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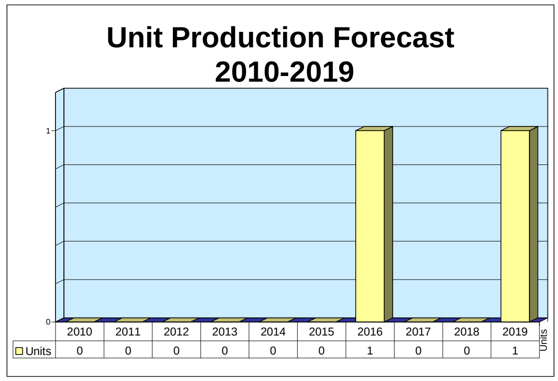
Swedish Science Spacecraft

Outlook

- Prisma technology demonstration mission launched in June 2010; satellites separated in August
- SNSB focuses heavily on international programs
- Production opportunities limited over the next 10 years



Orientation

Description. Swedish science spacecraft are small platforms designed for a variety of missions.

Sponsor. Varies depending on program: Viking, Freja, and Odin were primarily sponsored by the Swedish Space Board. SMART-1 is the first of the European Space Agency's Small Missions for Advanced Research in Technology spacecraft.

Status. In development and operation; SMART-1 launched on an Ariane 5 in 2003. Prisma was launched on board a Dnepr in 2010.

Total Produced. Seven

Application. Swedish science satellites have a range of applications. These include studying the acceleration region of auroral particles (Viking), taking high-resolution measurements in the upper atmosphere and lower magnetosphere (Freja), imaging the aurora (Astrid), measuring the electrical and magnetic fields (Astrid-2), (Odin), establishing climatology of the stratosphere and troposphere (ACE+), and demonstrating innovative and key technologies for scientific deep-space missions (SMART-1). In addition, some of these satellites (Odin) are used to conduct astronomical and atmospheric research.

Price Range. Viking, $20 million; Astrid-1, $1.2 million; Astrid-2, $1.5 million; Freja, $19 million including launch and 2.5 years of operation; Odin, $4.3 million; SMART-1, approximately $25 million; and Prisma, approximately $35 million.

Contractors

Prime

Swedish Space Corp, SSC	http://www.ssc.se/, PO Box 4207, Solna strandväg 86, Solna, SE-171 04 Sweden, Tel: + 46 8 627 62 00, Fax: + 46 8 98 70 69, Email: fsj@ssc.se, Prime

Subcontractor

ACR Electronics Inc	http://www.acrelectronics.com/, 5757 Ravenswood Rd, PO Box 5247, Fort Lauderdale,

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	FL 33312 United States, Tel: + 1 (954) 981-3333, Fax: + 1 (954) 983-5087 (Astrid Solar Panels and Sun Sensor)
AeroAstro Inc	http://www.aeroastro.com, 20145 Ashbrook Pl, Ashburn, VA 20147-3372 United States, Tel: + 1 (703) 723-9800, Fax: + 1 (703) 723-9850 (Astrid-2 Downlink and Uplinks)

Boeing	http://www.boeing.com, 100 N Riverside, Chicago, IL 60606 United States, Tel: + 1 (312) 544-2000, Fax: + 1 (312) 544-2082 (Viking Satellite Platform)
Conti Temic Microelectronic GmbH, Continental Teves AG	http://www.temic.de/, PO Box 90 01 20, Frankfurt, 60488 Germany, Tel: + 49 069 76 03 1, Fax: + 49 069 76 10 61 (Freja Onboard Computer)
Danish Space Research Institute, DSRI	http://www.dsri.dk, Juliane Maries Vej 30, Copenhagen, DK-2100 Denmark, Tel: + 45 3532 5830, Fax: + 45 3536 2475 (Viking Wave Experiment)
RUAG Space AB	http://www.ruag.com/en/Space/Space_Home, Solhusgatan 11, Göteborg, 405 15 Sweden, Tel: + 46 31 735 00 00, Fax: + 46 31 735 40 00 (Astrid Mass Memory)
Saft Aerospace Batteries Center	http://www.saftbatteries.com, 107 Beaver Ct, Cockeysville, MD 21030 United States, Tel: + 1 (410) 771-3200, Fax: + 1 (410) 771-1144 (Battery)
Southwest Research Institute	http://www.swri.org/, 6220 Culebra Rd, PO Drawer 28510, San Antonio, TX 78228-0510 United States, Tel: + 1 (210) 648-5111 (Astrid-2 MEDUSA Instrument)

