ISRAEL

Ballistic Missiles and Space for Survival

Development of ballistic missiles was essential for survival of Israel as a country surrounded by hostile Arab neighbors intent on physical annihilation of the Jewish state. The achieved national ballistic missile capabilities subsequently enabled space launches. Naturally, the major objectives of the space program were also driven by the national security requirements and concentrated on space-based reconnaissance and communications. The country's space effort received important boost in 1982 with the formation of the *Israel Space Agency* (ISA). Physicist Yuval Ne'eman, 1925–2006, played a crucial role in shaping the Israel's program and became president of ISA.

First Satellite

Israel's first step into space was a launch of a simple *Ofeq-1* (*ofeq* means *horizon* in Hebrew) satellite on 19 September 1988, with the *Israel Aircraft Industries* (IAI) leading the effort as the prime contractor. The spacecraft was designed and built by IAI's *MBT Division*, and the satellite control center was established at MBT's facility in Yahud near Tel Aviv. The spin-stabilized (at 60 rpm) Ofeq-1 was deployed in a low-Earth orbit with perigee 248 km (154 miles) and apogee 1150 km (715 miles). Low orbit perigee resulted in large atmospheric drag, and the satellite reentered the atmosphere in four months on 14 January 1989.

Ofeq-1

The Ofeq-1 spacecraft was an octagon with the lower- and upper-base diameters 1.3 m (4.3 ft) and 0.7 m (2.3 ft), respectively, and height 2.3 m (7.5 ft). The spacecraft total mass was 156 kg (344 lb), with the mass breakdown among the subsystems, as follows: 33 kg (73 lb) for structures, 58 kg (128 lb) for electric power, 5 kg (11 lb) for thermal control, 12 kg (26 lb) for communications, 7 kg (15 lb) for onboard computer, 32 kg (71 lb) for spacecraft instrumentation and balancing masses, and 9 kg (20 lb) for cabling. The body-mounted solar panels supported average power consumption of 53 W, and the onboard battery had capacity 7 A-h. The S-band communications system provided a 2.5-kbit/s transmission rate.

PROGRADE AND RETROGRADE ORBITS

Typically, spacecraft are launched in the eastern direction (from left to right, if one looks at the map). Therefore, most satellites move around the Earth in the same general direction as the Earth rotates. Such orbits are called *prograde*.

The rotation of our planet is not negligible and provides significant help for launching satellites. The velocity of a point on the Earth's surface is approximately equal to $465 \times \cos(\lambda)$ m/s, where λ is geographical latitude of the launching site. Thus, one gets “for free” a significant velocity (465 m/s at the equator) when launching a satellite due east.

Possible launch directions are usually restricted by safety considerations, to prevent first rocket stages, or malfunctioning rocket, from falling on populated areas. In Israel's case, political considerations do not allow space launches in the eastern direction. Therefore, the country has to launch satellites over the Mediterranean sea in the *western* direction, against the Earth’s rotation. Such orbits are called *retrograde*. Launch in low-inclination retrograde orbits is highly unfavorable and requires significantly larger rockets than for similar eastward launches.

M. Gruntman *Blazing the Trail. The Early History of Spacecraft and Rocketry*, AIAA, Reston, Va., 2004, p. 451 http://astronauticsnow.com/blazingthetrail/

