provide meteorological data. Accurate forecasting was so important in the War that US personnel were stationed in some pretty remote places at considerable cost of resources in order to provide the basic data needed for good forecasting. The first US satellite dedicated to making meteorological observations was the *Television Infra-Red Observation Satellite* (*TIROS-1*), launched on April 1, 1960. Again, a very short amount of time elapsed between *Explorer 1* and *TIROS-1*, helped along in part because RCA designed the basic satellite and its systems. The short development time is also a sign of the recognition at the time that the importance of meteorological observations from LEO were well worth the costs. It was true then, and it is still true today. Many different models of the TIROS system were launched in the ensuing decades as the technologies involved advanced. We are so used to seeing satellite-derived meteorological data on the local news weather report that we think nothing of the technologies that make it possible.

Satellite weather data has saved many lives and many dollars, especially when it comes to large-scale storms. Such data inform models of hurricane behavior, for example, and allow a more-timely warning in areas to be affected than would otherwise be possible. And is it any wonder that Space Aliens stopped making ships disappear in the Bermuda Triangle just at the same time hurricane information became readily available to mariners?

A study conducted in 1972, and reported on here, showed that satellite reconnaissance of storms could reduce damages that, even with an investment in spending on protection measures, a total savings of ~15% on storm-related losses could be realized. But annual losses are a large number, and that 15% translated to over $700 million, in 1972 dollars!

Much of the handling of weather data in the US is federalized. The US Weather Bureau and NOAA acquire and utilize meteorological data and models. There is less room for commercial entities to compete in this arena, other than to provide enabling technology. However, commercial involvement with the third well-foreseen initial use of LEO, communications, is a different story.

A few weeks ago, the Item of the Week was about long-distance radio communications, focusing on the roles Marconi and Fessenden played in the development and early utilization of radio technology. They took advantage of the Heaviside Layer in the ionosphere, where ionized gases reflect a radio signal, allowing for reception "over the horizon." It worked, but was subject to disruption due to solar and/or meteorological conditions. A better situation would be to hang a reflector high in the sky and bounce signals off of it to go over the horizon.

August 12, 2020, is the 60th anniversary of the launch of the *Echo 1* satellite. It was a large balloon (100-meter diameter) made of aluminized mylar. It was launched successfully inflated, and worked well. However, it had a tiny mass/cross-section ratio, so even the slightest atmospheric drag would bring it down in a few days/weeks. Radio signals bounced of *Echo 1* still had to traverse a lot of atmosphere, and a lot of potential atmospheric distortion, and *Echo 1* was a moving target, which complicated its use.

Two improvements were needed to make communications via satellite more practical. The first was the capability of the satellite. The Echo's were merely reflectors, they did nothing to amplify/process the signal hitting them. A repeater system in the sky that could amplify signals and direct them to specific ground receiving stations would be an important upgrade. But such satellites were still moving targets.

A straightforward application of Newtonian mechanics shows that there is a height above the surface of the Earth at which a satellite in a circular orbit would have an orbital period of exactly one day. This is a very desirable location, for a communications relay in orbit there would be easier for a ground station to track. Such orbits are called "geosynchronous," literally, "in time with the Earth." If a geosynchronous satellite is in an inclined orbit, it will appear to move northward or southward as seen from the ground, but would not move in the east-west direction. Even better, if the geosynchronous satellite orbits in the plane of Earth's Equator, it will not move in either direction, but remain at a fixed point in the sky as seen from the ground. Such satellites are called "geostationary," and now the ground stations they communicate with need only a fixed antenna to work well.

Construction, launch, and management of communication satellite systems and constellations is now a multi-billion-dollar business. All enabled, and enabled sooner, by the development of access to LEO and the supporting technologies. Communications was a utilization of LEO, like military and meteorological, that was easily foreseeable, and therefore, quickly obtained.

I won't cover here the fourth important utilization of LEO that has also become very important and financially lucrative: Navigation. Its enabling technology came later, so its impact lagged the other three. But where would we be without our GPS?

Last Edited on 12 August 2020