Technical Data

Design Features

Odin. A dual-purpose satellite, Odin performs astronomical and atmospheric research. This satellite's main objective is to provide detailed studies of the physics and chemistry of the interstellar medium. Its atmospheric research centers on measurements of the stratosphere and mesosphere. The spacecraft carries a submillimeter-wave radio telescope and a spectrometer for UV to near-infrared light.

Odin is much heavier and larger than its predecessors – it is 2 meters high and 3.8 meters wide, with a 170-kilogram bus and 80 kilograms of payload. Odin was launched in February 2001 on a Start-1 booster.

In February 2005, Odin's mission was extended for a fifth year. The spacecraft was designed to operate for two and a half years, but due to the extension, it is now expected to operate through April 2006.

SMART-1. This satellite is the first of the European Space Agency's Small Missions for Advanced Research in Technology (SMART) spacecraft. Originally, SMART-1 was to begin its trip to the moon aboard an Ariane 5 rocket in 2002, but it wasn't launched until September 2003. The satellite will demonstrate solar electric propulsion as the primary means of propulsion for future deep-space missions, including Bepi Colombo (see separate report in this tab). SMART-1 also carries cameras and other instruments for high-resolution infrared mapping and lunar observations. Instruments include:

- EPDP/SPEDE (Electric Propulsion Diagnostic Package/Spacecraft Potential, Electron and Dust Experiment) – to monitor side effects of electric propulsion
- OBAN (onboard autonomous navigation) – to test autonomous navigation
- SIR (infrared exploration of the lunar surface) – for detailed analysis of surface composition
- D-CIXS (Demonstration of a Compact Imaging X-ray Spectrometer) – a new generation of X-ray imagers for planetary observation

The SMART-1 project is the first of its kind for the European community, and could pave the way for more ambitious endeavors, such as a planned trip to Mercury. SMART-1 reached the moon in November 2004 and, since its arrival, has been conducting observations from lunar orbit.

In February 2005, the SMART-1 mission was extended by one year, which put the official end of operations at August 2006 instead of the previously planned retirement of August 2005. This mission extension was implemented in two periods of six months that corresponded to different orbital parameters and illumination conditions. During the first period, the southern survey lunar study was completed, and dedicated pointings made for multi-angle, stereo, and polar illumination studies.

The second period entailed high-resolution coverage of the moon on the equator and part of the northern hemisphere, made possible by the favorable illumination conditions. High-resolution follow-up observations of specific targets were also made, as well

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as observations relevant to the preparation of future international lunar exploration missions.

The SMART-1 was deliberately crashed into the lunar surface in September 2006 after three years of highly successful operations.

Astrid. Astrid's main instrument was the neutral particle imager, Prelude in Planetary Particle Imaging (PIPPI). It consisted of a solid-state detector (SSD) camera, which resolved the energy of detected particles, and a microchannel plate (MCP) camera that forced charged secondary particles from a graphite target so they could be detected. PIPPI also served as the data processing unit for EMIL and MIO.

The electron spectrometer, EMIL (Electron Measurements - In-situ and Lightweight), measured the electron distribution at 62.5 ms or 125 ms resolution. There were two UV imaging photometers, called MIO (miniature imaging optics) – one observed Lyman alpha-emissions from the Earth's geocorona; the other observed auroral emissions.

Some units, such as the transmitter and the command receiver, were Freja flight spares. Others were "leftovers," such as the quality level B-2 microcircuits and JANTXV semiconductors, and the main spacecraft microprocessor, the 80C31, from Matra-Harris (now part of Temic/Atmel). The main electronics box, the Astrid System Unit, was an improved version of the Freja System Unit.