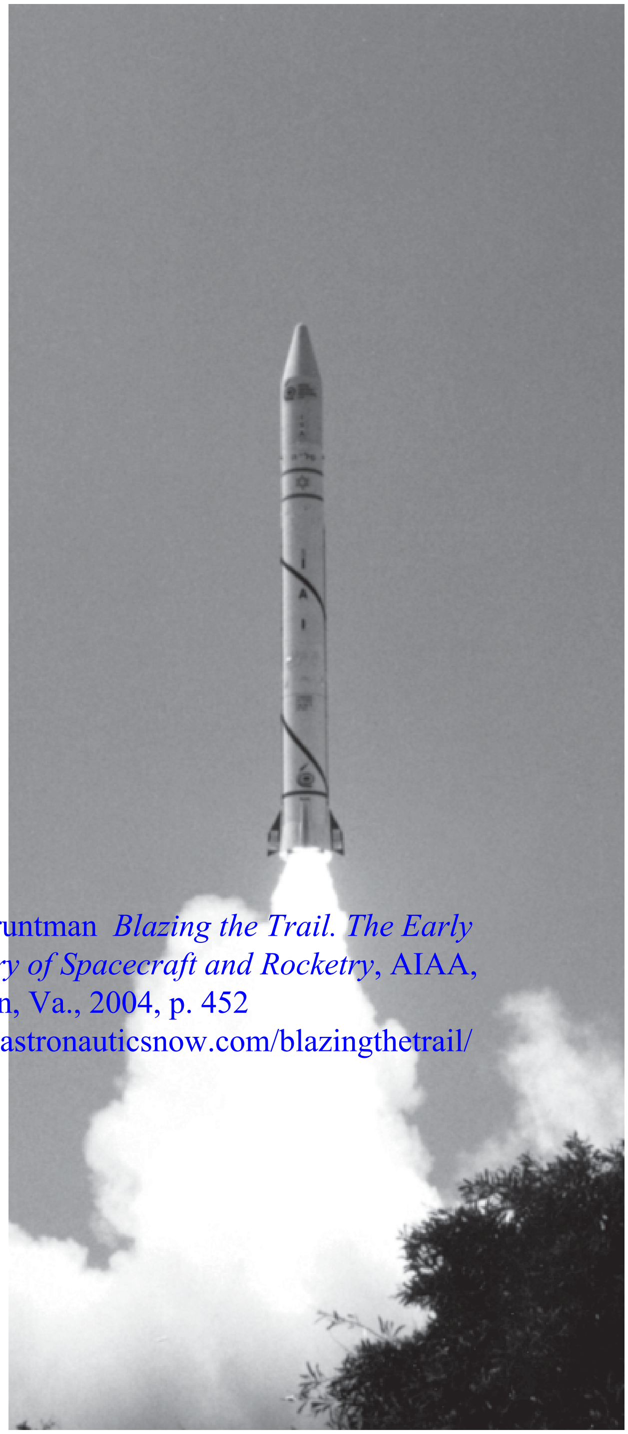

Fig. 17.21. Israel's three-stage rocket Shavit launches a satellite from the Palmachim Air Force Base near Tel Aviv. Photo courtesy of Israel Space Agency.

Adverse Launch Conditions

Space launch is especially challenging for Israel because political constraints limit possible launch azimuth to western directions against the Earth's rotation. Therefore, Ofeq-1 (as well as the follow on satellites) was placed in retrograde orbit with inclination 143 deg (or 37 deg retrograde). The IAI's *MLM Division* built a capable *Shavit* (*comet* in Hebrew) three-stage solid-propellant launcher to deploy satellites under such adverse restrictions. The solid motors of the first two stages were built by *Israel Military Industries*; the third-stage motor was designed by *Rafael*.

Shavit Launcher

Shavit launched the Israel's first satellite from the *Palmachim Air Force Base* in Yavne, 15 miles (25 km) from Tel Aviv. Israel is a small country, and this is the only place in the world where satellites are launched from a site so near to a major metropolitan area. The Shavit's second stage cut off at approximately 110 km (68 miles) altitude. After coasting, the third stage was fired at 250–260 km (160 miles) injecting the spacecraft into the desired orbit. The shroud was jettisoned just before firing of the third stage.

Fig. 17.22. Israel's third satellite, Ofeq-3, successfully launched in April 1995. A three-axis-stabilized spacecraft (attitude accuracy 0.1 deg) was deployed in a 143-deg-inclination (or 37 deg retrograde) low-Earth orbit. Israel's first satellite, Ofeq-1, had a similar body, but without deployable solar panels. Photo courtesy of Israel Space Agency.

Focused Space Program

With the launch of Ofeq-1, Israel also became a member of the small elite group of nations with space launch capabilities. The country continued its energetic and focused space program with the successive satellites increasing in so-

Winner of the *Luigi Napolitano Book Award* (2006) from the International Academy of Astronautics

Blazing the Trail

The Early History of Spacecraft and Rocketry

Mike Gruntman

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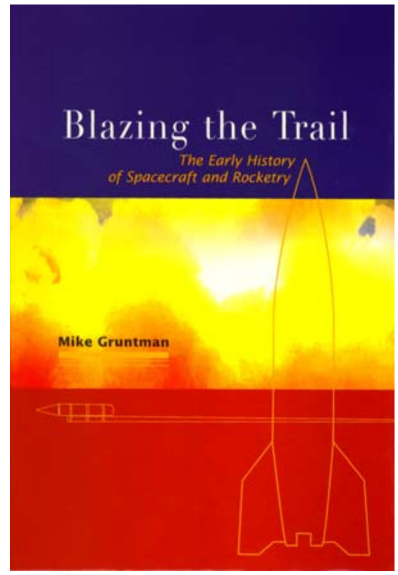

505 pages with 340 figures
Index: 2750+ entries, including 650 individuals

This book presents the fascinating story of the events that paved the way to space. It introduces the reader to the history of early rocketry and the subsequent developments which led into the space age. People of various nations and from various lands contributed to the breakthrough to space, and the book takes the reader to far away places on five continents.

This world-encompassing view of the realization of the space age reflects the author's truly unique personal experience, a life journey from a child growing on the Tyuratam launch base in the 1950s and early 1960s, to an accomplished space physicist and engineer to the founding director of a major U.S. nationally recognized program in space engineering in the heart of the American space industry.

Most publications on the topic either target narrow aspects of rocket and spacecraft history or are popular books that scratch the surface, with minimal and sometimes inaccurate technical details.

This book bridges the gap. It is a one-stop source of numerous technical details usually unavailable in popular publications. The details are not overbearing and anyone interested in rocketry and space exploration will navigate through the book without difficulty. The book also includes many quotes to give readers a flavor of how the participants viewed the developments. There are 340 figures and photographs, many appearing for the first time.

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Book details (including **index** and **reviews**) at: **http://astronauticsnow.com/blazingthetrail/**

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