	Metric	U.S.
Odin		
Dimensions		
Height	2.0 m	6.5 ft
Width (solar panels deployed)	3.8 m	12.4 ft
Weight		
Total mass	250 kg	551 lb
Platform mass	170 kg	374.7 lb
Payload mass	80 kg	176.3 lb
Performance		
Solar array power	340 W	
Downlink data rate	720 kbps	
Data storage	100 Mbytes in solid-state memory	
Orbit	600 km circular sun-synchronous with ascending node at 18:00	
System life	2 years minimum	
UHF commands	9,600 bps	
Onboard telemetry memory	32 mb	
Average power	5 watts	
Platform control	MHS 80C31 microcontroller	
Astrid-1		
Dimensions		
Height	2.9 m	9.5 ft
Width	4.5 m	15 ft
Depth	4.5 m	15 ft
Weight		
Total mass	27 kg	59.6 lb
Platform mass	22.64 kg	50 lb
Payload mass	4.36 kg	9.6 lb
Performance		
Platform	9.87 W	
Payload	11.88 W	
Solar array power	290 x 450 mm	
Battery	22 standard Ni-Cd Gates 2.3 Ah	
Telecommand	Two S-band antennas	
Attitude control	Flux-gate magnetometer and a solar aspect angle sensor	
Stabilization	Spin stabilized	

SMART-1		
Weight		
Launch mass	350 kg	772 lb
Payload mass	15 kg	33 lb
Xenon propellant mass	82 kg	180 lb
Performance		
Solar array power	1,970 W BOL with dual-junction Cascade cells	
Telecommand	Two S-band TT&C transponders	
Attitude control	Four reaction wheels	

Artist's Depiction of the SMART-1 Spacecraft Orbiting the Moon

Source: Swedish Space Corporation

Variants/Upgrades

Viking. Sweden's first satellite, launched in 1986. It studied the magnetosphere until contact was lost in May 1987.

Freja. Sweden's second satellite, launched in 1992. It measured the upper ionosphere and lower magnetosphere of the auroral zone until it ceased operations in October 1996.

Astrid-1. Based on the Freja-C platform, Astrid-1 was launched in 1995 to image the aurora.

Astrid-2. Astrid-2 was launched aboard a Cosmos in 1998 to measure electrical and magnetic fields; however, contact with the spacecraft was lost in July 1999.

Odin. Launched aboard a Start-1 in February 2001, the dual-use Odin satellite performs both astronomical and atmospheric research.

Munin. A Swedish nanosatellite.

SMART-1. ESA's first SMART spacecraft, launched on an Ariane 5 in 2003 to study the moon. SMART-1 was deliberately crashed into the lunar surface in September 2006.

ACE+. The Atmospheric Climate Experiment is designed to observe temperature, pressure, and water vapor fields in the atmosphere. Although rejected in 2004, ACE+ could again be considered in the future for the ESA's Living Planet Program.

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Prisma. The program is a technology mission primarily aiming at the demonstration of different sensor technologies and guidance/navigation strategies for rendezvous and formation flying in space. The project consists of two spacecraft (one advanced and highly maneuverable), previously called MAIN, and one simplified, previously called TARGET. In September 2008, the two spacecraft were officially renamed Mango and Tango. The satellites were launched in June 2010 to a sun-synchronous orbit at 700 kilometers altitude by a Russian Dnepr rocket either from Baikonur in Kazakhstan or from Yasni in southern Russia. The mission duration is approximately 10 months.

Program Review

Background. Sweden began launching small, inexpensive science satellites long before NASA began its "cheaper, better, faster" phase. Indeed, its first science satellite, Viking, was launched in 1986 and cost only $20 million. Since then, the Swedish National Space Board, which funds the majority of the country's science satellites, has launched spacecraft weighing only about 30 kilograms and small enough to sit on an office desktop.

Although small and inexpensive, Sweden's science satellites have returned a wealth of information, especially in the area of space physics. Satellites such as SMART-1 are aimed at testing technologies that may later be used for more ambitious efforts, such as the ESA's proposed Mercury rendezvous mission, Bepi Colombo.

Viking. The first Swedish science satellite, Viking, studied the magnetosphere. The spacecraft was launched in 1986 aboard an Ariane 1. Operations were nominal for its eight-month design life, but in October 1986, one of the electrical shunts used to dump excess solar panel power shorted out, lowering the ability to charge the battery. The harsh radiation in space degraded Viking's solar panels; in May 1987, the battery could no longer be charged, and contact with Viking was lost.

Freja. Sweden's second satellite was the first to make high-resolution measurements in the upper ionosphere and lower magnetosphere of the auroral zone. Freja was launched into a 600 x 1,770 kilometer orbit in 1992 aboard a Long March 2C. It delivered some 200 megabytes of data per day until it ceased operations in October 1996. The seven instruments on board were built by groups in Sweden, Germany, Canada, and the United States. As with Viking, the Alfvén Laboratory built the instrument measuring the electric field.

Astrid-1. This small, spin-stabilized satellite was launched aboard a Cosmos rocket on January 24, 1995. It is Sweden's third scientific satellite and first microsatellite. The Astrid project was intended as a precursor to more sophisticated microsatellites for space science and as a test flight of a basic microsatellite design. The project proved that a microsatellite with a serious space science mission could be built and launched in about a year for $1.4 million, paving the way for the development of Astrid-2.

Astrid carried an Energetic Neutral Atom Analyzer, an electron spectrometer, and two UV imagers for imaging the aurora. The platform was designed and developed by the Swedish Space Corp's Space Systems Division in Solna, Sweden. The payload was developed by the Swedish Institute of Space Physics in Kiruna. The initial orbit of Astrid was 966.3 to 1,026.3 kilometers at an inclination of 82.93°.

Astrid-2. Astrid-2 was the second scientific microsatellite developed by Swedish Space Corp's Space Systems Division in Solna, Sweden. It was launched piggyback on a Cosmos 3M rocket from Plesetsk on December 10, 1998. On July 24, 1999, contact with the satellite was lost during a passage and could not be re-established. The Astrid-2 payload carried instrumentation provided by the Alfvén Laboratory for measuring electric fields, magnetic fields, ions, electrons, plasma density, and temperature. It also featured three photometers. The orbit was circular, at 1,000 kilometers in altitude and 83° inclination.

ACE+. The Atmospheric Climate Experiment is still in its development phase. ACE+ is designed to observe global temperature, pressure, and water vapor fields in the atmosphere in order to improve predictions of climate change. When missions were being decided upon by the ESA in 2004, the system was not selected as a Future Mission of Opportunity under ESA's Living Planet program.

ACE+ will demonstrate use of radio occultation to establish accurate global profiles of temperature in the troposphere, and water vapor in the troposphere and stratosphere. Over an expected lifetime of five years, the mission will provide high-accuracy data with high vertical resolution, providing precision of better than 3 percent for specific humidity and 0.2K for temperature. Potentially, ACE+ could also contribute to weather forecasting.

Four satellites are proposed to fly as two pairs in the same orbital plane but at two different altitudes, one at 650 kilometers and the other at 850 kilometers. The use of two satellites in each of the two non-sun-synchronous orbits is designed to maximize geographic coverage. The satellites in the 650-kilometer orbit will counter-rotate with respect to the satellites in the 850-kilometer orbit. The counter-rotation is needed for cross-link occultations between the low-Earth-orbit (LEO) satellites of the ACE+ mission, also called LEO-LEO cross-link. Consequently, the orbits all have a 90° inclination.

Odin. This astronomical and atmospheric research satellite completed its first full year in orbit in February 2002. During its first year, Odin observed Jupiter and the ozone hole over the Antarctic, and detected massive, high-speed outflow of water vapor at the comet 2001-A1 LINEAR. Odin also detected vast amounts of water vapor in the Orion star formation cloud and in the mass outflow from a newborn star.

In February 2007, Odin completed six successful years in orbit. Although it has been operated more than twice as long as the design lifetime, the Odin satellite is reportedly in perfect condition.

SMART-1. While the Ariane 5 at Kourou, French Guiana, sat patiently waiting for its go for launch, experiencing delay after delay, the SMART-1 was being held up due to India's INSAT-3E. The INSAT-3E had faulty solid-state power amplifiers and bad welds on top of that, forcing the satellite to be shipped back to India. Finally, all was resolved, and the Ariane 5 launched in September 2003, lofting the INSAT-3E, Eutelsat's e-Bird, and of course the SMART-1.

The SMART-1 reached lunar orbit in November 2004 and had its mission extended by one year to August 2006.

A Spectacular Finish

SMART-1 ended its mission with a planned crash into the lunar surface. The spacecraft, which had been in orbit around the Moon since late 2004, crashed into a small lava plain called the Lake of Excellence at 1:42 a.m. EDT (0542 GMT) on September 3, 2006. The impact was declared a success by ESA, although a last-minute orbit correct was needed to prevent the spacecraft from colliding with a crater wall. The location and timing of the impact were selected to allow the flash and dust plume from the impact to be seen by observers on the Earth; at least one telescope in Hawaii reported seeing the impact flash.

Prisma. The Prisma project was established in 2005. The project consists of two satellites and is used to test formation flying and rendezvous technology in space. France's CNES and Germany's DLR are participating in the program. The two satellites are named Mango and Tango.

The two Prisma satellites were launched on June 15, 2010, on board a Dnepr launch vehicle from Yasny, Russia. The satellites successfully separated from each other on August 12, 2010.

Swedish Science Satellites

Launch Date	Payload	Mission	Mass (kg)	Launch Site	Vehicle	Trajectory (km)	Orbit
Feb 1986	Viking	Plasma Physics	538	Kourou	Ariane 1	790-13,379	98°
Oct 1992	Freja	Plasma Physics	214	Jiuquan	CZ-2C	601-1,756	63°
Jan 1995	Astrid-1	Plasma Physics	27	Plesetsk	Cosmos	966-1,027	83°
Dec 1998	Astrid-2	Plasma Physics	30	Plesetsk	Cosmos	1,000	83°
2001	Odin	Astrophysics/ Aeronomy	250	Svobodny	Start-1	1,600	98°
2003	SMART-1	Technology Demonstration	350	Kourou	Ariane 5	Escape	N/A
2010	Prisma (Tango)	Formation flying	40	Yasny	Dnepr	700	N/A
2010	Prisma (Mango)	Formation flying	150 kg	Yasny	Dnepr	700	N/A

N/A = Not Available.

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Timetable

Month	Year	Major Development
Feb	1986	Viking launched on Ariane 1
Oct	1992	Freja launched on Long March 2C
Jan	1995	Astrid-1 launched on Cosmos
Dec	1998	Astrid-2 launched on Cosmos
Feb	2001	Launch of Odin on Start-1
Sep	2003	Launch of SMART-1 on Ariane 5
	2004	ESA names new Missions of Opportunity for Living Planet program; ACE+ not selected
Jun	2010	Prisma launched on Dnepr
	2012	Proba-3 expected to launch

Forecast Rationale

In June 2010, Prisma launched on board a Russian Dnepr rocket. The science mission remains operational, and is proceeding as planned.

The Swedish National Space Board (SNSB) has a long history of launching scientific satellite missions. The SNSB typically launches lightweight, inexpensive spacecraft. Prisma is one such example of this SNSB objective; the lightweight spacecraft is currently studying formation flying in space.

An important goal of SNSB missions is to advance Swedish industry. Many Swedish companies have been beneficiaries of Swedish science missions, especially Swedish Space Corp (SSC).

As space programs become more expensive, SNSB is focusing more on international cooperation. Even the smaller missions that have been SNSB's focus have become more costly.

With Prisma launched and in operation, SNSB currently does not publicly list any future satellite programs. Company officials at SSC's Spacecraft Department believe that future development will continue at the same pace as in previous years. This means that satellites will be developed at a slow but steady pace over the next 10 years. Even with the slow pace of satellite development at SNSB, companies such as SSC will remain busy by participating in international programs. SSC is active in the ESA Proba program and the Small GEO program.

With no programs currently being worked on, Forecast International believes that the next SNSB program will not be delivered until 2016. This will allow time to develop requirements, award contracts, manufacture the satellites, and line up launch dates. Until that time, SNSB, along with Swedish spacecraft companies, will be active participants in international programs.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR UNIT PRODUCTION

Designation or Program		High Confidence				Good Confidence			Speculative			
	Thru 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Swedish Space Corp												
Swedish Science Spacecraft Additional Production												
	0	0	0	0	0	0	0	1	0	0	1	2
Total	0	0	0	0	0	0	0	1	0	0	1	2